THE MAGNET IS ALWAYS ON!

UCSF MRI SAFETY PRIMER
Introduction

- With the rapid deployment of high field MRI systems at UCSF, comes the increase of potentially lethal safety hazards to unknowing patients and staff.
Goal

To educate hospital personnel of the ever present dangers of a static magnetic field and radio frequency related heat generated by a high field strength MR system.
Objective

At the end of this presentation, you will have enough information to function safely in a MRI environment.
Section 1
THE BASICS OF MRI IMAGING
Section 1: MRI Basics

Magnetic resonance imaging (MRI) is an imaging technique that uses radio waves and a strong magnetic field to provide clear and detailed images of internal organs and tissue.
Section 1: MRI Basics

The diagnostic benefits of MRI are numerous; however, there are hazards intrinsic to the MR environment, which must be acknowledged and respected.
Section 1: MRI Basics

These hazards may be attributed to the 3 main components that make up the MRI environment:

1. A strong static magnetic field
2. A pulsed radio frequency (RF) field
3. Gradient Fields
Section 1: MRI Basics
The Magnetic Field

- The intense static magnetic field is always present even when the scanner is not imaging and may be up to 100,000 times the magnetic field strength of the earth.
Section 1: MRI Basics
The Magnetic Field

- Magnetic field strength is measured in Tesla (T) or Gauss (G) \( (1\, \text{T} = 10,000\, \text{G}) \)

- **Five Gauss line**: Parameter around the MRI system where field strengths are over 5 Gauss. At 5 Gauss pacemakers may be affected, ferrous items become potential flying projectiles, and magnetic strips are erased.

- Below 5 Gauss is considered to be a safe level of magnetic field exposure to the general public.
Section 1: MRI Basics
Magnet Video
(Double click box to view)
Section 1 questions:

1. Which of the following statements regarding MRI are correct:
   
a. The magnet is only on during the working day
   
b. A strong magnetic field produces x-rays used for imaging
   
c. The static magnetic field strength may be up to 100,000 times the magnetic field strength of the earth
Section 1 answer:

**Answer: c**

The magnet is always on and results in a continuous strong static magnetic field such that pacemakers may be affected, ferrous items become flying projectiles and magnetic strips may be erased.

MRI uses radio waves not x-rays to generate images.
MR systems require the use of radio frequency (RF) pulses to create the MR signal. This RF energy is transmitted readily through free space from the transmit RF coil to the patient.
Section 1: MRI Basics
Gradient Fields

- Metal coils are wrapped around the magnet in 3 planes to generate gradient fields in 3 imaging directions (x, y, and z)

- The gradient fields are operated with high power amplifiers to produce miniscule changes in the primary magnetic field to spatially encode the MR signal.
Section 2

POTENTIAL HAZARDS
POTENTIAL HAZARDS

- Missile effect
- Effects on magnetic switches in pacemakers
- Tissue heating
- Peripheral nerve stimulation
- Acoustic noise
Section 2: Potential Hazards
“Missile Effect”

- The "missile effect" refers to the capability of the edge of the static magnetic field of an MR system to attract a ferromagnetic object, drawing it rapidly into the scanner by considerable force.

- The missile effect can pose a significant risk to the patient inside the MR system and/or anyone who is in the path of the projectile
Section 2: Potential Hazards Magnet Force Video (Double click box to view)
July 30, 2001 **Child Dies in MRI Machine** By THE ASSOCIATED PRESS • Filed at 2:42 p.m. ET VALHALLA, N.Y. (AP)

-- A child undergoing an MRI exam received a fatal head wound when the machine's powerful magnet pulled a metal oxygen canister inside, the Westchester Medical Center said Monday.
Section 2: Potential Hazards Effects on magnetic switches in pacemakers

Currently pacemakers and implantable cardioverter defibrillators (ICDs) are generally not considered to be MRI compatible or safe. The major concerns regarding pacing devices are potential arrhythmias and device malfunction which is a consequence of myocardial tissue heating during the scan.

*Pacemaker dependant patients should not be imaged with MRI.*
Section 2: Potential Hazards
Tissue heating

- Heating effects from MRI may be:
  - focal (surface)
  - thermal (molecular)
Section 2: Potential Hazards
Focal tissue heating

- Placement of metallic objects within the RF field used to create MR signal, may result in electrical currents sufficient to cause excessive localized heating and tissue damage i.e.

  - "Focal RF heating around metals (glasses, jewelry, implants, some tattoos, open wires or cables, some halos, etc.) can lead to burns".
Section 2: Potential Hazards
Molecular tissue heating

- RF heating of the whole body also occurs during the course of MR imaging.

- The amount of RF heating of the body that occurs over a given period of time is measured by the Specific Absorption Rate (SAR). SAR indicates the potential for heating of the patient’s tissue due to the application of the RF energy necessary to produce the MR signal.

- $\text{SAR} = \text{RF power absorbed per unit mass (watts per kilogram)}$
Section 2: Potential Hazards
Molecular tissue heating

- All MRI systems have mechanisms in place to monitor and restrict SAR to levels deemed safe by the FDA.

- FDA SAR Limits:
  - 4w/kg averaged over the whole body for any 15 minute period.
  - 3w/kg averaged over the head for any 10 minute period.
  - 8w/kg in any gram of tissue in the extremities for any period of 5 minutes.
Section 2: Potential Hazards
Peripheral nerve stimulation

- During MRI the gradient magnetic fields \((x, y, z)\) may stimulate nerves or muscle by inducing electrical fields in patients.

- At a certain rate of field change peripheral nerve stimulation is perceptible as “tingling or tapping” sensation.

- At extremely high rates of gradient change the patient may become uncomfortable or experience pain. Such rates are considered a significant risk by the FDA. Current MR systems have built-in mechanisms to monitor and restrict the rate of gradient change.
Section 2: Potential Hazards
Acoustic noise

- The gradients are also responsible for the substantial acoustic noise. The possibility exists that significant gradient magnetic field induced noise may produce substantial hearing problems in patients who are susceptible to the damaging effects of loud noises.

- FDA states that acoustic noise cannot exceed 99 dBA (A-weighted scale) with hearing protection in place.

- *Earplugs must be provided to every patient prior to imaging.*
Section 2 questions:

1. Which of the following statements regarding MRI are correct:
   
a. A heart patient with a pacemaker can undergo MRI of the spine as long as there is a crash cart in the scanner
   
b. Tattoos may result in skin heating
   
c. Earplugs should be provided upon request
   
d. Although the magnet is strong, patients who require oxygen may be scanned with standard oxygen cylinders which should always be present at the magnet
Section 2 answers:

*B is correct:*

Certain tattoos may have metallic properties (e.g. tattooed eyeliner)

Pacemakers are generally not considered safe in a magnet.

*Earplugs must be provided to every patient prior to imaging*

Standard oxygen cylinders *should not be used* since they may act as a missile and could result in death of the patient or staff
Section 3
ACCESS CONTROL
Section 3: Access Control

- Access control is an integral element of a successful MR safety program
Section 3: Access Control Zones

- At UCSF the MRI suite is subdivided into 2 zones:

- **ZONE 1**: consists of the MRI control room, which has restricted access. Optimally all equipment used in this area is MR safe.

- **ZONE 2**: consists of the MRI exam (magnet) room, which has limited access. The magnet room is locked when unattended and access without authorization or supervision of trained MR personnel is not permitted.
Section 3: Access Control
Entrance to MRI Safe Zone

- Doors are to be secured at all times.

- Yellow trim signify caution. Take time to understand safety issues and be prepared to follow safety policies before entering.
Section 3: Access Control Standardization

- Access control to all MR areas is standardized at UCSF.

- Standardized access control to Zone 1 includes:
  - Yellow paint around door entrance
  - Card access
  - Camera / intercom system
  - Signage
  - Lockers
  - Portable metal detector (wand)
Section 3: Access Control
Camera / Intercom System

- Stand in front of camera / intercom system.
- Push call button, and wait for response from technologist.
- If MR safety guidelines are followed, doors will be electronically released.
Section 3: Access Control: Proximity Card Access

- The goal of card access to the MR safe zone is to achieve maximum security and restrict untrained individuals from the area.

- Card access is only given to trained hospital staff who have completed the MRI safety course.
Section 3: Access Control
MR Safety Signage

MRI is ON
DO NOT ENTER with any METAL

WARNING

DO NOT ENTER WITH ANY METAL ITEMS
- OXYGEN TANKS
- KNIVES/SCAPELS
- TOOLS / PENS
- STETHOSCOPES
- PACEMAKERS
- BODY IMPLANTS
- NAIL CLIPPERS
- CLOTHING WITH METAL FASTENERS
- ELECTRONIC DEVICES
- PAGERS / PDA
- CELLPHONES
- LAPTOP COMPUTERS
- HEARING AIDS
- WATCHES / JEWELRY
- HAIR PINS / PAPER CLIPS
- COINS / KEYS
- CREDIT CARDS

MAGNET IS ALWAYS ON
Section 3: Access Control

Lockers

- Lockers located outside of the entrance to the MR safe zone.

- Use lockers to store personal belongings that may be ferrous in nature or has a magnetic strip (e.g. credit cards).

- The lockers have programmable locks.
Section 3 questions:

1. Which of the following statements regarding access control are correct:
   a. Access is allowed only after safety screening
   b. Card access is given only to hospital staff who have completed the MRI safety training course
   c. Use lockers to store personal belongings that may be ferrous in nature or has a magnetic strip
Section 3 answers:

*A, B and C are correct.*

Access to MRI is allowed only after safety screening. Card access is given only to hospital staff who have completed the MRI safety training course. Lockers outside the MRI control room should be used to store personal belongings that may be ferrous in nature or have a magnetic strip.
Section 4

SAFE AND UNSAFE EQUIPMENT IN MRI
Section 4: Safe and Unsafe Common Objects Not Allowed in MR Safe Zone

- Ferrous oxygen tanks (Green)
- Knifes/Scalpels
- Ferrous Tools/Pens
- Ferrous stethoscopes
Section 4: Safe and Unsafe Common Objects Not Allowed in MR Safe Zone

- Pagers/PDA
- Cell phones
- Laptop Computers
- Hearing Aids
Section 4: Safe and Unsafe Common Objects Not Allowed in MR Safe Zone

- Hairpins and paperclips
- Watches/Jewelry
- Coins/Keys
- Cards with magnetic strips (Credit Cards)
Section 4: Safe and Unsafe ITEMS NOT ALLOWED IN MRI

- Ferrous gas tanks.
- *Green color signifies ferrous cylinder.*
Section 4 : Safe and Unsafe Items

MRI Safe

- MRI safe aluminium gas cylinder.

- **MR safe cylinders are silver in color**

- Make sure dolly and regulator are also non-ferrous by checking with a bar magnet located in the MR control area
Section 4: Safe and Unsafe Items Video (Double click box to view)
Section 4: Safe and Unsafe MRI Safe Equipment

- Equipment used in the MRI environment must be checked by the Bio-Med department and labeled MRI safe prior to implementation.
Section 4 questions:

1. Which of the following statements regarding MRI safe equipment are correct:
   
a. Stethoscopes and pagers may only be worn by the code team to reduce risk of injury

b. Only silver aluminum gas tanks may be taken into the MR scanner

c. Equipment used in the MRI environment must be checked by the Bio-Med department and deemed MRI safe and labeled as such prior to implementation
Section 4 answers:

*B and C are correct.*

Stethoscopes and pagers may not be taken into the scanner room since they are potential missiles.

Only silver aluminum gas tanks are not ferrous and may be taken into the MR scanner, however the regulator and tank holder must also be labeled MR safe.

Equipment used in the MRI environment must be checked by the Bio-Med department and deemed MRI safe and labeled as such prior to implementation.
Section 5

SCREENING FOR CONTRAINDICATIONS
Section 5: Screening MRI History and Assessment Form

• Prior to any MRI procedures, patients must complete the MRI History and Assessment form that addresses possible contraindications.

• A family or caregiver representing the patient may complete the form if a patient is not able to complete the form.

• Hospital staff members who are involved with the MRI environment must complete an MR screening form.
Section 5: Screening
MRI History and Assessment Form

MAGNETIC RESONANCE IMAGING HISTORY & ASSESSMENT

1. Have you had prior surgery or an operation (e.g., arthroscopy, endoscopy, etc.) of any kind? □ No □ Yes
   If yes, please indicate the date and type of surgery:
   Date ___ / ___ / ___ Type of surgery: __________________________
   Date ___ / ___ / ___ Type of surgery: __________________________

   Please turn over to continue questionnaire.

MAGNETIC RESONANCE IMAGING HISTORY & ASSESSMENT

2. Have you had prior diagnostic imaging study or examination (MRI, CT, Ultrasound, X-ray, etc.)? □ No □ Yes
   If yes, please list:
   Body part: __________ Date: __________ Facility: __________
   MRI: __________________ CT/CTA: __________________
   Ultrasound: __________________ X-ray: __________________
   Nuclear Medicine: __________________
   Other: __________________

3. Have you experienced any problem related to a previous MRI examination or MRI procedure? □ No □ Yes
   If yes, please describe:

4. Have you had an injury to the eye involving a metallic object or fragment
   (e.g., metallic shavings, shards, foreign body, etc.)? □ No □ Yes
   If yes, please describe:

5. Have you ever been injured by a metallic object or foreign body (e.g., bullet, shotgun) or fragment? □ No □ Yes
   If yes, please describe:

6. Are you currently taking or have you recently taken any medication or drug? □ No □ Yes
   If yes, please list:

7. Are you allergic to any medication? □ No □ Yes
   If yes, please list:

8. Do you have a history of asthma, allergic reaction, respiratory disease, or reaction to a
   contrast medium or dye used for an MRI, CT, or X-ray examination? □ No □ Yes
   If yes, please describe:

9. Do you have anemia or any disease(s) that affects your blood, a history of renal (kidney)
   disease, or edema? □ No □ Yes
   If yes, please describe:

10. How much do you weigh?

   For female patients:
   11. Date of last menstrual period: ___ / ___ / ___ Post menopausal: □ No □ Yes

   Are you pregnant or experiencing a late menstrual period? □ No □ Yes
   Are you taking any type of fertility medication or having fertility treatments? □ No □ Yes
   Are you currently breastfeeding? □ No □ Yes

I have read and understood the contents of this form and have the opportunity to ask questions regarding the information on this form and regarding the MRI examination.

Signature of Person Completing Form: ____________________________
Order: __________
Form Completed by: ________ Patient □ Relative □ Nurse: ________
Form Information Reviewed By: ____________________________
MRI Technologist: __________________ Name: __________________
Radiologist: __________________ Other: __________________
Section 5: Screening
Review of Screening form

Before the patient can enter the MRI scan room, the following must occur:

1. MRI staff must review the screening form.
2. In particular, the following questions must be asked prior to the patient entering the MR scanner:

   • “Have you had any injuries to eye or body where metal was left in you?”
   • “Have you had any surgeries where metal implants or clips were placed in you?”
   • “Is there any other metal that you have on you?”
Section 5: Screening Potential Contraindications to MRI

- **Absolute:**
  - Cochlear Implants
  - Pacemakers
  - Intra-ocular foreign body

- **Relative:**
  - Aneurysm Clips
  - Deep Brain Stimulators
  - Drug delivery patches
  - Cervical Halos
  - Foreign Body (Shrapnel / Bullet)
  - Post-operative implants
  - Pregnancy

*STOP AND CHECK!!!*
Section 5: Screening Cochlear Implants

- Cochlear implants are electronically-activated devices and attracted to the magnetic field.

- Consequently, an MR procedure is **contraindicated** for a patient with this type of implant because of the possibility of injuring the patient and/or altering or damaging the function of the device.

- *Individuals with cochlear implants should be prevented from entering the MR environment.*
Section 5: Screening Pacemakers

- Cardiac pacemakers are considered to be a relative contraindication, and patients with pacemakers should be prevented from entering the MRI environment.
Section 5: Screening Pacemakers

- Cardiac pacemakers have been suggested to present potential problems to patients undergoing MRI procedures from various mechanisms, including:

  (1) movement of the pulse generator or lead(s);
  (2) temporary or permanent modification of the function of the device;
  (3) inappropriate sensing, triggering, or activation of the device;
  (4) excessive heating of the leads; and
  (5) induced currents in the leads.
Section 5: Screening
Intra-Ocular Ferrous Foreign Bodies

• Metallic loose foreign bodies in or around the eye can be deflected by the magnetic field, causing injury to the eye or surrounding tissue.

• This includes patients who have worked with sheet metal, or as a welder, since it is not uncommon for these patients to have metal fragments or slivers lodged in or around their eyes.

• A CT scan of the orbits is the exam of choice to rule out an intra-ocular ferrous foreign body.
Section 5: Screening Aneurysm Clips

- Aneurysm clips made from ferromagnetic materials are contraindicated for MR procedure, since excessive magnetically induced forces may displace these clips, causing serious injury or death.

- By comparison aneurysm clips classified as non-ferromagnetic (e.g., Titanium alloy) have been tested and shown to be safe for patients undergoing MR procedures at 1.5T or lower.
Section 5: Screening Aneurysm Clips

- Written documentation stating the make, model, and date of insertion must be present and reviewed by the MR staff before the patient is allowed into the scan room.

- MR compatibility of these clips can be checked through the manufacturer or the online database, www.mrisafety.com
Section 5: Screening Deep Brain Stimulators

- Deep brain stimulators are a relative contra-indication to MRI. The greatest concern for electronically activated or electrically conductive implants in the brain is excessive MR imaging-related heating, which can cause irreversible tissue damage.

- This may lead serious injury to the patient, including the possibility of transient dystonia, paralysis, coma, or even death.
Section 5: Screening
Deep Brain Stimulators (DBS)

- The basic implantable system is composed of the neurostimulator, DBS lead, and an extension that connects the lead to the implantable pulse generator.

- *Patients with DBS implants can only have MRI imaging of the brain with a head coil (transmit-receive head coil, where the RF is not transmitted by the body coil).*

- Imaging of parts of the body other than the head is prohibited.

- Exact safety recommendations provided by the DBS manufacturer must be strictly followed.
Section 5: Screening
Drug Delivery Patches and Pads

- Some drug delivery patches contain metallic foil. Scanning the region of the magnetic foil may result in localized heating and burns.

- Removal or repositioning of the patch may alter the drug dose, and consultation with patient’s prescribing physician would be indicated.

- If the patch is removed, a specific staff member should be given responsibility for ensuring that it is replaced or repositioned.
Section 5: Screening Cervical Fixation Halo

- Most halo cervical fixation devices are considered MR safe at 1.5 Tesla.

- Some devices have been associated with vibration and skin burns.

- Other devices have ferromagnetic components and are categorized as “conditional”. Generally the ferromagnetic interactions are minor at 1.5T, but skin burns have been reported.
Section 5: Screening Cervical Fixation Halo

- The halo cervical fixation device is accompanied by tools attached to the patient at UCSF.

- UCSF policy requires these tools to be taped to the chest plate on the patient so that they are readily available if emergency removal of the device is required for urgent care.
Section 5: Screening
Cervical Fixation Halo

- These tools are ferrous and not MRI safe.

- Prior to entering the MR scan room, these tools must be located and removed from the patient and placed with the patient chart.
Section 5: Screening
Foreign bodies - Bullets, Pellets, and Shrapnel

- There is certain ammunition that is made of ferrous material, (steel-shot), and can be potentially hazardous in a MR environment.

- The location of the bullet or piece of shrapnel in relation to vital organs must be defined before MR imaging is performed.
Section 5: Screening
Postoperative MR Procedures

- For an implant or device that exhibits weakly magnetic qualities, it is necessary to wait for 6-8 weeks, after implantation before performing an MR procedure or allowing the individual to enter the MR environment.

- Stents and filters normally become firmly incorporated into the surrounding tissue.

- Devices that are rigidly fixed in the body, such as a bone screw, may be imaged immediately.
Section: 5 Screening
Pregnancy and MRI

- MRI is not contra-indicated in pregnancy. MRI poses no known risk to the fetus in the second and third trimester. *MRI in the first trimester should only be performed after consultation with radiology faculty.*

- MR procedures have been used to evaluate obstetric, placental, and fetal abnormalities for the last 18 years
Section: 5 Screening
Pregnancy and MRI

- The use of gadolinium should be avoided unless the fetus is at full term or at least beyond organogenesis.
Section: 5 Screening Pregnancy

- While written informed consent is not necessary, it is advisable to explain the negligible nature of the risk to the patient and document this discussion in either the chart or the radiology report.
Section 5 questions:

1. Which of the following statements regarding MRI screening are correct:

   a. Prior to any MRI procedures, patients must complete the MRI History and Assessment form that addresses possible contraindications.

   b. A screening CT is necessary for suspected intra-ocular foreign bodies

   c. Aneurysm clips are unsafe in a MRI scanner.

   d. It is necessary to wait for 6-8 weeks, after implantation of a stent or filter before performing an MR procedure.
Section 5 answers:

*A, B and D are correct:*

Prior to any MRI procedures, patients must complete the MRI History and Assessment form that addresses possible contraindications.

Metallic loose foreign bodies in or around the eye can be deflected by the magnetic field, causing injury to the eye or surrounding tissue.

Titanium alloy aneurysm clips have been shown to be safe for patients undergoing MR procedures at 1.5T or lower. It is necessary to wait for 6-8 weeks, after implantation of a stent or filter before performing an MR procedure.
Section 6

CRITICAL CARE
EMERGENCIES IN MRI
Section 6: 
Critical Care Emergency In MRI

- All medical interventions must be done in the MRI control area *NOT IN THE SCAN ROOM.*

1. Assess patient condition.
2. Call Code Blue if warranted.
3. Remove patient from the MRI scan room, and secure the scan room door.
4. Open proximity access doors to MRI suite.
5. Begin emergency care in MRI control area.
6. It is the responsibility of the MRI staff to guard and monitor door to scan room after the arrival of emergency personnel.
Section 6 questions:

1. Which of the following statements regarding emergency care in MR area are correct:
   
a. The technician must quench the magnet prior to allowing the code team to enter the scanner.

b. The patient should be removed from the MRI scan room, and the scan room door secured

c. The proximity access doors to MRI suite should be opened.

d. Emergency care cannot begin in the MRI control area.
Section 6 questions:

*B and C are correct:*

The patient should be removed from the MRI scan room, and the scan room door secured. The proximity access doors to MRI suite should be opened and emergency care can begin in the MRI control area.
Section 7

MAGNET QUENCH
Section 7: MAGNET QUENCH
What is a Quench?

- Magnet quench is the manual shut down of the magnetic field.
- Can occur intentionally or by system malfunction.
Section 7: Magnet Quench
What is a Quench?

- The quench results in:
  1. Rapid Loss of Magnetic field
  2. Eliminates field within 2 minutes.
  3. Only to be performed under life-threatening circumstances

(e.g. pinning of a person against the magnet; non-extinguishable fire in the scan room - Code Red).
Section 7: Magnet Quench
What is a Quench?

- Check with Supervisor prior to quenching if time allows.
- Quench is achieved by hitting the “Emergency Run Down” Button.
- Contact service immediately
Section 7: Magnet Quench
Important Things To Do During a Quench

- During a quench, liquid helium turns to gas which is vented from the room. Venting may cause a loud noise.

- Open door to magnet room if possible, or break glass window to scan room.

- Remove all persons from the affected area.
Section 6 questions:

1. Which of the following statements regarding quenching are correct:
   
a. Should never be performed.

b. Is a safe procedure.

c. Should only be conducted if thirsty.
Section 6 questions:

None are correct.

A quench should only to be performed under life-threatening circumstances (e.g. pinning of a person against the magnet; non-extinguishable fire in the scan room - Code Red).
Conclusion

By bringing MRI safety to the forefront and providing continual education, MRI safety becomes a team effort. Everyone, from physicians to environmental service staff is responsible for being “MRI safe” before entering the MRI suite, and during the MRI procedure.
Conclusion

MRI Safety is always on!