Magnet Safety: Big Things

"Large ferromagnetic objects that were reported as having been drawn into the MR equipment include a defibrillator, a wheelchair, a respirator, ankle weights, an IV pole, a tool box, sandbags containing metal filings, a vacuum cleaner, and mop buckets."

- Chaljub et al., (2001) AJR

MRI Safety – Patient Screening

What is the purpose of a patient screening?

- Explain the procedure.
- Allay the patient fears.
- Acquire a patient history.
- Identify ferromagnetic materials within the patient.
Remember safety considerations are different depending on field strength.

ALWAYS double and triple check for safety!

“The List”

http://www.mrisafety.com

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MRI Safety Resources

http://www.mrisafety.com

Manufacture/product insert or prosthesis card
Radiologists

“The List”

Safe – The object is considered to be safe for the patient undergoing an MR procedure or an individual in the MR environment, with special reference to the highest static magnetic field strength that was used for the MR safety test. The object has undergone testing to demonstrate that it is safe or it is made from material(s) considered to be safe with regard to the MR environment (e.g., plastic, silicone, glass, etc.) or an MR procedure.

Source: http://www.mrisafety.com/list.asp

“The List”

Conditional – The object may or may not be safe for the patient undergoing an MR procedure or an individual in the MR environment, depending on the specific conditions that are present.

Source: http://www.mrisafety.com/list.asp
Conditional 1 – The object is acceptable for the patient or individual in the MR environment, despite the fact that it showed positive findings for magnetic field interactions during testing. Notably, the object is considered to be “weakly” ferromagnetic, only.

Source: http://www.mrisafety.com/list.asp

Conditional 2 – These particular “weakly” ferromagnetic coils, filters, stents, clips, cardiac occluders, or other implants typically become firmly incorporated into the tissue six weeks following placement. Therefore, it is unlikely that these objects will be moved or displaced by interactions with the magnetic fields of MR systems operating at the static magnetic field strength used for testing.

Source: http://www.mrisafety.com/list.asp

Conditional 3 – Certain transdermal patches with metallic foil (e.g., Deponit, nitroglycerin transdermal delivery system) or other metallic components, although not attracted to an MR system, have been reported to heat excessively during MR procedures. This excessive heating may produce discomfort or burn a patient or individual wearing a transdermal patch with a metallic component. Therefore, it is recommended that the patch be removed prior to the MR procedure. A new patch should be applied immediately after the examination. This procedure should only be done in consultation with the patient’s or individual’s personal physician responsible for prescribing the transdermal medication patch.

Source: http://www.mrisafety.com/list.asp
Conditional 4 - This halo vest or cervical fixation device may have ferromagnetic component parts, however, the magnetic field interactions have not been determined. Nevertheless, there has been no report of patient injury in association with the presence of this device in the MR environment at the static magnetic field strength used for MR safety testing. Issues may still be present with regard to MRI-related heating. As such, guidelines provided in the Product Insert or Instructions for Use for a given halo vest or cervical fixation device should be carefully followed. Halo vests and cervical fixation devices made from conducting metals may heat excessively during an MR procedure, resulting in serious patient injury. Contact the manufacturer for further information. Also, refer to recent information for cervical fixation devices, as several have now been evaluated at 3-Tesla.

Source: http://www.mrisafety.com/list.asp

Conditional 5 - This object is acceptable for a patient undergoing an MR procedure or an individual in the MR environment only if specific guidelines or recommendations are followed (see specific information for a given object on this website and contact the manufacturer for further information). Please refer to the specific criteria for performing the MR procedure by reviewing the information for the object on this website. Consult the manufacturer of the particular device for the latest safety information.

Source: http://www.mrisafety.com/list.asp

Conditional 6 - This implant/device was determined to be MR-conditional according to the terminology specified in the American Society for Testing and Materials (ASTM) International, Designation: F2503. Standard Practice for Marking Medical Devices and Other Items for Safety in the Magnetic Resonance Environment.

Non-clinical testing demonstrated that the implant/device is MR Conditional. A patient with this implant/device can be scanned safely immediately after placement under the following conditions:

See website for conditions………

Source: http://www.mrisafety.com/list.asp
Conditional 7 - Important Note: This device is not intended for use during the operation of an MR system for an MR procedure. That is, this device should not be inside of the bore of the MR system, exposing this device to the time-varying and RF fields activated during an MR procedure.

Attention: Contact the manufacturer of this implant/device for further information.

Source: http://www.mrisafety.com/list.asp

Conditional 8 - Note: This information pertains to an implant/device that has MRI labeling at 1.5-Tesla and 3-Tesla, ONLY. In some cases, it may pertain to a single and two-overlapped version of a stent. Contact the manufacturer for additional MRI information, as needed.

The implant/device was determined to be MR-conditional according to the terminology specified in the American Society for Testing and Materials (ASTM) International, Designation: F2503: Standard Practice for Marking Medical Devices and Other Items for Safety in the Magnetic Resonance Environment.

Non-clinical testing demonstrated that the implant/device is MR Conditional. A patient with this implant/device can be scanned safely immediately after placement under the following conditions:

See website for conditions........

Source: http://www.mrisafety.com/list.asp

Unsafe 1 – The object is considered to pose a potential or realistic risk or hazard to a patient or individual in the MR environment primarily as the result of movement or displacement of the object. Other risks or a different hazard may also exist. Therefore, in general, the presence of this object is considered to be a contraindication for an MR procedure and/or for an individual to enter the MR environment depending on the nature of the object or item.

Note that the “default” static magnetic field strength for an unsafe implant or device is typically 1.5-Tesla.

Source: http://www.mrisafety.com/list.asp
Unsafe 2 – This object displays only minor magnetic field interactions which, in consideration of the in vivo application of this object, is unlikely to pose a hazard or risk in association with movement or displacement. Nevertheless, the presence of this object is considered to be a contraindication for an MR procedure or for an individual in the MR environment. Potential risks of performing an MR procedure in a patient or individual with this object are related to possible induced currents, excessive heating, or other potentially hazardous conditions. Therefore, it is inadvisable to perform an MR procedure in a patient or individual with this object.

source: http://www.mrisafety.com/list.asp

Unsafe 2 (continued) – For example, although certain cardiovascular catheters and accessories typically do not exhibit magnetic field interactions, there are other mechanisms whereby these devices may pose a hazard to the patient or individual or in the MR environment (e.g., excessive MRI-related heating).

The Swan-Ganz thermodilution catheter (and other similar catheters) displays no attraction to the MR system. However, there has been a report of a Swan-Ganz catheter that “melted” in a patient during an MR procedure. Therefore, the presence of this cardiovascular catheter and any other similar device is considered to be a contraindication for a patient undergoing an MR procedure.

source: http://www.mrisafety.com/list.asp

Field Strength – This is the highest strength of the static magnetic field of the MR system that was used for safety testing of the object. In most cases, a 1.5-Tesla MR system was used for testing. However, there are some objects that were tested at field strengths lower (e.g., 0.15-Tesla) or higher (e.g., 3-Tesla) than 1.5-Tesla. Note that the “default” static magnetic field strength for an unsafe implant or device is typically 1.5-Tesla.

Important Note: An object that exhibits only “mild” or “weak” magnetic field interactions in association with exposure to a 1.5-Tesla MR system may be attracted with sufficient force by a higher field strength scanner (e.g., 3-Tesla), potentially posing a risk to a patient or individual.

source: http://www.mrisafety.com/list.asp
Principal Investigators should be sure all lab members are aware of hazards.

Make sure that anyone who is about to enter the magnet room has been filled out consent and screening forms (subjects, lab members, visitors).

Remove all metal, coins, credit cards etc. as soon as you enter the magnet area.

Think! Train yourself to mini-screen yourself every time you approach the magnet room.

Do not enter the magnet room with any tools (e.g., scissors). Use only magnet-friendly tools in the toolbox in the magnet room.
ACR Safe Practice Guidelines

Establish, Implement, and Maintain Current MR Safety Policies and Procedures

Review when introducing new equipment and personnel.
ACR Safe Practice Guidelines

Each site will name a medical director whose responsibilities include ensuring that MR safe practice guidelines are established and maintained as current and appropriate for the site.

ACR Safe Practice Guidelines

It is the responsibility of the site’s administration to ensure that the policies and procedures are implemented and adhered to at all times by the site’s personnel.

Very Serious Risk

**Boy, 6, killed in MRI accident**

By MELISSA KLEIN AND OLIVER W. PRICHARD

THE JOURNAL NEWS

(Original publication: July 30, 2001)

VALHALLA — A 6-year-old boy died two days after he was smashed in the head by a metal oxygen canister that was pulled by magnetic force into the MRI machine where he was being examined, Westchester Medical Center officials said yesterday.

An unidentified hospital employee brought the oxygen tank within reach of the 10-ton magnet's field, and it shot through the air to the center of the machine, the hospital said.

Westchester NY, 2001

Source: http://www.mrireview.com/docs/mrideath.pdf
Very Serious Risk

- MDR-17310.1
  A patient with an implanted cardiac pacemaker died during or shortly after an MRI exam. The cause is determined to be from the interaction of the pacemaker to the MRI system. (01/08/05)

- MDR-306950
  A patient with an implanted internal defibrillator died as a result of an arrhythmia scan test. The defibrillator was triggered when exposed to the magnetic field. The lead up pacing test obtained information indicating that the material in this clip could be scanned safely. (11/11/92)

- MDR-415700
  A case of scissors was pulled out of a patient's hand as she entered the magnet room. The scissors hit a patient causing a laceration to the patient's head. (02/94)

- MDR-501671
  A patient received a burn to the right hand from an ECG cable while the patient was anesthetized. A skin graft was required to treat the affected area. (10/99)

- MDR-303222
  Dislodgement of an iris clip in a patient's eye during MR imaging resulted in vision loss in that eye. (16/95)

- MDR-391471
  A patient received small but focused burns to the left thumb and left big toe. Reportedly, the operator input an incorrect patient weight resulting in an incorrect SAR value. (21/09/00)

Source: [http://www.fmrib.ox.ac.uk/peterj/safety_docs/fda_primer.html](http://www.fmrib.ox.ac.uk/peterj/safety_docs/fda_primer.html)

Magnet Safety: Little Things

- Aneurysm clips can be pulled off vessels, leading to death.

Flying things can kill people:
Even in less severe incidents, they can fly into the magnet and damage it or require an expensive shutdown.

Magnet Safety

As you approach the magnet, the fringe magnetic field gets STRONGER.
Fringe Diagram of Active Shield 1.5 T*

Subject Safety

Anyone going near the magnet – subjects, staff and visitors – must be thoroughly screened:

- Subjects must have no metal in their bodies:
  - pacemaker
  - aneurysm clips
  - metal implants (e.g., cochlear implants)
  - intrauterine devices (IUDs)
  - some dental work (but fillings are okay)

- Subjects must remove metal from their bodies:
  - jewellery, watch, piercings
  - coins, etc.
  - wallet
  - any metal that may distort the field (e.g., underwire bra)

- Females must not be pregnant or at risk of conceiving
  - Some institutions even require pregnancy tests for any female, every session

- Subjects must be given ear plugs (acoustic noise can reach 120 dB)

Room Safety

- MR Safe
- MR Conditional
- MR Unsafe

Siemens Symphony
RF Safety

Biological effects of RF magnetic fields
- Similar to ultrasound since as long as the energy deposited is below established limits, minimal heating of tissues occurs.
- Extra precautions are necessary for patients with compromised thermoregulation: fever, diabetes, obesity, cardiovascular disease, old age, medicated (β and Ca channel blockers), anesthesia

Temperature FDA Guidelines
- Normal Body Temp 37 °C or 98.6 °F
- FDA Limits:
  - increase of 38 °C (100.4 °F) in the head.
  - increase of 39 °C (102.2 °F) in the trunk
  - increase of 40 °C (104 °F) in the extremities

SAR and FDA Guidelines
Biological effects of RF magnetic fields
- Specific Absorption Rate (SAR) – Tissue heating and the body’s ability to dissipate excess heat.
- Magnets have SAR limits to prevent overheating
  - depends on body size (height and weight), and thermoregulation
  - SAR depends upon flip angle, TR, tissue density, RF pulse duration and frequency, RF coil radius, tissue conductivity and static magnetic field.
SAR and FDA Guidelines

- Specific Absorption Rate (SAR) – Tissue heating and the body’s ability to dissipate excess heat.
- Measured in Watts/Kg
  
  FDA:
  - 0.4 W/kg whole body
  - 3.2 W/kg head
  - 8.0 W/kg small volume

- Updated July 2004:

Time-Varying Magnetic Field (TVMF) Safety

Consider electrical conductivity (Faraday’s law of induction) and not just ferromagnetic properties.

Scalp burn from a cervical halo

TVMF Safety

Biological effects of TVMF magnetic fields
- Thermal burns
  - Electrical conductors can absorb energy and become extremely hot
  - Avoid having any cable wire or lead in contact with the patient
  - Surface coil cables can be placed in sleeves to prevent burns
3rd degree from Pulse oximeter cable. Toe required amputation.

2nd degree from EKG cables

Tattoos
Transdermal patches

See the following information:
MRIsafety.com
http://www.mrisafety.com/safety_article.asp?subject=56
FDA

Other safety issues

- fire safety
  - always give subjects a panic button
  - make sure that subject can be evacuated quickly if needed
  - have an MR-compatible fire extinguisher available
  - operator must know safety protocols
- quenching
  - rapid decrease in magnetic field strength
  - helium boils off and can fill room (displacing oxygen)
  - only voluntarily initiated in extreme situations

Other safety issues

- claustrophobia
  - subject screening
- acoustic noise
  - soundproofing
  - earplugs
  - headphones
If a patient states that 30 years ago, he had a small piece of metal removed from his eye, what should be employed before scanning is to begin?

* Plain films or CT of the Orbit *

Which of the following cases would be safe to scan?

A. Patient with an intracranial ferromagnetic aneurysm clip.
B. Patient with a thoracic nonferrous aneurysm clip.
C. Patient with a known nonferrous intracranial aneurysm clip.

B. Patient with a thoracic nonferrous aneurysm clip.
C. Patient with a known nonferrous intracranial aneurysm clip.
Summary

- Develop, implement and update written MR safety policies and procedures
- Be proactive
- Be familiar with ACR guidelines
- Don’t assume MR safety of implants/devices
- Radiologists must be involved in safety of each patient

References:

- MRI Safety: William Faulkner Jr. B.S., R.T. (R) (MR) (CT), FSMBT
- www.simplyphysics.com
- Magnetic Safety: fMRI 4 Newbies
- www.mrisafety.com