THE MAGNET IS ALWAYS ON!

UCSF MRI SAFETY

Department of Radiology
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.
The goal is to ensure a safe environment for staff and patients around the MRI through education of hospital personnel about the ever present dangers of a static magnetic field and radio frequency related heat generated by the high field strength MR system.
Objective

At the end of this presentation, you will have information to be safely in a MRI environment.
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.
MRI Basics

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

[tethered scissors]
The Magnetic Field

- Magnetic field strength is measured in Gauss (G).

- The scan room door is considered the beginning of the 5 Gauss field.

- Outside of the 5 Gauss field, is considered to be safe to the general public with no potential risk.

- Within the 5 Gauss field, there is the danger of ferrous objects to become a flying projectile, pacemakers to stop working.
Potential Hazards of the Magnetic Field: “The Missile Effect”

- The "missile effect" refers to the capability of the static magnetic field of a 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.
The risk is real and dangerous

- On July 30, 2001 Child Dies in MRI Machine, reported by THE ASSOCIATED PRESS
  Filed at 2:42 p.m. ET VALHALLA, N.Y. (AP)

A child undergoing a MRI exam received a fatal head wound when the machine's powerful magnet pulled a metal oxygen canister inside.
Potential Hazards
Magnet Force Video (Double click to view)
Select the correct answer:

Which of the following statements regarding MRI is correct:

a. The magnet is only on during the working day.

a. A strong magnetic field produces x-rays used for imaging.

a. The static magnetic field strength may be up to 100,000 times the magnetic field strength of the earth.
The magnet is always on and results in a continuous strong static magnetic field such that pacemakers may be affected, ferrous items become flying projectile and magnetic strips may be erased.

MRI uses radio waves not x-rays to generate images.
Select the correct answer:

Which statement is true of the 5 Gauss line?

a. Within the 5 Gauss field, there is no danger of ferrous objects to become a flying object.

b. The 5 Gauss field starts at the scan door.

c. The magnetic field starts at the 5 Gauss field.
Answer: b

The magnetic field is stronger closer to the magnet. Within the 5 Gauss field, there is the danger of the ferrous projectiles to become a flying object, pacemakers to stop working. The scan room door is considered the beginning of the 5 Gauss field.
Radio Frequency (RF) field

MRI systems require the use of radio frequency (RF) pulses to create the MR signal. The radio frequency energy that is created, can be a source of heating effects.
Potential Hazards

Tissue heating

- Heating effects from MRI may lead to skin burns. Focal heating is surface heating from metals in or on the patient.

- Thermal is molecular heating of the body tissue
Potential Hazards
Focal tissue heating

- Placement of metallic objects within the RF field may result in electrical currents sufficient to cause excessive localized heating and tissue damage.
- Focal heating from items such as glasses, jewelry, implants, some tattoos, open wires, and non MRI compatible cables can lead to skin burns.
Potential Hazards
Molecular tissue heating

- RF heating of the whole body also occurs during the course of MR imaging.
- All MRI systems have mechanisms in place to monitor levels deemed safe by the FDA.
Gradient Fields

- Magnetic gradient fields generated by high power amplifiers, produce miniscule changes in the primary magnetic field to help create the MR signal. This is responsible for the loud noise heard during imaging.
Potential Hazards
Peripheral nerve stimulation

- During MRI, the magnetic gradient fields may stimulate nerves or muscle by inducing electrical fields in patients.

- At a certain rate of field change, peripheral nerve stimulation can be perceived as a “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.
Acoustic noise

- The magnetic gradient fields are also responsible for the substantial acoustic noise. The possibility exists that significant magnetic gradient 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.
Select the correct answer:

Which of the following statements regarding MRI is correct:

a. Radio frequency pulse can cause peripheral nerve stimulation.

b. Certain tattoos may result in skin heating.

c. Earplugs should be provided upon request.
B is correct:

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

Changes in the gradient fields can cause peripheral nerve stimulation.

*Earplugs must be provided to every patient prior to imaging*
ACCESS CONTROL
Access Control: Safety Zones

- At UCSF the MRI suite is divided into 2 safety zones:
  - **ZONE 1:** The MRI control room and area outside of the scanner, which has restricted access. Optimally, all equipment used in this area is MR safe.
  - **ZONE 2:** Inside the MRI room (magnet room). The magnet room is locked when unattended. Access is restricted, and access without supervision of trained MR personnel is not permitted.
Access Control
Entrance to MRI Safe Zone 1

- Doors are to be secured at all times.

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

• Access control to all MR areas is standardized at UCSF.
  – Yellow paint around door entrance
  – Card swipe for staff entry
  – Camera / intercom system for general entry
  – MRI safety signage at doors
  – Lockers are available for belongings
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.
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.
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
Access Control

Lockers

- Lockers are 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.
Select the correct answer:

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

d. All the above.
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 has a magnetic strip.
EQUIPMENT Safety IN MRI

What equipment is MRI safe?
Objects Not Allowed in MR

- Green Ferrous oxygen tanks
- Knifes/Scalpels
- Ferrous Tools/Pens
- Ferrous stethoscopes
Objects Not Allowed in MR

- Pagers/PDA
- Cell phones Laptop Computers
- Hearing Aids, Hairpins and paperclips
- Watches/Jewelry, Coins/Keys
- Cards with magnetic strips (Credit Cards)
Objects Not Allowed in MR

• To minimize the possibility of ferrous objects being brought into scan room, all patients must change into provided hospital attire prior to entering the magnet room.

• All cotton clothing without pockets or metal zippers or grommets is acceptable.
ITEMS NOT ALLOWED IN MRI

- Ferrous gas tanks.

- *Green color signifies ferrous cylinder.*
Items that are MRI Safe

- MRI safe aluminum gas cylinder.
- MR safe cylinders are silver in color.
- Dolly and regulator must also be non-ferrous.
MRI Safe Equipment

- Equipment used in the MRI environment must be checked by the Bio-Med department and labeled MRI safe prior to implementation.
Select the correct answer:

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
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.
MRI Screening form

• Patients must complete the MRI screening form prior to every MRI scan.

• 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 need entry in the MRI environment must complete an MR screening form.
## MRI SCREENING

You have been scheduled for an MRI exam. The MRI scanner uses extremely strong magnetic fields that can produce heating, movement, or electric currents in **ANY metal** in or on your body. **WARNING:** This can be hazardous to you, if you have certain metal objects in or on you. Please complete this accurately and carefully.

(Please circle Yes/No responses)

1. Do you have any metal or possibly metal containing objects in or on your body?
   - Aneuysm clip
   - Cardiac pacemaker
   - Implanted cardioverter defibrillator (ICD)
   - Electronic implant or device
   - Magnetic stem, filter, or coil
   - Neurostimulator, deep brain stimulator
   - Spinal cord stimulator
   - Internal electrodes or wires
   - Bone growth/bone fusion stimulator
   - Cochlear, otologic, or other ear implant
   - Insulin or other infusion pump
   - Implanted drug infusion device
   - Prosthesis of any kind (eye, penis, etc.)
   - Heart valve prostheses
   - Artificial or prosthetic limb
   - Shunt (programmable)
   - Shunt (non-programmable)
   - Feeding tube with mercury tip
   - Radiation seeds or implants
   - Medication patch
   - Any metallic fragment or foreign body
   - Breast tissue expander
   - Surgical staples, clips
   - Bone/plate pin, screw, nail, wire, plate
   - IUD, diaphragm, or passyary
   - Dentures or partial plates
   - Permanent makeup or eyeliner
   - Body piercing jewelry
   - Eye lid spring or wire
   - Wireless endoscopic camera
   - Hearing aid (remove prior to entry)

   If yes, give details and check box.

2. Have you had an injury to the eye involving a metallic object or fragment?
   - Yes
   - No

3. Have you ever been injured by a metallic object or foreign body (e.g., BB, bullet, shrapnel)?
   - Yes
   - No

4. List any past surgeries/Date:

   Height

5. **To be completed for patients who may receive MRI CONTRAST (GADOLINIUM)**
   - Have you ever had a previous reaction with intravenous contrast ("x-ray dye")?
     - Yes
     - No
   - If yes, give details:

6. Have you ever had a life-threatening allergic reaction?
   - Yes
   - No
   - If yes, give details:

7. **To be completed ONLY FOR WOMEN OF CHILD-BEARING AGE**
   - Are you 60 years of age or older?
     - Yes
     - No
   - Do you take medication for diabetes?
     - Yes
     - No
   - Do you take medication for high blood pressure?
     - Yes
     - No
   - Do you or your family suffer from kidney disease?
     - Yes
     - No
   - Do you have one kidney or a kidney transplant?
     - Yes
     - No
   - Do you have any organ transplant?
     - Yes
     - No
   - Do you have multiple myeloma?
     - Yes
     - No

8. **eGFR (To be completed by RN or technologist)**
   - "Yes" answer: enter eGFR within 3 months.
   - "No" answer: if eGFR is available, enter it below.

   Level: [ ]
   Date: / /

   [ ] < 60
   [ ] ≥ 60

14. Is there any possibility that you may be pregnant?
   - Yes
   - No

   Form completed by:

   Signature of Patient/parent/guardian:

   Signature of RN/technologist:
Review of Screening form

Prior to the patient entry into MRI, the MRI staff must review the screening form, and verbally ask the patient:

- “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?”
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!!!
MRI Screening
Effects on pacemakers

Current pacemakers and implantable cardiac 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 have MRI.
MRI 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.
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 (eg. Titanium alloy) have been tested and shown to be safe for patients undergoing MR procedures at 1.5T or lower.
MRI 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
Deep brain stimulators are a relative contraindication 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.
Patients with DBS implants can 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.
MRI 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 nurse or prescribing physician is necessary.
MRI Screening
Cervical Fixation Halo

- Most halo cervical fixation devices are considered MR safe.
- Some devices have been associated with vibration and skin burns.
MRI Screening
Cervical Fixation Halo

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

- Prior to entering the MR scan room, these tools must be located and removed from the patient before entering the scan room and placed with the patient’s chart.
MRI Screening

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.
MRI Screening
Postoperative MRI

- 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.
Pregnancy and MRI

- MRI is not contraindicated 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.

- The use of contrast (gadolinium) should be avoided unless the fetus is at full term or at least beyond organogenesis.
Select the correct answer:

1. Which of the following statements regarding MRI screening is correct:
   
   a. A screening CT is necessary for suspected intra-ocular foreign bodies.
   
   b. Patients with implants may not have a MRI.
   
   c. Patients with aneurysm clips may not have a MRI.
Correct answer: a

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

For an implant or device that exhibits weakly magnetic qualities, it is necessary to wait for 6-8 weeks.

Titanium alloy aneurysm clips have been shown to be safe for patients undergoing MR procedures at 1.5T or lower.
Patient Care

EMERGENCIES IN MRI
Patient Care Emergency In MRI

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

1. Assess the patient’s condition.
2. Call Code Blue if needed.
3. Remove the 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.
Select the correct answer:

Which of the following statements regarding emergency care in MR area are correct:

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

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

c. Emergency equipment is not allowed in MRI control area.
A and B 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.
MAGNET QUENCH

What is a quench?
MAGNET QUENCH

- Magnet quench is the manual shut down of the magnetic field.
- Quenching can occur intentionally or by system malfunction.
- Manual Quench is achieved by hitting the “Emergency Run Down” Button, only to be done by authorized MRI staff.
Magnet Quench

The quench results in the rapid loss of the magnetic field.
A quench is only to be performed under life-threatening circumstances such as pinning of a person against the magnet or non-extinguishable fire in the scan room.
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.
Select the correct answer:

Which of the following statements regarding quenching are correct:

a. Should never be performed.

b. Is a safe procedure.

c. Quenching the magnets is necessary in life-threatening circumstances.
Correct answer: c

A quench should only 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!*