MRI Safety & Patient Screening
Day-to-Day Safety for the working technologist

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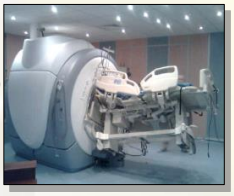
Outline

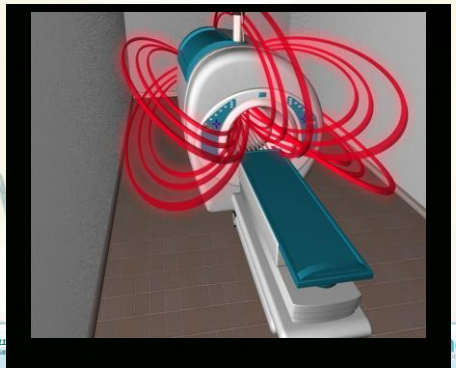
- **Who should be doing the screening?**
- **How should the screening be performed?**
- New Guidelines & Recommendations
- Why should we screen for that?
- Hardware considerations in MRI…
  - Time Varied Magnetic Fields (TVMF)
    - RF field considerations
    - Gradient field considerations
  - B0 (Static field considerations)
    - **MSG** / Within the bore
    - Fringe field
- What can go wrong?
- To Scan or Not to Scan?



Outline

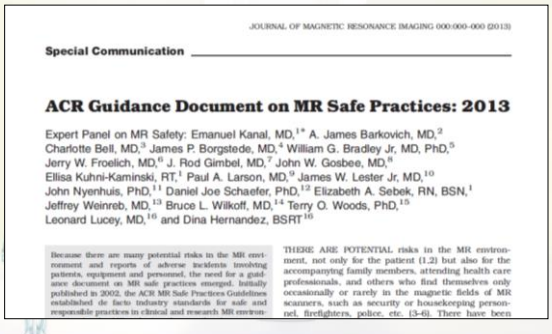
- 2001 – 6yo killed in MRI / by O2 tank
- What does the general public believe?
  - Hollywood
  - What really happens…
- MRI Hardware… Magnetic fields
  - Static field (projectiles, torque, tec)
  - Gradient fields (PNS, acoustic noise)
  - RF fields (heating, burns, flames)
- Safety associated with MR Hardware
- MRI Safety Training… Who needs it?
  - EVERYONE
  - Why ?
  - How Often ?

This really happens… Don't try this at home!



Why do they think its ok to enter the room?

New ACR Recommendations 2013



JOURNAL OF MAGNETIC RESONANCE IMAGING 000:000–000 (2013)

Special Communication

ACR Guidance Document on MR Safe Practices: 2013

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,[1] Jeffrey Weinreb, MD,[13] Bruce L. Wilkoff, MD,[14] Terry O. Woods, PhD,[15] Leonard Lucey, MD,[16] and Dina Hernandez, BSRT[16]

Because there are many potential risks in the MR environment and reports of adverse incidents involving patients, equipment and personnel, the need for a guidance document on MR safe practices emerged. Initially published in 2002, the ACR MR Safe Practices Guidelines established de facto industry standards for safe and responsible practices in clinical and research MR environ-

THERE ARE POTENTIAL risks in the MR environment, not only for the patient (1,2) but also for the accompanying family members, attending health care professionals, and others who find themselves only occasionally or rarely in the magnetic fields of MR scanners, such as security or housekeeping personnel, firefighters, police, etc. (3–6). There have been

Who Needs Patient Screening?

Everyone who wants to enter the MRI environment, including:

- Patient / Family / visitors
- Ancillary staff education
  - Transport personnel
  - Construction / maintenance
  - Nursing
  - Patient support
- Emergency response
  - Security
  - Fire department
- Research and Document ***EVERYTHING***!

"The screening process and screening forms for patients, non-MRI personnel, and MRI personnel should be essentially identical. Specifically, one should assume that non-MRI personnel, health care practitioners, or MRI personnel may enter the bore of the MRI imager during the MRI imaging process." – ACR White Paper

From the ACR Guidance Document for Safe MRI Practices 2007

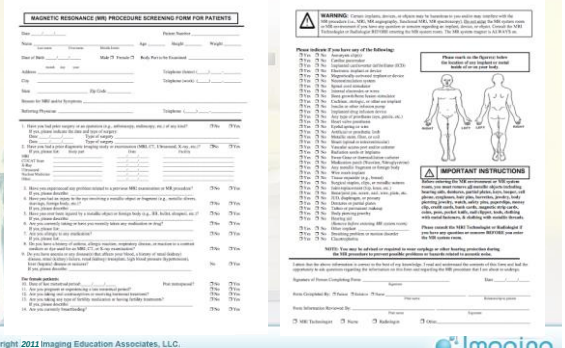
> " The screening process and screening forms for patients, non-MR personnel, and MR personnel should be essentially identical. Specifically, one should assume that screened non-MR personnel, health care practitioners, or MR personnel may enter the bore of the MR imager during the MR imaging process."

ACR Guidance on MR Safe Practice, 2013 pg 5

Patient Support Personnel

- Screening Procedures
  - Identical to Patients (less clinical)
  - Document

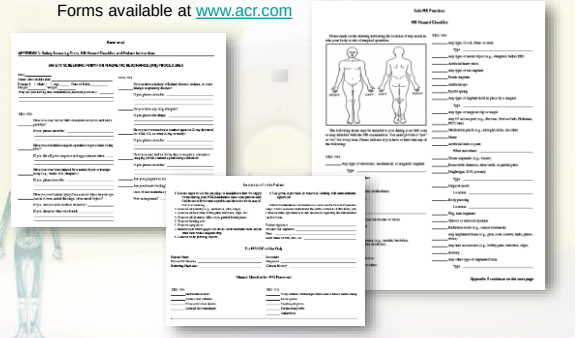
Sample Screening Form



Courtesy Dr. Frank Shellock, mrisafety.com

Recommended Screening Forms – ACR

Forms available at www.acr.com

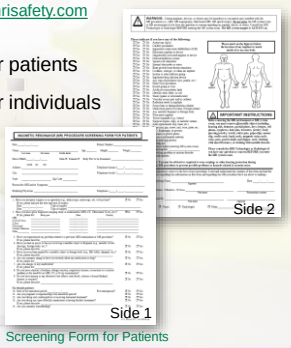


Recommended Screening Forms

Forms available at www.mrisafety.com

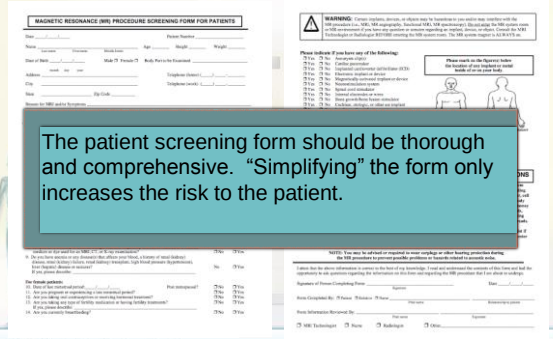
- Forms for patients
- Forms for individuals

Screening Form for Individuals



Screening Form for Patients

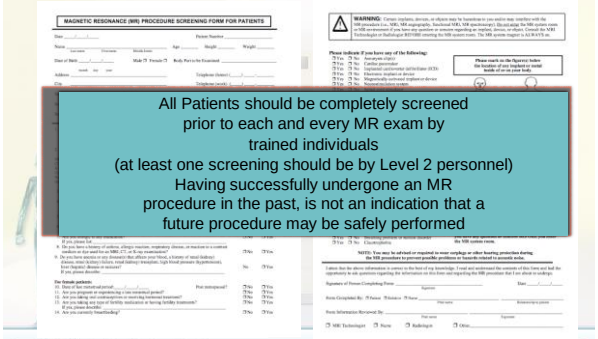
Sample Screening Form



The patient screening form should be thorough and comprehensive. "Simplifying" the form only increases the risk to the patient.

Courtesy Dr. Frank Shellock, mrisafety.com

Sample Screening Form



All Patients should be completely screened prior to each and every MR exam by trained individuals (at least one screening should be by Level 2 personnel) Having successfully undergone an MR procedure in the past, is not an indication that a future procedure may be safely performed

Courtesy Dr. Frank Shellock, mrisafety.com

Unresponsive Patient Screening

If no reliable patient metal exposure history can be obtained, and if the requested MR examination cannot reasonably wait until a reliable history might be obtained, it is recommended that such patients be physically examined by level 2 MR personnel. All areas of scars or deformities that might be anatomically indicative of an implant, such as on the chest or spine region, and whose origins are unknown and which may have been caused by ferromagnetic foreign bodies, implants, etc., should be subject to plain-film radiography (if recently obtained plain films or CT or MR studies of such areas are not already available). The investigation described above should be made to ensure there are no potentially harmful embedded or implanted metallic foreign objects or devices. All such patients should also undergo plain film imaging of the skull or orbits and chest to exclude metallic foreign objects (if recently obtained such radiographic or MR information not already available).

ACR Guidance on MR Safe Practice, 2013 pg 6

Who performs the screening ?

- Screened by level 2 personnel
- More than once
- Verbally & visually
- Written

– or –

- X-rays

From the ACR Guidance Document for Safe MRI Practices 2007

Verbal and Interactive Screening

1. Screening should be performed by trained individuals
2. Screen non-emergent patients at least twice
3. The technologist who is performing the MR exam should interview / screen the patient verbally and interactively

Courtesy Chattanooga Imaging

FDA MAUDE Database

Event Date 03/19/2015
Event Type Injury
Event Description

Pt arrived to emergency room on (b)(6) 2015 at 08:44 with admission diagnosis of acute encephalopathy. Ct head with contrast was ordered and completed at 09:51 with radiologist impression stating mri would be more definitive if clinically warranted. Xr chest ordered and performed at 10:30 noting a dual-lead pacemaker. Mri brain with contrast ordered same day at 12:14 and pt was transported to department around 13:07. Pt did not feel well, was vomiting and was sent to admitted inpatient room without study completed. Pt was again transported to department on (b)(6) 2015 around 18:00 and waited in mri holding for other pt to finish scan. The mri techs were working in department and finished the last outpatient scan. After outpatient schedule was completed one mri tech left for the day. The remaining mri tech verbally reviewed implants with the pt prior to scanning and he denied the presence of a pacemaker. The mri technologist then took the pt into mri zone 4 for scan. The technologist reviewed the paper mri screening form during this time which revealed the pt did have a pacemaker. She then verified the presence of the pacemaker on the pt's recent chest x-ray and immediately removed the pt from the scanner/zone 4. The pt's mri unsafe pacemaker was exposed to the magnetic field, rf and gradients for approximately 7-10 minutes. The following were immediately notified of the incident: mri lead technologist, mrsd, administrative imaging director, pt's rn. The hsrd notified the charge rn the pt's pacemaker could potentially be damaged and not function properly and recommended remote telemetry. The report was filed to the hospital's risk management department. The mrsd communicated the incident with the imaging medical director for additional communication with treating provider. The provider noted the pt was doing well without any adverse medical event. Procedures are in place for annual mri safety training however and immediate safety training facilitated by the mrsd was conducted to re-educate mri techs on policies and procedures on (b)(6) 2015. The scanning mri technologist failed to follow safe procedures prior to scanning pt due to the assumption of her fellow co-workers already screening pt.

"The scanning technologist failed to follow safe procedures prior to scanning pt due to the assumption her fellow co-workers already screening [*sic*] pt."

Be aware of what can happen with a "hand-off"

Patient Preparation for MRI

- Remove metal
- Change patient

- "**Any individual undergoing an MRI procedure…**
  - **must remove all readily removable metallic personal belongings and devices on or in them** (e.g., watches, jewelry, pagers, cell phones, body piercings [if removable], contraceptive diaphragms, metallic drug delivery patches, cosmetics containing metallic particles [such as eye make-up], and clothing items that may contain metallic fasteners, hooks, zippers, loose metallic components, or metallic threads).
- "**It is therefore advisable to require that the patients or research subjects wear a site-supplied gown with no metal fasteners when feasible."**

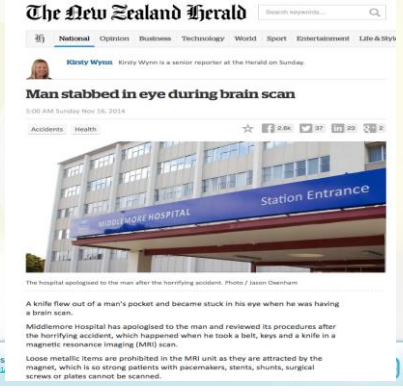
Even in the gown, they LIE!!!
Ask my resident with kept on her Bra, and her weave!

From the ACR Guidance Document for Safe MRI Practices 2007

Patient Dress

- Remove all removable items
- Dress all patients in MR-appropriate attire

Importance of MR Appropriate Attire



The New Zealand Herald

National Opinion Business Technology World Sport Entertainment Life & Style

Kirsty Wynn Kirsty Wynn is a senior reporter at the Herald on Sunday.

Man stabbed in eye during brain scan

5:00 AM Sunday Nov 16, 2014

Accidents Health

The hospital apologised to the man after the horrifying accident. Photo / Jason Oxenham

A knife flew out of a man's pocket and became stuck in his eye when he was having a brain scan.

Middlemore Hospital has apologised to the man and reviewed its procedures after the horrifying accident, which happened when he took a belt, keys and a knife in a magnetic resonance imaging (MRI) scan.

Loose metallic items are prohibited in the MRI unit as they are attracted by the magnet, which is so strong patients with pacemakers, stents, shunts, surgical screws or plates cannot be scanned.

Firearms in MRI

IndyStar
December 31, 2015

A veteran was wounded Wednesday at Richard L. Roudebush Veterans Affairs Medical Center when a handgun he brought into the Indianapolis hospital accidentally discharged in his pocket while he was in a procedure room — possibly an MRI suite.

Hospital officials confirmed the accidental shooting in a statement issued Thursday and reported the victim, whose name was not released, received immediate medical attention. The statement added the man's wound did not threaten his life.

A hospital spokesman initially confirmed in a telephone call from The Indianapolis Star that the incident involved an MRI, but the subsequent statement said only that the incident occurred "in a procedure room." When asked for clarification about the involvement of the MRI, the spokesman said in an email that the statement "is our response at this time."

The statement noted it is a violation of federal and state law to bring a firearm into the hospital and "notification of this law is posted at every entrance."

Importance of MR Appropriate Attire

Event Description

A female patient was undergoing a scan of the left shoulder. During the first sequence (3. 5 mins), the patient's blouse caught on fire producing a flame of approximately 20 centimeters. The scan was stopped immediately and the patient was evacuated. The patient suffered 3rd degree burns to the forearm. The customer continued to use the device and scan additional patients before requesting a system check. Initial investigation revealed that the blouse of the patient was apparently electrically conductive. Incident was not caused by system failure.

Blouse catches fire during 1st sequence of a shoulder exam.
3rd degree burns to forearm.

- FDA MAUDE database

Importance of MR Appropriate Attire

COPPER FACTS

TOMMIE COPPER PRO+IONIC COPPER-INFUSED FABRIC TECHNOLOGY

High density activated copper is permanently infused into all performance yarns. The proprietary PRO+IONIC copper fabric releases ions, which may help reduce the oxidants in the body and is a natural, permanent anti-bacterial agent with skin benefits.

Some benefits of copper are:

- Increases oxygen transport in compression products
- Neutralizes "free radicals"
- Improves muscle tone
- Emits ions
- Has been used in medicine for thousands of years
- Is one of the necessary micro-nutrients found naturally in the body

PRO IONIC COPPER FABRIC

Importance of MR Appropriate Attire


Published December 15, 2011 as 10.3174/ajnr.A2827

TECHNICAL NOTE

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

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

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

Sports attire

11-year-old girl presented for outpatient MR imaging of the spine for evaluation of scoliosis, wearing a gray undershirt under a long-sleeved white tee shirt and gray sweat pants

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Importance of MR Appropriate Attire

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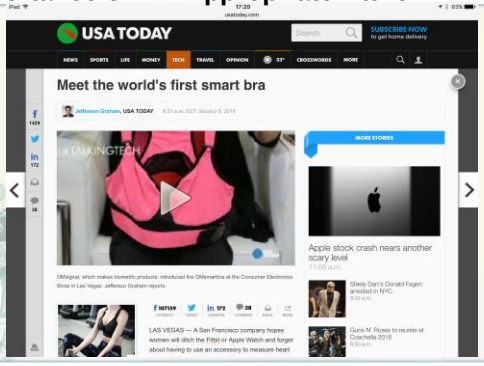
Importance of MR Appropriate Attire



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Importance of MR Appropriate Attire

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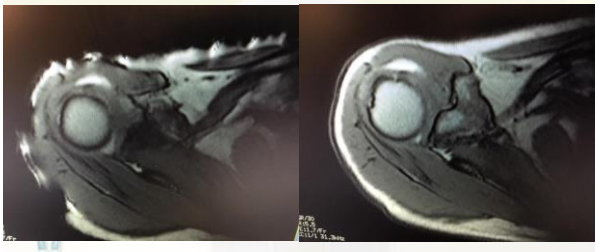
Importance of MR Appropriate Attire



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Screening Devices / Old Fashioned 'Metal Detectors'


Metal detectors

"The usage in MRI environments of conventional metal detectors which do not differentiate between ferrous and non-ferromagnetic materials is not recommended. Reasons for this recommendation against conventional metal detector usage include, among others:

1. They have varied – and variable – sensitivity settings.
2. The skills of the operators can vary.
3. Today's conventional metal detectors cannot detect, for example, a 2 × 3 mm, potentially dangerous ferromagnetic metal fragment in the orbit or near the spinal cord or heart.
4. Today's conventional metal detectors do not differentiate between ferromagnetic and non-ferromagnetic metallic objects, implants, or foreign bodies.
5. Metal detectors should not be necessary for the detection of large metallic objects, such as oxygen tanks on the gurney with the patients. These objects are fully expected to be detected – and physically excluded – during the routine patient screening process.


Hand held Metal detectors

From the ACR Guidance Document for Safe MRI Practices 2007

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Screening tools – Ferromagnetic Metal

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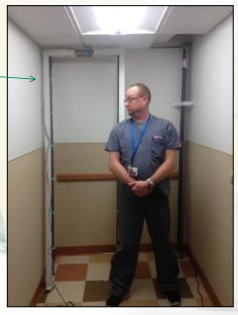
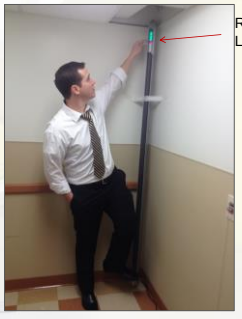
Safe, Unsafe or Conditional





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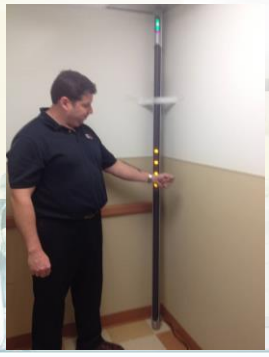
Screening Devices



- Mandatory in some states
- Like any device, these ‘’screeners” are only As good as the user

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Hand-Held Magnets

- Ferromagnetic detection systems are currently available that are simple to operate, capable of detecting even very small ferromagnetic objects external to the patient, and now, for the first time, differentiating between ferromagnetic and non-ferromagnetic materials.
- While the use of conventional metal detectors is not recommended, the use of **ferromagnetic detection systems** is recommended as an adjunct to thorough and conscientious screening of persons and devices approaching Zone IV. It should be reiterated that their use is in no way meant to replace a thorough screening practice, which rather should be supplemented by their usage.

Hand-held magnets can, in some cases provide a false sense of security.

Ask my patient with Steel Tipped boots!

From the ACR Guidance Document for Safe MRI Practices 2007

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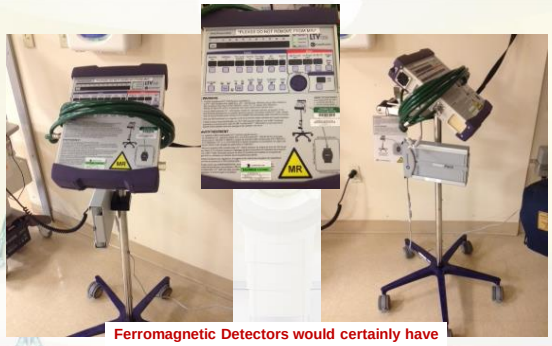
MR Conditional Devices



Ferromagnetic Detectors would certainly have noticed this small amount of metal!

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Devices might do more than ‘fly’ in!

- If MRI safety data are not prospectively available for a given device, initial testing for the purpose of this labeling is to be accomplished by the site’s MRI personnel by exposing the metallic object to a handheld magnet (≥ 1000 gauss).
- If grossly detectable attractive forces are observed between the object being tested or any of its components and the handheld magnet, it is to be labeled with a circular red “not MRI safe” label.
- If no or negligible attractive forces are observed, a triangular yellow “MRI conditional” label is to be attached to the object. It is only when the composition of an object and its components are known to be nonmetallic that the green “MRI safe” label is to be affixed to a device or object.

It’s not only about the device itself… what about the spring that holds the device on the finger… or toe!

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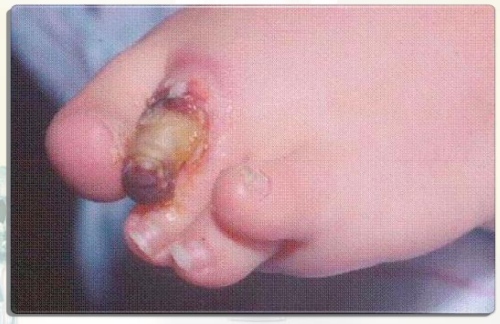
3rd Degree from Pulse Ox Clip



www.simplyphysics.com

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- *New Guidelines & Recommendations*
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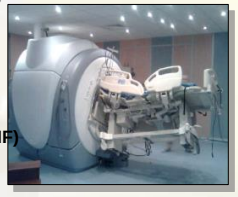

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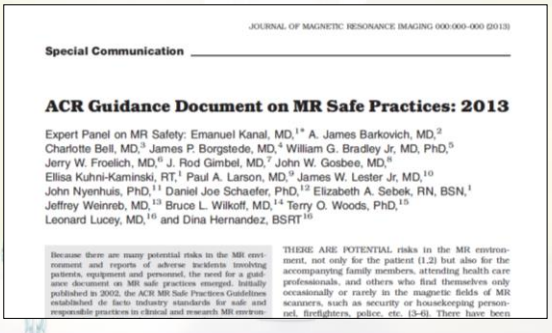
New ACR Recommendations 2013



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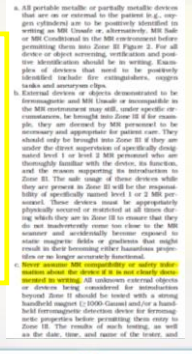
Documenting Devices

ACR Guidance on MR Safe Practices

5. Device and Object Screening

Ferrous objects, including those brought by patients, visitors, contractors, etc., should be restricted from entering Zone III, whenever practical.

As part of the Zone III site restriction and equipment testing and clearing responsibilities, all sites should have ready access to a strong handheld magnet (≥1000-Gauss) and/or a handheld ferromagnetic detection device. This will enable the site to test external, and even some superficial internal devices or implants for the presence of grossly detectable ferromagnetic attractive forces.



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How are the identified?

Figure 2. U.S. Food and Drug Administration labeling criteria (developed by ASTM [American Society for Testing and Materials] International) for portable objects taken into Zone IV. Square green "MR safe" label is for wholly nonmetallic objects, triangular yellow label is for objects with "MR conditional" rating, and round red label is for "MR unsafe" objects.

- How many conditions are there?

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Levels & Zones - According to ACR

Personnel In the MRI Environment	Locations In the MRI Environment
Non-MRI Personnel – No MRI Training	Zone I – Level 1 or 2 Non-MRI Personnel
Level 1 – Limited MRI Training	Zone II – Level 1 or 2 Non-MRI Personnel
Level 2 – Extensive MRI Training	Zone III – Only level 2
	Zone IV – Only level 2

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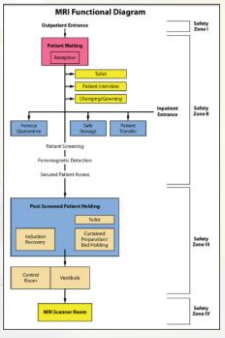
New Site Recommendations - Zones

Zones 2002

Zones 2004 & 2007



ACR Guidance Document for Safe MRI Practices 2007

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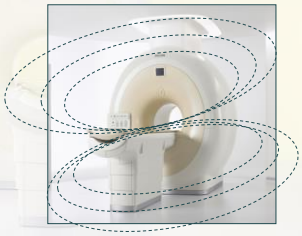
MRI Safety Update – Hardware

- Magnetic fields
  - **Time varied magnetic fields (TVMF)**
    - **Radiofrequency Fields (RF)**
    - **Gradient fields**
- Static magnetic field
  - Within the bore
  - Outside the bore
    - Fringe field
    - Stray field

Most commonly occurring …

under-estimated and under reported



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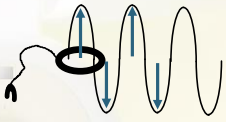
RF Field Safety

- RF
  - Power
  - Wavelength
- Bio-effects
  - RF Heating
    - More problematic when dealing with metallic materials within the imaging volume of the magnet
    - Different issues with higher field strengths
    - Varies with system
  - SAR
- FDA Regulations



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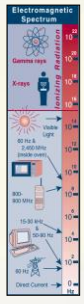
Bio-effects of RF

- Most of the RF power used in MRI imaging
  - Is transformed into heat
  - Is absorbed in the patient's tissues
- Bio-effect of RF absorption is heating of tissue
  - FDA limits to an increase in core body temperature of 1 degree…Centigrade (^{0}C)
  - FDA limits the absorption of RF
    - To 4.0 watts/kilogram (w/kg) for whole body absorption
    - Averaged over 15 minutes for clinical imaging



Non-ionizing Electromagnetic Radiation

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SAR Limits for RF Fields

Food and Drug Administration (FDA) /
Criteria for Significant Risk Investigations of Magnetic Resonance Diagnostic Devices (CDRH)
Issued – 07/14/03

Specific Absorption Rate			
Site	**Dose (W/kg)**	**Time (min)**	**SAR**
Whole Body	Averaged Over	15	4
Head	Averaged Over	10	3
Head or Torso	Per Gram of Tissue	5	8
Extremities	Per Gram of Tissue	5	12

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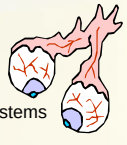
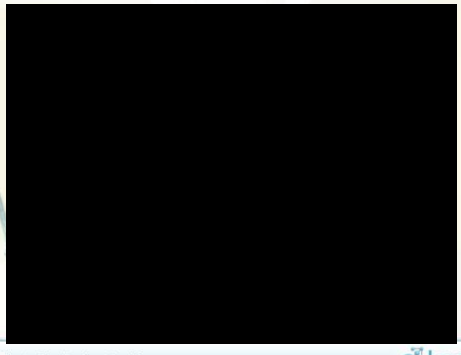
Increased … RF Effects

- Scans & options
  - Magnetic Transfer (MTI)
  - Fast Spin Echo (FSE)
    - More heat / more RF pulses
    - Double the flip, 4X the power
- Patients with compromised thermoregulatory systems
  - Higher risk for RF effects
- Patients with higher risk include:
  - Cardiovascular disease
  - Hypertension, diabetes, fever, elderly & obese
  - Certain medications can alter thermoregulatory response to heat load.
  - Areas of particular concern
    - Eyes
    - Testis



Slide - 48

House - Tattoo



Burn Possibilities

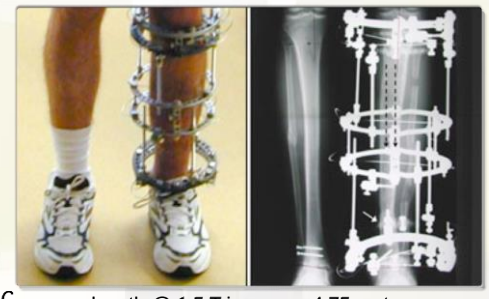
- Tattoos
- Metal in trans-dermal patches
- Metallic leads/probes
  - Coil cables
  - ECG leads
- Risk increases with field strength

For patients with extensive or dark tattoos, including tattooed eyeliner, in order to decrease the potential for RF heating of the tattooed tissue, it is recommended that cold compresses or ice packs be placed on the tattooed areas and kept in place throughout the MRI process if these tattoos are in the volume in which the body coil is being used for RF transmission.

This approach is especially appropriate if fast spin-echo (or other high RF duty cycle) MRI sequences are anticipated in the study. If another coil is being used for RF transmission, a decision must be made if high RF transmitted power is to be anticipated by the study protocol design. If so, then the above precautions should be followed. Additionally, patients with tattoos that had been placed within 48 hours prior to the pending MRI examination should be advised of the potential for smearing or smudging of the edges of the freshly placed tattoo.

From the ACR Guidance Document for Safe MRI Practices 2007

MR Conditional Devices

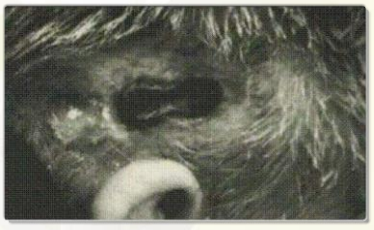


$\lambda = \frac{c}{f}$ wavelength @ 1.5 T is approx 4.75 meters
30 cm = 1/8 wavelength

Courtesy Frank Shellock, Ph.D.

Scalp burn from halo

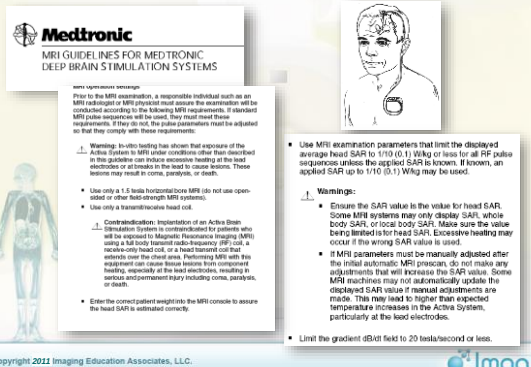
$\lambda = \frac{c}{f}$



wavelength @ 1.5 T is approx 4.75 meters
30 cm = 1/8 wavelength

Courtesy Frank Shellock, Ph.D.

Deep Brain Stimulators (DBS)



Medtronic

MRI GUIDELINES FOR MEDTRONIC DEEP BRAIN STIMULATION SYSTEMS

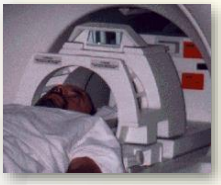
MRI Operation Settings

Prior to the MRI examination, a responsible individual such as an MRI radiologist or MRI physicist must assure the examination will be conducted according to the following MRI requirements. If standard MRI pulse-sequences will be used, they must meet these requirements. If they do not, the pulse parameters must be adjusted so that they comply with these requirements:

- Warning: In-vitro testing has shown that exposure of the Activa System to MRI under conditions other than described in this guideline can induce excessive heating at the lead electrodes or at breaks in the lead to cause lesions. These lesions may result in coma, paralysis, or death.
- Use only a 1.5 tesla horizontal bore MRI (do not use open-sided or other field-strength MRI systems).
- Use only a transmit/receive head coil.
- **Contraindication:** Implantation of an Activa Brain Stimulation System is contraindicated for patients who will be exposed to Magnetic Resonance Imaging (MRI) using a full body transmit radio-frequency (RF) coil, a receive-only head coil, or a head transmit coil that extends over the chest area. Performing MRI with this equipment can cause tissue lesions from component heating, especially at the lead electrodes, resulting in serious and permanent injury including coma, paralysis, or death.
- Enter the correct patient weight into the MRI console to assure the head SAR is estimated correctly.
- Use MRI examination parameters that limit the displayed average head SAR to 1/10 (0.1) W/kg or less for all RF pulse sequences unless the applied SAR is known. If known, an applied SAR up to 1/10 (0.1) W/kg may be used.
- **Warnings:**
  - Ensure the SAR value is the value for head SAR. Some MRI systems may only display SAR, whole body SAR, or local body SAR. Make sure the value being limited is for head SAR. Excessive heating may occur if the wrong SAR value is used.
  - If MRI parameters must be manually adjusted after the initial automatic MRI prescan, do not make any adjustments that will increase the SAR value. Some MRI machines may not automatically update the displayed SAR value if manual adjustments are made. This may lead to higher than expected temperature increases in the Activa System, particularly at the lead electrodes.
- Limit the gradient dB/dt field to 20 tesla/second or less.

Burn Possibilities

- Report of permanent brain injury from DBS probe (burn during MRI exam) at 1.0 T
  - Some can only be scanned with transmit/receive head coil.
  - Before scanning, be sure the coil is not receive only!
  - Be sure that a device/implant is safe before scanning.
- Report of 3rd degree burn (1.5 T) with Intracrania pressure (ICP) catheter



Burn Possibilities – Config. & Field Strength

- It is possible, to introduce resonant circuitry between the transmitted RF power & the lead (depending upon lead length, field strength and parameter settings)
- This can also occur with implanted leads or wires, even when they are not connected to any other device at either end.
- The FDA has noted several reports of serious injury, including coma and permanent neurologic impairment, in patients with implanted neurologic stimulators who underwent MRI imaging examinations. The injuries in these instances resulted from heating of the electrode tips.

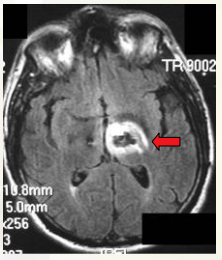
- It is entirely possible for a lead or wire to demonstrate no significant heating while undergoing MRI imaging examinations at 1.5 Tesla (T), yet demonstrate clinically significant and potentially harmful degrees of heating within seconds at, for example, 3T. It has also been demonstrated that leads may show no significant heating at 3T, yet may rapidly heat to hazardous levels when undergoing MRI imaging at, for example, 1.5.

From the ACR Guidance Document for Safe MRI Practices 2007

Guidelines not followed


CASE REPORTS

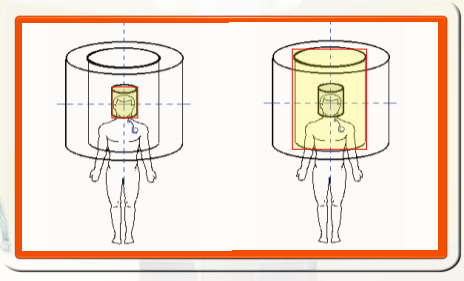
PERMANENT NEUROLOGICAL DEFICIT RELATED TO MAGNETIC RESONANCE IMAGING IN A PATIENT WITH IMPLANTED DEEP BRAIN STIMULATION ELECTRODES FOR PARKINSON'S DISEASE: CASE REPORT



1.5 T ONLY
T/R Head coil ONLY
Head SAR 0.1 W/kg

Courtesy: Frank Shellock, Ph.D.

RF Coils



T/R Head Coil vs. Transmit Body/Receive-only Head Coil

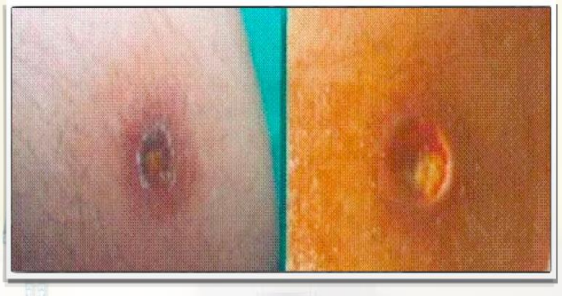
FDA Reports

Examples of patient injuries and incidents reported to the FDA in April of 2009

FDA Reports – Hip MRI / Burn

The coil was positioned for a hip examination. It was observed that the coil cable was routed between the left arm and left breast. Immediately after the examination, first and second degree burns with a 17 mm and a 24 mm blister appeared on the inside of the left upper arm and left breast.

Skin-to-Skin Contact

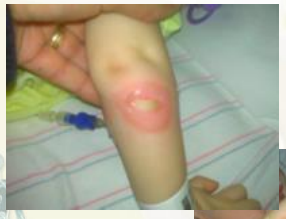


www.simplyphysics.com

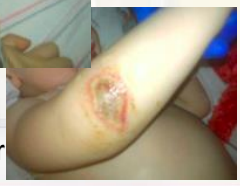
FDA Reports – Sacrum MRI / Burn

The site reported that the pt sustained quarter size blisters on both elbows during a MR exam of the sacrum using a torso array surface coil. The pt was not being monitored during the exam. The pt's hands were not clasped during the exam. Also, there was no cable or conductive material in contact with the pt during the exam. According to the site, no padding was used on the pt. Instead, the site used sheets and blankets

RF Burns



Initial Injury

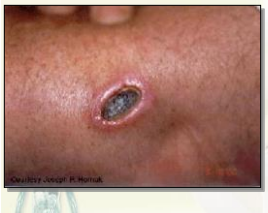


Few days later

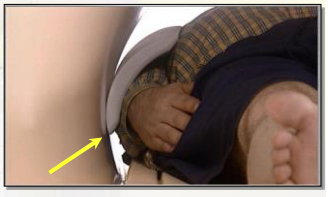
FDA Reports – Hip MRI / Burn

The site reported that a pt sustained a blister on the left arm during a MR hip exam using an 8-channel body array coil. According to the site supervisor, the pt ws sedated and placed into the bore with an intravenous (iv) line in the left arm. Due to the size of the pt, padding was not used.

RF Burns



All too common injury



Always use proper insulating pads

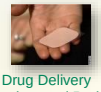
FDA Reports – Foot MRI & Foil / Flames !

The operator was using a head coil to do the foot study. The hospital did not have an extremity coil at the time of the event. The operator introduced a metallic film approximately 8 inches wide which was wrapped around the patient's right leg as an rf blanket. The metallic film caused the heating and resultant fire. The patient received second degree burns when the fire occurred

Medication Patches – ACR

Drug Delivery Patches and Pads

- Metallic drug delivery patches
  - Some drug delivery patches contain metallic foil. Scanning the region of the metallic foil may result in thermal injury
- Remove
  - Since removal or repositioning can result in altering of patient dose, consultation with the patient's prescribing physician would be indicated in assessing how to best manage the patient.
  - If the patch is removed, a specific staff member should be given responsibility for ensuring that it is replaced or repositioned.
- Ice pack
  - Alternative options may include placing an ice pack directly on the patch.
  - This solution may still substantially alter the rate of delivery or absorption of the medication to the patient



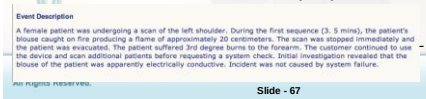
Drug Delivery Patches and Pads

Placement of Drug Delivery Patches and Pads

From the ACR Guidance Document for Safe MRI Practices 2007

FDA Reports – Shoulder MRI / Flames!

A patient was undergoing a scan of the left shoulder. During the first sequence (3.5 min) the patient's blouse caught on FIRE (producing a flame of approximately 20 cm). The scan was stopped immediately and the patient was evacuated. The patient suffered 3rd degree burn to the forearm. The customer continued to use the device (scanner) and scan additional patients before requesting a system check. Initial investgation revealed that the blouse of the patient was apparently electrically conductive. Incident was not caused by system failure.


Event Description

A female patient was undergoing a scan of the left shoulder. During the first sequence (3. 5 mins), the patient's blouse caught on fire producing a flame of approximately 20 centimeters. The scan was stopped immediately and the patient was evacuated. The patient suffered 3rd degree burns to the forearm. The customer continued to use the device and scan additional patients before requesting a system check. Initial investigation revealed that the blouse of the patient was apparently electrically conductive. Incident was not caused by system failure.

- FDA MAUDE database

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MRI Safety Training Cont.

STOCKTON – "A firefighter chopping a hole in the roof of a burning medical building Sunday had his ax ripped from his hands and through the roof by the force of a magnet in an MRI machine below, officials said."

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MRI Safety Training Cont.

Slide - 69

MRI Safety Training Cont.

Slide - 70

Preventing Patient Burns

1. Use thoroughly tested devices/accessories.
2. Only properly trained individuals should operate devices.
3. Routinely check "integrity" of devices/accessories.
4. Remove all electrically conductive materials.
5. Keep conductive materials from contacting patient.
6. Prevent formation of "conductive loops".
7. Position cables/wires to exit down center of the table.
8. Position patient between MR system bore and patient.
9. Prevent contact between MR system bore and patient.
10. Do not position conductive material across external prosthesis.
11. Follow all instructions for the proper operation of equipment.
12. Dress all patients in MR appropriate attire

Courtesy Frank Shellock, Ph.D.

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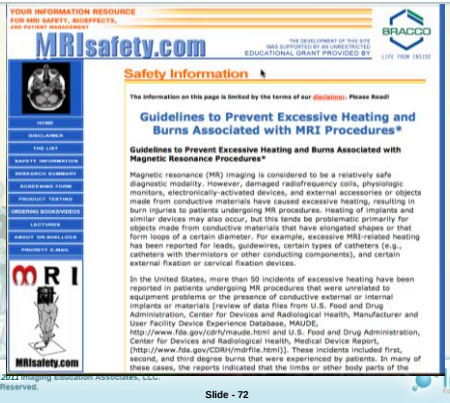
Preventing burns



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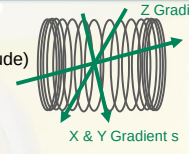
Gradient Field / TVMF Safety

- Gradient units
  - 1 mT/m = 10 g/cm (strength / amplitude)
  - Microseconds (speed / rise time)
  - t/m/s (slew rate – strength & speed)
- Gradient switching
  - Higher slew rates increase possibility of current induction
- Time varied magnetic fields
- Bio-effects
- FDA regulations



A view of the instrumentation within the bore

Bio-effects of TVMF

- Acoustic noise
  - Hearing protection
- Peripheral nerve stimulation
  - No loops
  - Do not cross hands or legs
  - Magnetophosphenes
    - Stimulate the retinal phosphenes
    - Stars in your eyes!

"According to the FDA, special consideration should be given to certain patient populations (pediatric patients, seriously ill) when performing certain MRI procedures that may produce peripheral nerve stimulation.

Patients should be instructed to report any painful sensations that occur during the procedure".

Gradient Sounds

" **Time-Varying Gradient Magnetic Field–Related Issues**: Auditory Effects

- All patients and volunteers should be offered and encouraged to use hearing protection prior to undergoing any imaging in the MRI scanners.
- All patients or volunteers in whom research sequences are to be performed (i.e., MRI scan sequences that have not yet been approved by the Food and Drug Administration) are to have hearing protective devices in place prior to the initiation of any MRI sequences. Without hearing protection in place, MRI sequences that are not FDA-approved should not be performed on patients or volunteers."

Pay attention to the 'sounds' of different 'scans'! **What type scan is loudest?**

SE T1 FSE T2 SS FSE DWI b = 1000 Fast 3D Angio

Temporary hearing loss has been reported using conventional sequences.

Earplugs - can reduce noise by 10 to 20 dB
- Recommended for all patients
- Recommended for anyone in scan room
- To reduce temporary and permanent acoustic damage

ACR Guidance Document for Safe MRI Practices 2007

Gradient Magnetic Fields

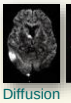
United States (US) Food and Drug Administration (FDA)
Center for Devices and Radiological Health (CDRH)

Criteria for Significant Risk Investigations of
Magnetic Resonance Diagnostic Devices, Issued on 07/14/03

"Any time rate of change of gradient fields (dB/dt) sufficient to produce severe discomfort or painful nerve stimulation."

Increased … TVMF Effects

- Scans & options
  - High speed gradients
  - EPI (Echo Planar Imaging) diffusion / perfusion
- No loops within the magnet
- Patients for increased risk of anxiety due to acoustic noise:
  - Head trauma, elderly, pediatric
  - Psychiatric disorders
- Time-varying gradient magnetic field-related issues:
  - Induced voltages in head trauma, elderly, pediatric
  - Patients with implanted or retained wires in anatomically or functionally sensitive areas (e.g. myocardium or epicardium)
  - Such patients should be reviewed by the level 2 MRI personnel-designated attending radiologist supervising the case or patient.


Diffusion


Diffusion Tensor Imaging

ACR Guidance Document for Safe MRI Practices 2007

Wires in the Magnet – No Loops

- "When electrically conductive materials are required to be within the bore of the MRI scanner with the patient during imaging, care should be taken to
  - Place thermal insulation (including air, pads, etc.) between the patient and the electrically conductive material, while simultaneously attempting (as much as feasible) to
  - Keep the electrical conductor from directly contacting the patient during imaging. It is also appropriate to try to
  - Position the leads or wires as far as possible from the inner walls of the MRI scanner if the body coil is being used for RF transmission.
- When it is necessary that electrically conductive leads directly contact the patient during imaging, consideration should be given to prophylactic application of
  - Cold compresses or ice packs to such areas.
- Depending on specific magnet designs, care may be needed to ensure that the patient's tissue(s) do not directly come into contact with the inner bore of the MRI imager during the MRI process. "


Insulated wires NO loops!


Use proper padding


NO skin-to -skin contact

From the ACR Guidance Document for Safe MRI Practices 2007

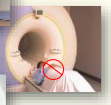
No Loops!

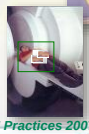
- It is important to ensure the patient's tissues do not form large conductive loops.
- Care should be taken to ensure that the patient's arms or legs are not positioned in such a way as to form a large-caliber loop within the bore of the MRI imager during the imaging process.
- It is preferable that patients be instructed not to cross their arms or legs in the MRI scanner.
  - –Unpublished reports of thermal injuries that seem to have been associated with skin folds, such as in the region of the inner thighs.
- While the cause of this is not yet fully understood, it might be prudent to
  - –Consider ensuring that skin folds and other such examples of tissue-to-tissue contact are minimized or eliminated in the region undergoing radiofrequency energy irradiation.

NO large conductive loops

NO skin folds

NO tissue-to-tissue contact





Uncross hands and feet

From the ACR Guidance Document for Safe MRI Practices 2007

Outline

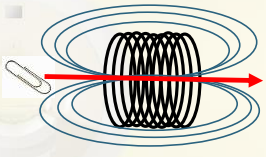
- Who should be doing the screening?
- How should the screening be performed?
- Safety Guidelines ACR (White paper & New Regs)
- Why should we screen for that
  - **B0 (Static field considerations)**
    - **MSG / Within the bore**
    - **Fringe field**
  - *Time Varied Magnetic Fields (TVMF)*
    - *RF field considerations*
    - *Gradient field considerations*
- To Scan or not to Scan?
- What can go wrong?

Ferromagnetic Detectors would certainly have noticed this small amount of metal!

Static Magnetic Field – Fringe Field

- Main magnetic field strength
  - Low field 0.2 – 0.35T
  - Mid field 0.5T
  - High field 1.0T – 2.0T
  - Ultra high field 3.0T
  - 10,000g = 1T
- Fringe field
  - Limit to 5 gauss
  - Shielding
- "Missile effects"
  - Occur when the fringe field draws ferromagnetic materials rapidly into the magnetic field
  - Terminal velocity of a projectile, determined by the mass of the object (ant its material) and distance from the magnet

"To date, there are no long-term biological affects associated with exposure to static magnetic fields!"



Warning vs. Danger Signs

Control Site Access

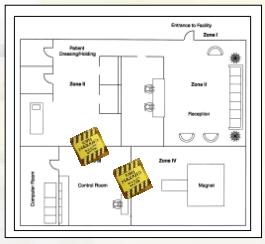
www.magmedix.com

Courtesy:
Anne Marie Sawyer @ Stanford

Where are the signs

Warning vs. Danger vs. Hazard Signs

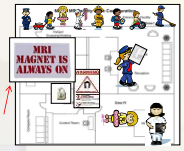
Courtesy: Christiana Imaging



Zone IV – Lighted Signs

"**Zone IV** should be clearly marked
- with a **red light and lighted sign stating, "The Magnet is On."**
- Except for resistive systems, this light and sign should be illuminated at all times and
- should be provided with a backup energy source to continue to remain illuminated for at least 24 hours in the event of a loss of power to the site."

Example of a red lighted sign.

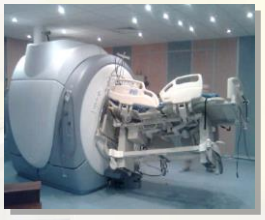


Location of the red lighted sign.

From the ACR Guidance Document for Safe MRI Practices 2007

Static Magnetic Field

FDA limit for exposure to static magnetic field
- 4.0 T < 1 month of age or less
- 8.0 T > 1 month



Superconducting Magnets… Always ON !

WHY?
- Uses cryogens
  - Liquid helium
- Helium stable as gas
  - Helium 750 liter (gas) to 1 liquid liter
  - 1,000 liquid liters per magnet
  - 750,000 liters of gas inside the magnet!
- Quench
  - Boil off of cryogen
- Quench hazards in the MRI scan room
  - Increased pressure, can't open door
  - Reduced room temperature – frostbite
  - Reduced oxygen – asphyxia

Boil off of Cryogen

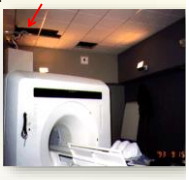
Can you EVER turn the Magnet off? What is a Quench? In DE !

Quench

Ramp Down vs. Quench (in Little Rock, AR)

- Ramp down
  - Controlled removal of cryogens
  - Controlled reduction of magnetic field
- Quench
  - Uncontrolled removal of cryogens
  - Cryogens are designed to vent into the ceiling through a venting system.
- Quench hazards in the MRI scan room
  - Note that the ceiling tiles have fallen out
  - The increased pressure from the quench moved the scan room walls. As a result, the ceiling tiles fell out.

Venting System



To Quench or not to Quench?

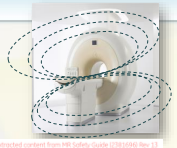
- During cardiac arrest
- Remove patient from the bore – field
- Begin CPR
- No need to quench!
- ACR Guidance Document for Safe MR Practices / quench
  - Not routinely advised for cardiac or respiratory arrest or other medical emergency
  - Quench can be hazardous
  - Ideally one should evacuate the magnet room
  - One should initiate life support measures while removing the patient from Zone IV

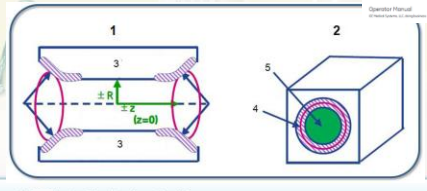
Now back to the Magnetic Field… from CNN

- From CNN
- News

How is the device tested?

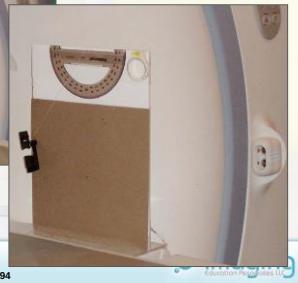
- What is MSG?
- An ingredient in Chinese food
  - Monosodium glutamate
- Or an MRI Concept?
  - Magnetic Spatial Gradient



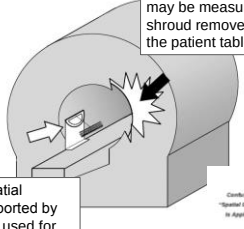


Safety Considerations for Implanted devices

How is the device is tested ?
with the cover (scroud) on
without the schroud
How Does the device Respond
steep deflection angle
not so steep



With or without the Schroud?



Position of the "highest spatial magnetic gradient field" reported by the MR system manufacturer. This may be measured with the covers or shroud removed, as well as without the patient table.

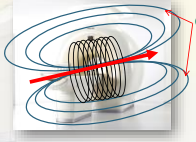
Position of the "highest spatial magnetic gradient field" reported by the implant tester, which is used for the deflection angle test. This is where the fixture or test apparatus is positioned.

Safety Considerations for the Static Magnetic Field

- Main magnetic field strength (T)
  - Within the bore
  - Direction
    - Vertical
    - Horizontal
- Fringe field (g)
  - Outside the imager
  - Projectiles
- Forces
  - Translational
  - Rotational
- Bio-effects
- FDA regulations
- Screening

Limited Fringe Field

Permanent Magnet Vertical Field



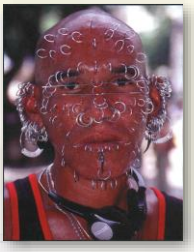
Considerable Fringe Field

Solenoid Magnet Horizontal Field Fringe Field

Why should screening be performed?

To determine…

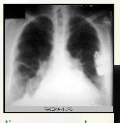
- MRI unsafe
  The big 3 contraindications
  - Pacemaker
  - Metal in the eyes
  - Aneurysm clip
- MRI safe
- MRI conditional

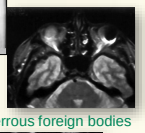


Some Implants are More Obvious Than Others

Contraindications for MRI Imaging

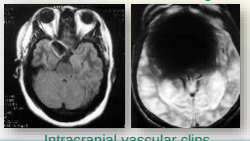
- Cardiac pacemaker
  - Dependent pacer patient
  - Non-dependent pacer patients
  - New cardiac pacemakers?
- Intra-ocular ferrous foreign bodies
  - Metal in the eyes
  - X-rays or removal
- Intracranial vascular clips
  - Aneurysm clips (head)
  - Torque





Cardiac pacemaker

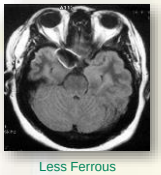
Intra-ocular ferrous foreign bodies



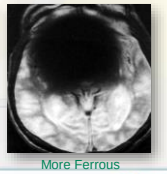
Intracranial vascular clips

Intracranial Aneurysm Clip

- Radiologist is responsible for the decision to scan.
- Risk vs. benefit
- Just because they have been scanned before, does not automatically make them safe this time!



Less Ferrous

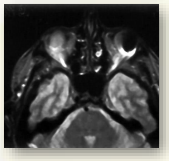


More Ferrous

Intraocular Ferrous Foreign Bodies (IFFB)

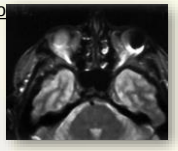
One Theory…

- J. American Journal Neuroradiology (AJNR); 2000 Feb; 21(2):426-33
- **Cost utility analysis of radiographic screening for an orbital foreign body before MRI imaging**
- Seidenwurm DJ, McDonnell CH 3rd, Raghavan N, Breslau CONCLUSION: Clinical screening before radiography increases the cost-effectiveness of foreign body screening by an order of magnitude, assuming base case ocular foreign body removal rates. Asking the patient "Did a doctor get it all out?" serves this purpose. Occupational history by itself is not sufficient to mandate radiographic orbital screening. Current practice guidelines for foreign body screening should be altered.



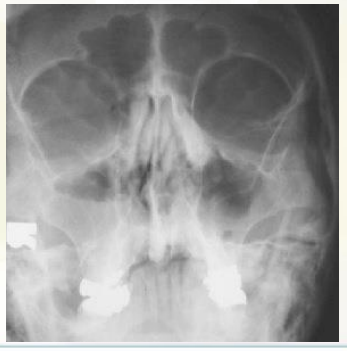
Intraocular Ferrous Foreign Bodies (IFFB)

- All such patients should also undergo plain film imaging of the skull or orbits and chest to exclude metallic foreign objects (if recently obtained plain films or CT or MRI studies of such areas are not already available).
- Should it be determined that non-MRI personnel wishing to accompany a patient into an MRI scan room require their orbits to be cleared by plain-film radiography, a radiologist must first discuss with the non-MRI personnel that plain X-ray films of their orbits are required prior to permitting them access to the MRI scan room.



From the ACR Guidance Document for Safe MRI Practices 2007

Screening Orbits



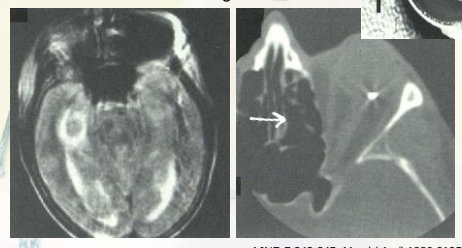
Orbital Metal / Other Implants

Ferromagnetism of Intraocular Foreign Body Causes Unilateral Blindness after MR Study

AJNR 7:243-245, March/ April 1986 0195-6108/86/0702-0243

Orbital Metal / Other Implants

2 x 3.5 mm rusted iron filing

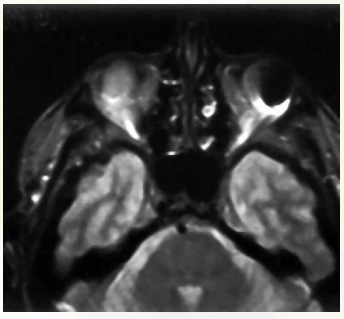


AJNR 7:243-245, March/ April 1986 0195-6108/86/0702-0243

ACR Guidelines

"All patients who have a history of orbit trauma by a potential ferromagnetic foreign body for which they sought medical attention are to have their orbits cleared by either plain X-ray orbit films (2 views) or by a radiologist's review and assessment of contiguous cut prior CT or MR images (obtained since the suspected traumatic event) if available."

ACR Guidance on MR Safe Practice Pg



Post Operative Patients

"Skin staples and superficial metallic sutures:

- Patients may be permitted to undergo the MRI examination if the skin staples or SMS are not ferromagnetic and are not in the anatomic volume of RF power deposition for the study to be performed.
- If the non-ferromagnetic skin staples or SMS are within the volume to be RF-irradiated for the requested MRI study, several precautions are recommended.
- Warn the patient and make sure that they are especially aware of the possibility that they may experience warmth or even burning along the skin staple or SMS distribution.
- The patient should be instructed to report immediately if they experience warmth or burning sensations during the study (and not, for example, wait until the "end of the knocking noise").
- It is recommended that a cold compress or ice pack be placed along the skin staples or SMS if this can be safely clinically accomplished during the MRI examination."

Metallic sutures within the patient

Metallic sutures

Adapted from the ACR Guidance Document for Safe MRI Practices 2007

Ballistics

- **What material are the bullets made of?**
  - "The ferromagnetism of various bullets and shotgun pellets was tested in vitro
    - Ferromagnetic bullets readily rotated within a gelatin phantom in response to magnetic torque. Non-ferromagnetic bullets and pellets demonstrated only mild to moderate metal artifact during spin-echo and gradient-echo magnetic resonance (MRI) imaging"
- **Where is the bullet?**
  - "Caution should be exercised with MRI imaging in the presence of metallic foreign bodies, particularly if they are located near vital neural, vascular, or soft-tissue structures. "
  - "Patients with retained bullets and shotgun pellets were imaged safely."
- **How long has the bullet been in?**
- **What protocol is being used to scan the patient?**

Metallic ballistic fragments: MRI imaging safety and artifacts
GP Teitelbaum, CA Yee, DD Van Horn, HS Kim and PM Colletti
Department of Radiology, LAC-USC Medical Center 90033.

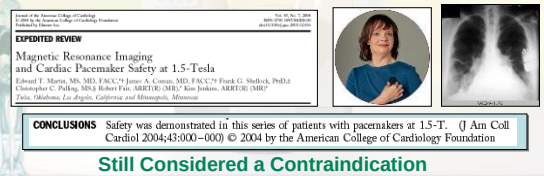
MRI in Patients with Intra-spinal Bullets

*Steven S. Smugar, MD, Mark E. Schweitzer, MD *, Eric Hume, MD*
Department of Radiology, Thomas Jefferson University Hospital, Philadelphia, PA.
**Correspondence to Mark E. Schweitzer, Department of Radiology*

Cardiac Pacemaker

Some facilities will scan pacemakers ONLY IF …

- The patient has a non-dependent pacer
- The patient meets the clinical criteria
- The cardiologist, radiologist, company that makes the pacer are present during and after the exam to Reset pacer & assess the patient
- Hey follow strict criteria, listed on www.mrisafety.com


EXPEDITED REVIEW

Magnetic Resonance Imaging and Cardiac Pacemaker Safety at 1.5-Tesla

CONCLUSIONS Safety was demonstrated in this series of patients with pacemakers at 1.5-T. (J Am Coll Cardiol 2004;43:000–000) © 2004 by the American College of Cardiology Foundation

Still Considered a Contraindication

MR Conditional Pacemaker - February 8, 2011

Revo MRI™ SureScan® Pacing System

MRI Conditional Labeling

- Revo MRI Pacemaker – 5086 MRI CapSureFix MRI Pacing Lead – SureScan Software

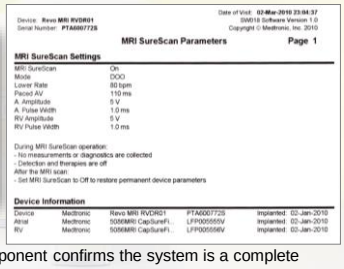
MRI Conditions for MR Conditional Pacer

- Brand name - Revo™ System
- Scanned with (and ONLY with)…
  - Cylindrical bore MR (solenoid electromagnet)
  - 1.5 T only
  - Whole body SAR not more than 2 W/Kg (normal mode)
  - Head SAR not more than 3.2 W/Kg
  - Maximum gradient slew rate ≤ 200 T/m/s
  - Isocenter (center of bore) superior to C1 or inferior to T12
  - Patient monitoring
    - Verbal and visual
    - Pulse Ox
    - ECG

www.mrisurescan.com

Programming for Revo™ System

- Must be programmed by cardiology personnel trained in operation of the SureScan™ component of the system.


MRI SureScan Parameters Page 1

MRI SureScan Settings

MRI SureScan	On
Mode	DOO
Lower Rate	80 bpm
Paced AV	110 ms
A Amplitude	5 V
A Pulse Width	1.0 ms
RV Amplitude	5 V
RV Pulse Width	1.0 ms

During MRI SureScan operation:
- No measurements or diagnostics are collected
- Detection and therapies are off

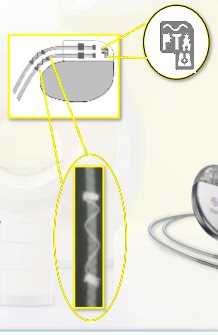
After the MRI scan:
- Set MRI SureScan to Off to restore permanent device parameters

Device Information

Device	Medtronic	Revo MRI RVDR01	PTA6007725	Implanted	02-Jan-2010
Atrial	Medtronic	5086MRI CapSureFi...	LFP005565V	Implanted	02-Jan-2010
RV	Medtronic	5086MRI CapSureFi...	LFP005566V	Implanted	02-Jan-2010

SureScan™ component confirms the system is a complete system and ensures the patient is ready for the MRI procedure.

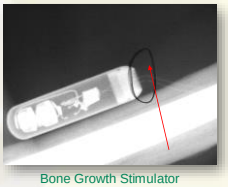
Identifying the MR Conditional Pacer



Can be identified Radiographically
Must be Programmed

Implants in MRI

- Medical risk vs. benefit decision
- Be sure to check field strength that the device / implant has been tested
- Up-to-date information is crucial
- **Beware of blanket statements!**
  Example: All stents are not safe
  - www.mrisafety.com
  - www.imrser.org
  - www.drkanal.com
- Concerns for implants & devices
  - Torque / movement (translational forces)
  - Electrical current induction (burns)
  - Tissue heating (burns)
  - Device failure



Bone Growth Stimulator with Broken Leads

Pregnancy: Patients

FDA -

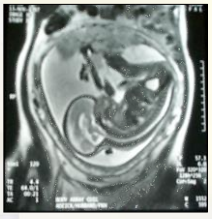
The safety of MR imaging during pregnancy has not been proved.

Slide - 115

MRI & Pregnancy - Patients

SMR Safety Committee -

"MR Imaging may be used in pregnant women if other nonionizing forms of diagnostic imaging are inadequate or if the examination provides important information that would otherwise require exposure to ionizing radiation."



Slide # 116

Pregnancy: Patients

ISMRM-

"MR Imaging may be used in pregnant women if other nonionizing forms of diagnostic imaging are inadequate or if the examination provides important information that would otherwise require exposure to ionizing radiation."

Slide - 117

Pregnancy: Patients

ACR

- Can be accepted at <u>any stage</u> of pregnancy
- Level 2-designated attending radiologist to confer with ordering physician and determine that the risk-vs-benefit ratio to the patient warrants the study

Slide - 118

Pregnancy: Patients

ACR

<u>Document in the report or patient's medical record:</u>

1. The information requested from the MR study cannot be acquired by means of nonionizing means (e.g., ultrasonography).
2. The data is needed to potentially affect the care of the patient or fetus *during* the pregnancy.
3. The referring physician believes that it is not prudent to wait until the patient is no longer pregnant to obtain this data.

Slide - 119

Pregnancy: Patients

ACR

Guidelines no longer specify informed consent

Slide - 120

Pregnancy: Patients

ACR Gadolinium

- Should not be routinely used in pregnant patients
- Case-by-case decision made by level 2 MR personnel-designated attending radiologist who will assess the risk-benefit ratio for the particular patient
- Decision to administer a GBCA should be accompanied by a well-documented and thoughtful risk-benefit analysis
- Risk to the fetus of a GBCA remains unknown and may be harmful

Breast Feeding and Gd

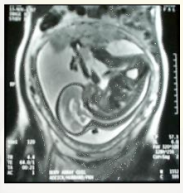
The literature on the excretion into breast milk of iodinated and gadolinium-based contrast media and the gastrointestinal absorption of these agents from breast milk is very limited; however, several studies have shown that the expected dose of contrast medium absorbed by an infant from ingested breast milk is extremely low.

Breast Feeding and Gd

Ultimately, an informed decision to temporarily stop breast-feeding should be left up to the mother after these facts are communicated. If the mother remains concerned about any potential ill effects to the infant, she may abstain from breast-feeding from the time of contrast administration for a period of 12 to 24 hours. There is no value to stop breast feeding beyond 24 hours.

MRI & Pregnancy – Health Care Workers

Technologists can enter the scan room
Can position the patient
But…
Recommended not to enter …
while RF & gradients are running



Pregnancy: Staff

ACR

- Permitted to work in and around the MR environment throughout all stages of their pregnancy
- May perform all job-related duties
- Requested not to remain with the scanner bore or Zone IV during active scanning

Claustrophobia / Anxiety

Recommendations for Claustrophobic Patients - ACR

1. Prepare the patient (explanation)
2. Allow a family member to accompany
3. Maintain verbal/visual contact
4. Headphones
5. Monitor – distraction
6. Virtual reality
7. Feet-first
8. Prone
9. Mirrors or prism glasses
10. Blindfold
11. Lights
12. Fan
13. Lemon or vanilla scent
14. Relaxation techniques
15. Systematic desensitzation
16. hypnosis

Claustrophobia / Anxiety

- Not a safety issue
- Do not use the terms “open” or “closed” MRI
- Do not ask prior to the study “are you claustrop
- The tech who scans the patient should be the c screen the patient

Claustrophobia / Anxiety

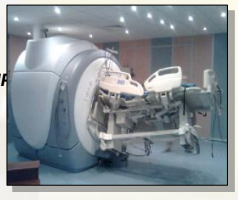
- Do not rush the patient - allow them time to ask questions
- Stay in contact with the patient until they are positioned in the magnet are state they are comfortable
- Cool wash cloth for the eyes
- Aromatherapy

To Scan, or Not to Scan

- **Final determination of whether or not to scan** any given patient with any given implant, foreign body, etc.,
  - Is to be made by the level 2 MRI personnel–designated **attending MRI radiologist**, the MRI medical director, or specifically designated level 2 MRI personnel
  - Following criteria for acceptability predetermined by the medical director.
- For implants that are strongly ferromagnetic, an obvious concern is that of magnetic translational and rotational forces upon the implant which might move or dislodge the device from its implanted position.
  - If an implant has demonstrated weak ferromagnetic forces on formal testing, it might be prudent to wait several weeks for fibrous scarring to set in, as this may help anchor the implant in position and help it resist such weakly attractive magnetic forces that might arise in MRI environments.
- For all implants that have been demonstrated to be nonferrous in nature, however, the risk of implant motion is essentially reduced to those resulting from Lenz’s forces alone.
  - These tend to be quite trivial for typical metallic implant sizes of a few centimeters or less. Thus, a waiting period for fibrous scarring to set in is far less important, and the advisability for such a waiting period may well be easily outweighed by the potential clinical benefits of undergoing an MRI examination at that time.
  - As always, clinical assessment of the risk–benefit ratio for the particular clinical situation and patient at hand are paramount for appropriate medical decision making in these scenarios.

Outline

- ***Who should be doing the screening?***
- ***How should the screening be performed?***
- ***New Guidelines & Recommendations***
- ***Why should we screen for that?***
- ***Hardware considerations in MRI…***
  - ***Time Varied Magnetic Fields (TVMF***
    - ***RF field considerations***
    - ***Gradient field considerations***
  - ***B0 (Static field considerations)***
    - ***MSG / Within the bore***
    - ***Fringe field***
- ***What can go wrong?***
- ***To Scan or Not to Scan?***



Thank you for your attention!

MRI Safety & Patient Screening

for the working technologist…

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candi@imaginged.com