MRI Physics V

MRI Safety

John N Oshinski, PhD

Radiology and Imaging Sciences, Emory University Hospital

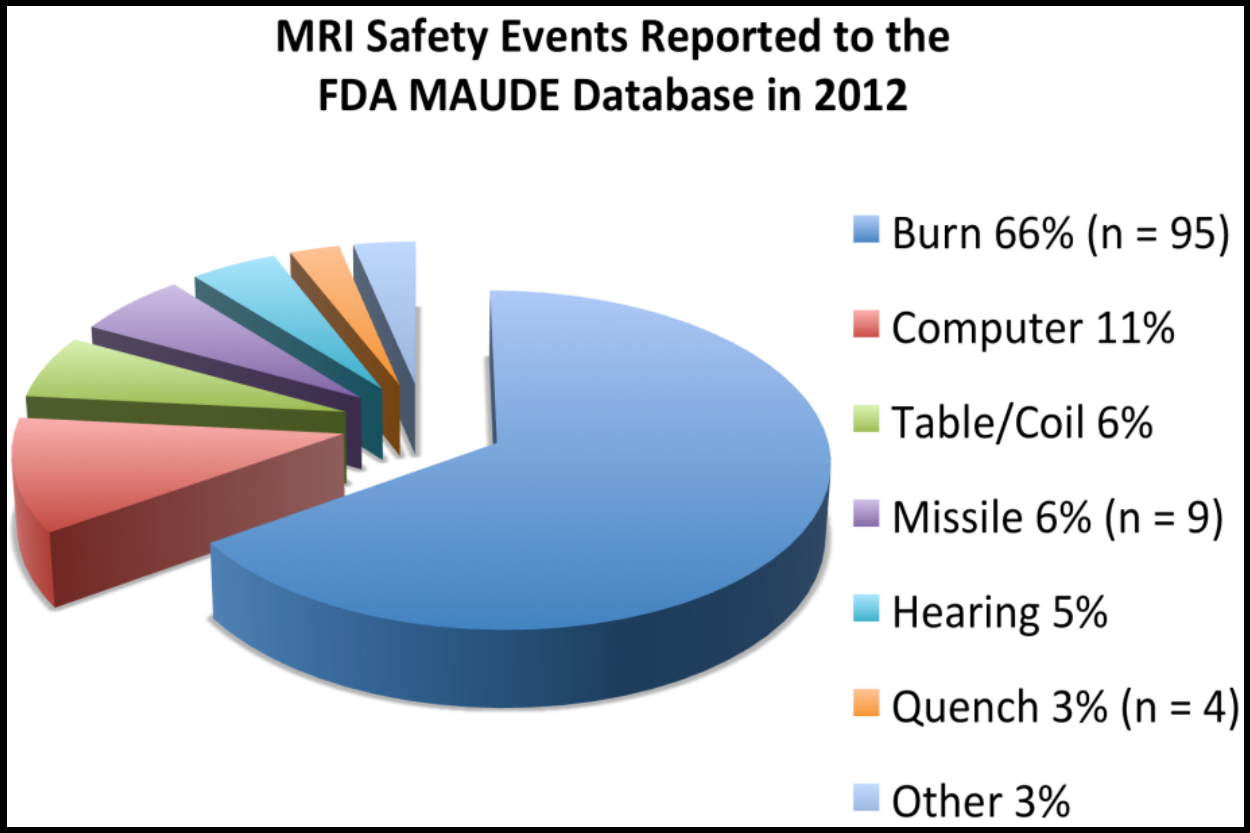
Biomedical Engineering, Emory/Georgia Tech

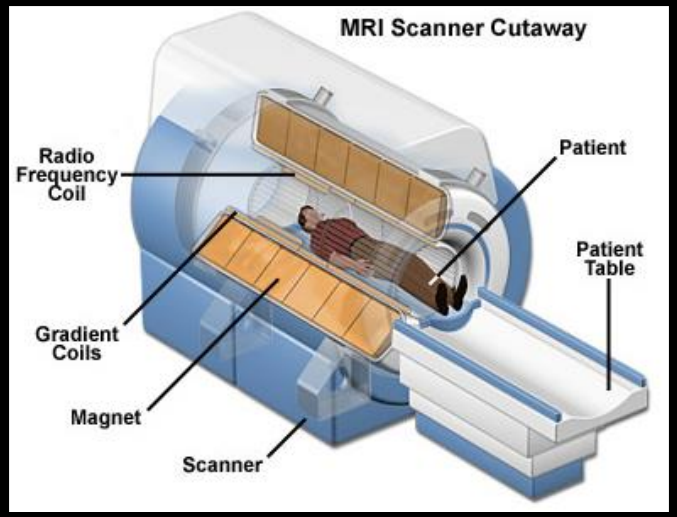
MRI Safety

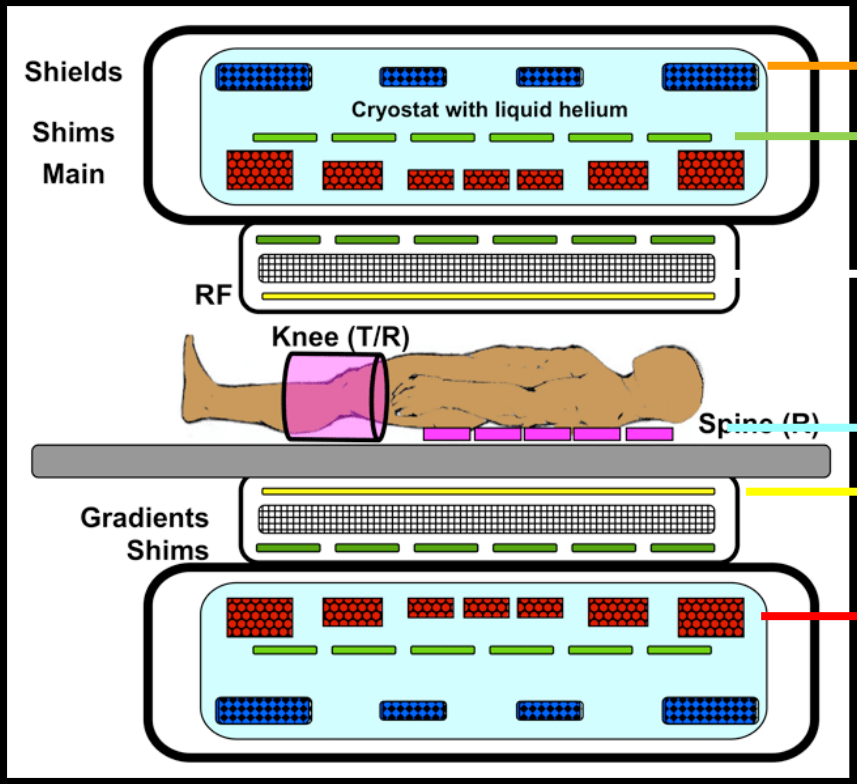
1. Static Main Magnetic Field
2. Radio Frequency (RF) pulse
3. Gradient Field
4. Devices/Implants

5. *Will not talk about contrast agents*

What causes the most safety issues in MRI?







Shield coils: reduces fringe field effects

Shim coils: improves homogeneity of a region

Gradient Coils: added changing electromagnetic field for imaging

Surface RF coils: Use to receive signal

Body RF coil: Use to transmit/receive field

Main Field Coil: Primary coil that produces Main fie (static field – does not change)

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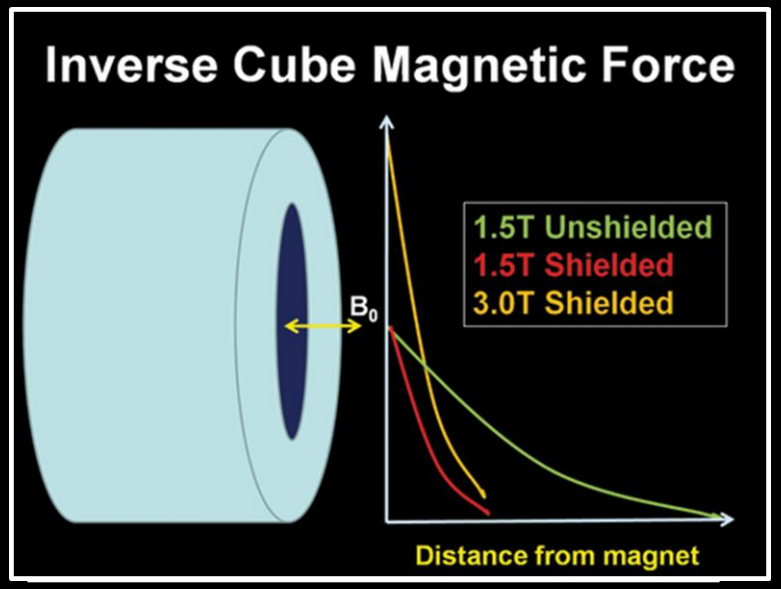
Main Magnet Safety Concerns

- Missile Effect
  - Any ferromagnetic object can be accelerated into the bore
  - Force dependent on
    - Size/weight
    - Ferromagnetic content
    - Magnetic field spatial gradient
  - An object's torque and path are unpredictable
- Device Effects (5 gauss line)
- Patient Effects (at high fields)



- https://www.youtube.com/watch?v=lEJ2notNLo0
- https://www.youtube.com/watch?v=vIQaGt_fkkw

Employees of the Westchester Medical Center in Valhalla, N.Y., gather outside after learning of the deadly MRI incident. (ABCNEWS.com)

Hospital Nightmare

Boy, 6, Killed in Freak MRI Accident

abcNEWS.com

July 31 — A 6-year-old boy died after undergoing an MRI exam at a New York-area hospital when the machine's powerful magnetic field jerked a metal oxygen tank across the room, crushing the child's head.

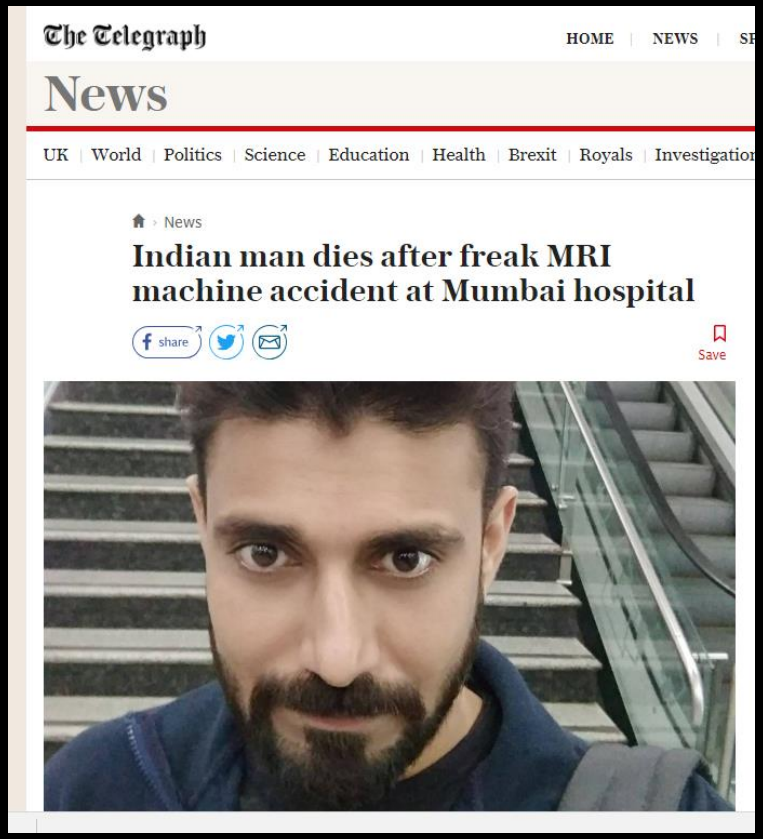
July 2001

The force of the device's 10-ton magnet is about 30,000 times as powerful as Earth's magnetic field, and 200 times stronger than a common refrigerator magnet.

The canister fractured the skull and injured the brain of the young patient, Michael Colombini, of Croton-On-Hudson, N.Y., during the procedure Friday. He died of the injuries on Sunday, the hospital said.

The routine imaging procedure was performed after Colombini underwent surgery for a benign brain tumor last week. Westchester Medical Center officials said he was under sedation at the time of the deadly accident.

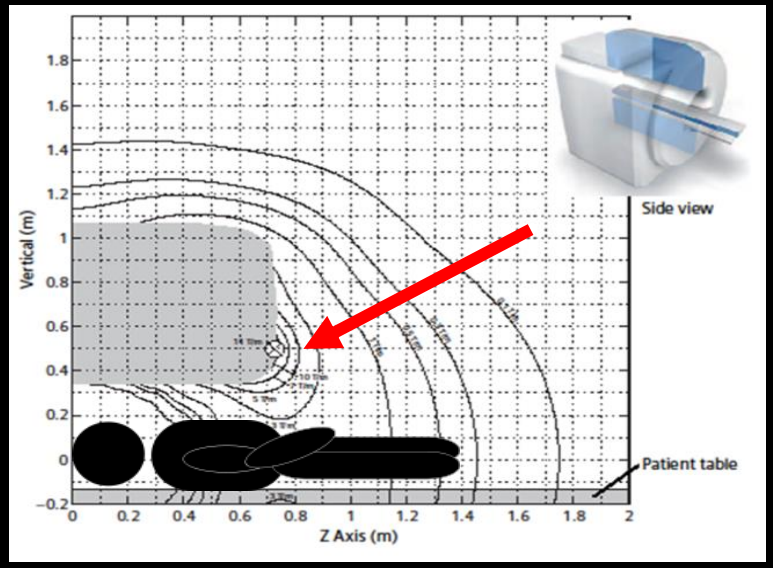
Hospital Takes 'Full Responsibility'



NDTV reports Mr Maru's hand was trapped in the machine when the damaged cylinder burst, "triggering a massive oxygen leak". He was rushed to an emergency room but was pronounced dead within 10 minutes.

His family say staff at the hospital assured them the machine was switched off before he entered the room.

Static Magnetic Field



Draw on board

Patient removal when a metallic object is present

- **DO NOT** attempt to move the object or ANY PART of the scanner (including the table)
- The object may change its magnetic polarity if dislodged and re-align with the field and become a projectile

- **FIRST** priority is to remove the patient
- Bring in MR compatible stretcher
- Transfer patient to the stretcher without dislodging the object or disturbing the parts of the scanner

“Shut off” Buttons

What do these buttons do? How are they different?

Site Modifications for Static Field Safety

Static Magnetic Field Must Have Controlled Supervised Access

ACR Guidance Document on MR Safe Practices: 2013

Zone I: Freely Accessible to General Public

Zone II: Interface Between Uncontrolled and Strictly Controlled Zone - Patients must be escorted.

Zone III: Control room and space with access to scanner door - Strictly Controlled by MR Personnel With Restricted Access

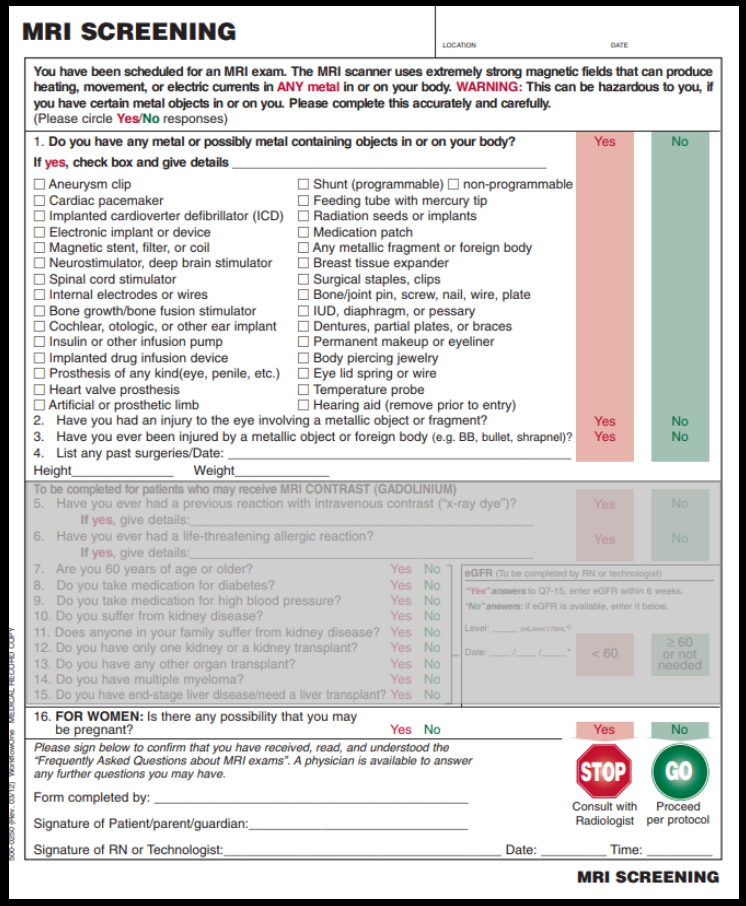
Zone IV: MR Scanner Magnet Room - Clearly marked with red light and lighted sign.

Static Magnetic Field Must Have Controlled Supervised Access

Metal Detectors

Marking of Magnetic Field Lines

Screening Form



MRI SCREENING

LOCATION DATE

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)

	Yes	No
1. Do you have any metal or possibly metal containing objects in or on your body?		

If yes, check box and give details _____

- ☐ Aneurysm clip
- ☐ Cardiac pacemaker
- ☐ Implanted cardioverter defibrillator (ICD)
- ☐ Electronic implant or device
- ☐ Magnetic stent, 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, penile, etc.)
- ☐ Heart valve prosthesis
- ☐ Artificial or prosthetic limb
- ☐ Shunt (programmable) ☐ 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/joint pin, screw, nail, wire, plate
- ☐ IUD, diaphragm, or pessary
- ☐ Dentures, partial plates, or braces
- ☐ Permanent makeup or eyeliner
- ☐ Body piercing jewelry
- ☐ Eye lid spring or wire
- ☐ Temperature probe
- ☐ Hearing aid (remove prior to entry)

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_____ Weight_____

To be completed for patients who may receive MRI CONTRAST (GADOLINIUM)

5. Have you ever had a previous reaction with intravenous contrast ("x-ray dye")? If yes, give details:_____	Yes	No
6. Have you ever had a life-threatening allergic reaction? If yes, give details:_____	Yes	No

7. Are you 60 years of age or older?	Yes	No
8. Do you take medication for diabetes?	Yes	No
9. Do you take medication for high blood pressure?	Yes	No
10. Do you suffer from kidney disease?	Yes	No
11. Does anyone in your family suffer from kidney disease?	Yes	No
12. Do you have only one kidney or a kidney transplant?	Yes	No
13. Do you have any other organ transplant?	Yes	No
14. Do you have multiple myeloma?	Yes	No
15. Do you have end-stage liver disease/need a liver transplant?	Yes	No

eGFR (To be completed by RN or technologist)
"Yes" answers to Q7-15, enter eGFR within 6 weeks.
"No" answers: if eGFR is available, enter it below.
Level: _____ (mL/min/1.73mL²)
Date: ____/____/____*
< 60
≥ 60 or not needed

16. **FOR WOMEN:** Is there any possibility that you may be pregnant? Yes No	Yes	No

Please sign below to confirm that you have received, read, and understood the "Frequently Asked Questions about MRI exams". A physician is available to answer any further questions you may have.

Form completed by: _____

Signature of Patient/parent/guardian:_____

Signature of RN or Technologist:_____ Date: _____ Time: _____

STOP — Consult with Radiologist

GO — Proceed per protocol

MRI SCREENING

INSTRUCTIONS FOR RADIOLOGY RN OR RT

YES answers to questions 7-16 and no recent eGFR available:
Proceed with an immediate Cr/eGFR test at the direction of the protocoling physician.

STOP - If there are ANY circles in the STOP column, further consultation with a supervising radiologist is required before administration of contrast. Nursing and technical staff should consult with a supervising radiologist for further instructions. Proceed only when the order for this examination has been reviewed, and is updated by the supervising radiologist in ImageCast.

GO - If ALL the circled responses are in the GO column: PROCEED with contrast administration as per the contingent order in ImageCast. This order is now final, and the electronic signature of the protocoling physician in conjunction with this form attests that the administration of contrast material has been reconciled with the patient's current medication.

IMPORTANT INSTRUCTIONS

Before entering the MRI environment or MRI system room, you must remove *all* metallic objects including hearing aids, dentures, partial plates, keys, beeper, cell phone, eyeglasses, hair pins, barrettes, jewelry, body piercing jewelry, watch, safety pins, paper clips, money clip, credit cards, bank cards, magnetic strip cards, coins, pens, pocket knife, nail clipper, tools, clothing with metal fasteners and clothing with metallic threads.

Please consult the staff if you have any questions or concerns BEFORE you enter the MRI system room.

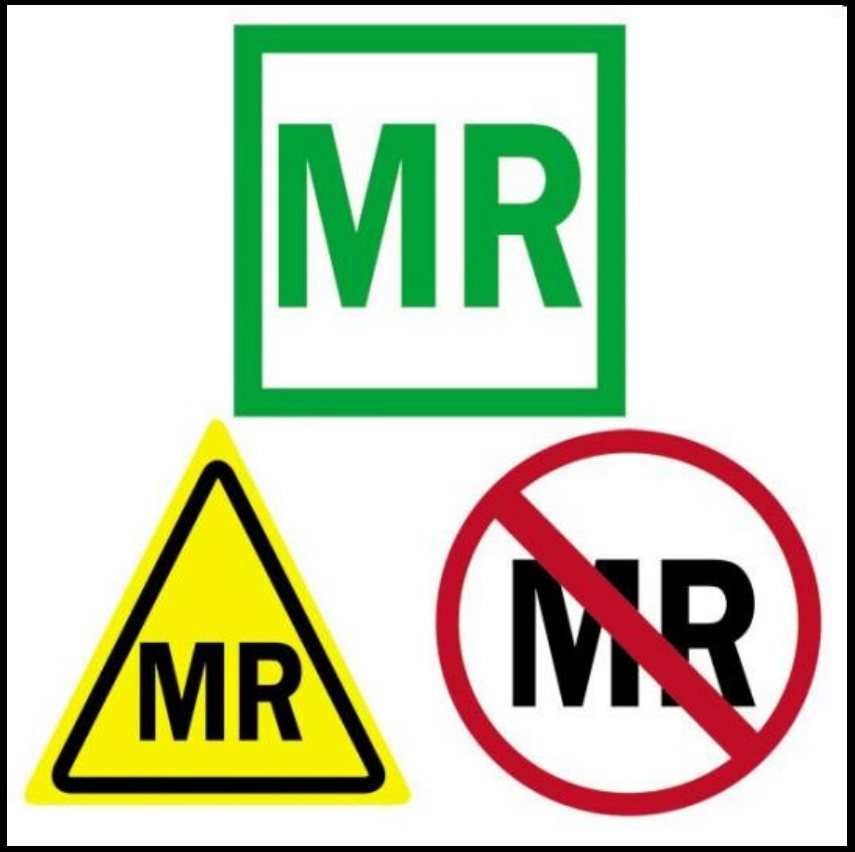
Filled out by staff:

1. Patient Screened for MRI contraindications?	☐ Yes	☐ No
2. Patient and Table Top Checked?	☐ Yes	☐ No
3. Staff Physicians Safety Trained?	☐ Yes	☐ No
4. Staff/Physicians Removed Metallic Objects?	☐ Yes	☐ No
5. Final verification/ "time-out" is performed by the team prior to entry into the magnet, including patient screening form, and all equipment checked for MRI safety or compatibility.	☐ Yes	☐ No

What do you do if something is positive on screening form?

- If a device:
  - What does manufacturer say? *MRIsafety.com website*
  - Does patient have info or card?
  - If Nitinol or Titanium, its generally OK immediately after placement
  - If it has electronics – generally stay away from scanning
- Special cases
  - Bullet or shrapnel fragment
  - Metal in eye – *Have they sought medical attention?*
  - Aneurysm clips
  - Pacemaker or pacemaker leads

Designations of Devices and Equipment



MR Safe

MR Conditional

MR Unsafe

*MR compatible**

What is the most important factor for Static Field MRI safety?

- Educate and Empower the MRI Techs
- They are in charge of access to control room and scanner

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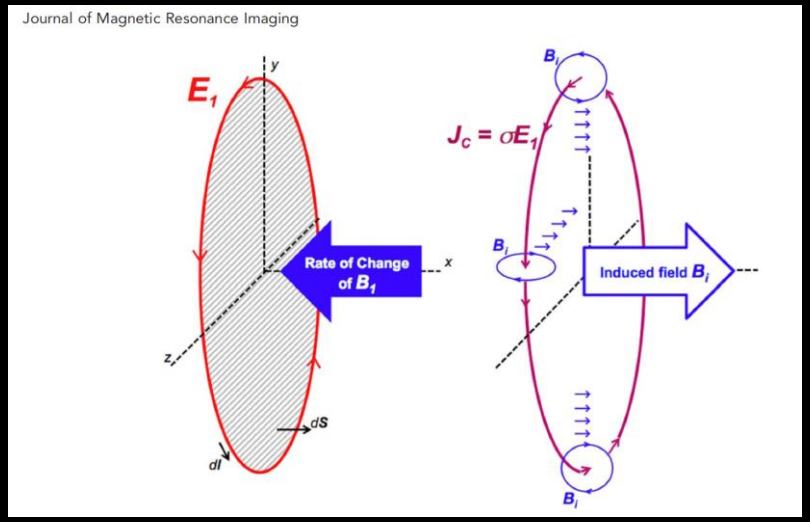
RF Pulse Safety

- Heating and Burns
- General Rules:
  - Beware conductors near the surface
  - Beware of loops or long lengths of wire

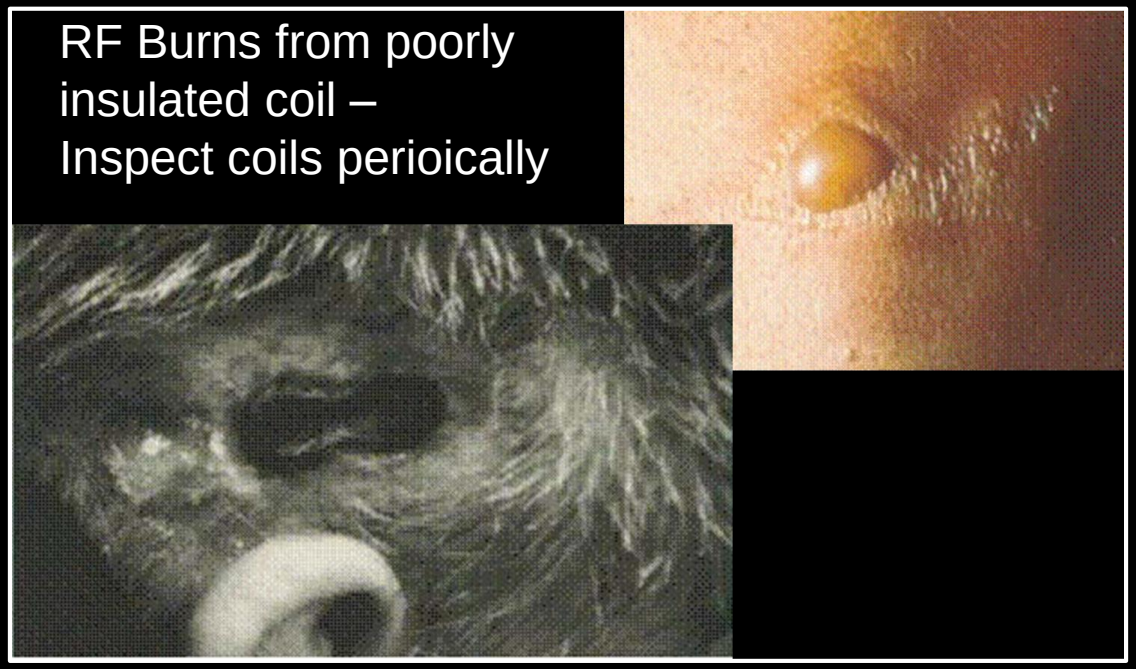


Specific Absorption Rate (SAR)

- Measure of the absorbed RF energy that can cause heating
- US FDA limits this to 4.0 W/kg in the body
- Difficult to measure, so its modelled
- Formula for a sphere says SAR = $\sigma r^2 B_0^2 \alpha^2 D$
- This is calculated by manufacturer and they will tell you when you are in danger of exceeding it.

RF Burns

RF Burns from poorly insulated coil –
Inspect coils perioically



RF and Tattoos

- May cause artifacts or short-term skin reactions
- Frequency and severity of reactions is low
- Should ***not*** prevent a patient from undergoing an MRI exam.
- Beware of iron-oxide based pigments.

Non-obvious RF issues

U.S. Department of Health & Human Services www.hhs.gov

FDA U.S. Food and Drug Administration A-Z Index Search go

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Drugs

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Drug Safety and Availability

Public Health Advisories (Drugs)

2009 Public Health Advisories

2008 Public Health Advisories

Public Health Advisory: Risk of Burns during MRI Scans from Transdermal Drug Patches with Metallic Backings

The FDA has been made aware of information about certain transdermal patches (medicated patches applied to the skin) that contain aluminum or other metals in the backing of the patches. Patches that contain metal can overheat during an MRI scan and cause skin burns in the immediate area of the patch.

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TECHNICAL NOTE

J.A. Pietryga
M.A. Fonder
J.M. Rogg
D.L. North
L.G. Bercovitch

Invisible Metallic Microfiber in Clothing Presents Unrecognized MRI Risk for Cutaneous Burn

SUMMARY: We report a case of a thermal burn that occurred during MR imaging likely caused by invisible silver-embedded microfibers in the fabric of an undershirt. As the prevalence of fabric containing nondetectable metallic microfiber increases in athletic and "tech" clothing, the importance of having patients change into safe facility-provided garments before MR imaging is emphasized.

ABBREVIATIONS: ACR = American College of Radiology; SAR = specific absorption rate; SMF = silver microfiber

Everyone changes into patient gown

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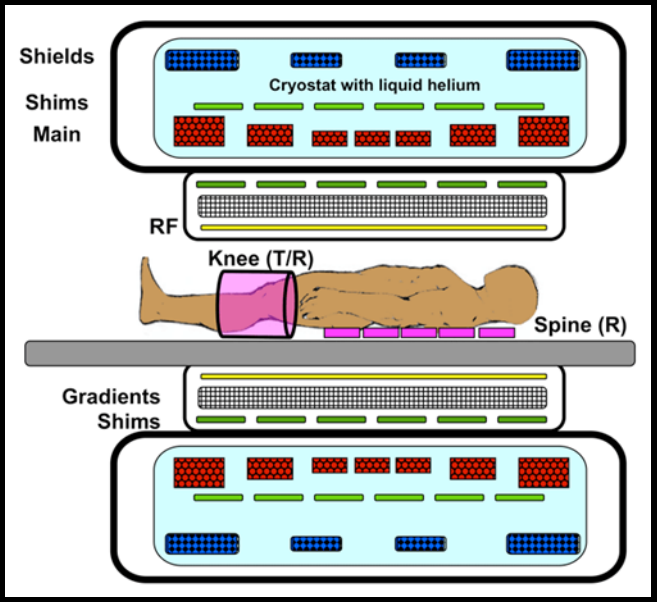
Gradient System Safety Concerns

- Acoustic Noise
  - Due to gradient force/pressure vibrations within the coil housing
- Nerve Stimulation
  - Fluctuating current may cause nerve stimulation



Acoustic Noise

- Noise level must be below 99 dB with protection in place.

- Hence everyone get hearing protection.
  - Ear pugs
  - Earphones

Summary

- MR Safety is a group effort - best to have a committee (Radiologists Physicists, hospital administration, nursing, building services)
- Pay attention to the screening form and talk to patients.
- Biggest issue is burns. Beware of loops and conductors near the surface
- Worse scenario is missile with patient inside
- Let the MR Technologists be in charge.