

Update on MRI Safety

Presented by

Carolyn Kaut Roth RT (R)(MRI)(CT)(M)(CV) FSMRT CEO, Imaging Education Associates candi@imaged.com	William H. Faulkner BSRT (R)(MRI)(CT) FSMRT CEO, Wm. Faulkner & Associates Faulkner@t2star.com
--	---

Produced by Imaging Education Associates
Sponsored by an unrestricted educational grant from Bracco Diagnostics

If you are viewing this presentation as an on-line (self-study) module, be sure to complete the post test to claim your credits.

Slide - 1

Disclaimer

© Copyright 2011 Imaging Education Associates, LLC. No part of this module may be reproduced or manufactured in any form or by any means, electronic or mechanical, including photocopying, recording or by any other information storage and retrieval system without permission in writing from the publisher (Imaging Education Associates, LLC).

Accreditation Information: According to the standards set forth by the ARRT (SMRT and the ASRT): In order to be awarded with continuing education credit for this module, the attendee of this course must view the material, take and pass the post test with a score of 75% or above. Furthermore, the course attendee is allowed three (3) attempts to obtain this score of 75% or above. After 3 failing attempts, the user will be disabled from this educational offering (based on the accrediting agencies' regulations). For this reason, we recommend that the viewer re-review the material (after one try), even if the viewer does not obtain a passing score of 75%.

This module may be available in several formats (on-line or CD). You may not redeem credit for this topic again in this or any subsequent biennium.

Disclaimer: This continuing educational offering is provided as an overview of accrediting processes for the healthcare provider. The information within this module should not be considered as medical advice. If you are a non-medical viewer, please consult your physician regarding any medical issues relating to diseases, conditions, symptoms, diagnosis, treatment and/or side effects.

The user of this module agrees to access and use this information at his/her own risk. Imaging Education Associates, LLC (and our speakers) disclaim any liability for the acts of any technologist, physician, individual, group, or entity acting independently or on behalf of any organization who receives any information on any medical procedure, activity, service, or other situation through this module.

Imaging Education Associates assumes no responsibilities for errors or omissions that may include technical or other inaccuracies, or typographical errors and accepts no legal responsibility for any accreditation failures, injury and/or damage to persons or property from any of the methods, products, instructions, or ideas contained herein.

Slide - 2

Outline

- American College of Radiology (ACR) guidelines & recommendations
- Considerations for hardware
- Site considerations / zoning
- Personnel considerations
- Device considerations / safety testing
- Patient considerations / screening
- Gadolinium considerations

Slide - 3

Objectives

Upon completion of this course, the learner should be able to:

- Describe the importance of safety in Magnetic Resonance Imaging (MRI).
- Recognize the American College of Radiology (ACR) recommendations associates with MRI safety.
- Explain magnetic field considerations with MRI safety.
- Describe static field (known as B₀), radiofrequency [RF, a time varied (oscillating) magnetic field known as B₁] field and gradient field [a time varied magnetic field (TVMF)] considerations.
- Demonstrate appropriate patient screening techniques in MRI.
- Identify safety considerations associated with contrast media (CM), typically gadolinium (Gd) in MRI.

Slide - 4

MRI Safety Update – ACR Guidelines

- History of MRI safety
- ACR white paper 2002
- ACR update
- ACR white paper 2004
- ACR white paper 2007
- Contrast media update 2010
- Up-to-the-minute updates!

Slide - 5

From Very Bad to Better!

- In 2001, a child was killed in New York
 - Oxygen tank flew into an MRI scanner!
 - Boy was hit in the head by the O₂ Tank!
- ACR develops a “Blue Ribbon” panel of MRI experts
 - Review existing MRI safety practices & guidelines
 - Establish recommendations for MRI safety training
- 2002 – White Paper on MR Safety
- 2002 – Commentary – ACR White Paper
- 2004 – Combined papers 2002 & 2004
- 2007 – ACR Guidance Document for MR Safe Practices
- 2010 – Contrast Media update

Slide - 6

Blue Ribbon Panel

- MRI experts
- Radiologists
- Physicians
- PhDs
- Technologists
- Representatives from corporate
- FDA
- Lawyers

ACR Guidance Document for Safe MR Practices: 2007

ACR Guidance Document for Safe MRI Practices 2007

Slide - 7

MRI Safety Resources

- Institute for Magnetic Resonance Safety, Education & Research
www.imrser.org
- Frank Shellock, PhD, MRI Safety Page
www.mrisafety.com
- American College of Radiology
www.acr.org

2007 ACR White Paper ACR Guidance Document for Safe MR Practices: 2007

2002 & 2004 combined ACR White Paper

2002 commentary on the ACR White Paper

"American College of Radiology White Paper on MRI Safety", a document that "is intended to be used as a template for MRI facilities to follow in the development of an MRI safety program."
Excerpt from the ACR White Papers

Slide - 8

ACR Recommendations

- Establish, implement & maintain safety policies & procedures
 - Develop current MRI safety policies & practices
 - Update with upgrades of equipment and protocols
- "Name" MRI medical director
 - Develop safety training program
 - Ensure that safe policies are established & maintained
 - Appropriate to site (equipment & practice)
 - Implemented and adhered to at all times
- Report incidents
 - Actual events & "near misses"
 - Within 24 hours of the event
 - "Med-watch" program

ACR Guidance Document for Safe MRI Practices 2007

Slide - 9

Magnetic Moment...

Slide - 10

Magnetic Moment...

The first ACR white paper on MRI Safety was published in:

- a. 1895
- b. 1975
- c. **2002**
- d. 2009

Slide - 11

Magnetic Moment...

The first ACR white paper on MRI Safety was published in:

- a. 1895
- b. 1975
- c. **2002**
- d. 2009

If you had difficulty answering this "Magnetic Moment" question correctly, or if you would like to re-review this concept: Click back to [slide 5 & 6](#) on the table of contents. **Remember**, you are NOW on [slide 12](#). Click [slide 12](#) to continue with this lecture.

Slide - 12

Magnetic Moment...

The main objectives for the production of the ACR white paper is to accomplish all of the following EXCEPT:

- a. Establish, implement & maintain safety policies & procedures
- b. "Name" MRI medical director
- c. Report incidents
- d. Optimize scan protocols

Slide - 13

Magnetic Moment...

The main objectives for the production of the ACR white paper is to accomplish all of the following EXCEPT:

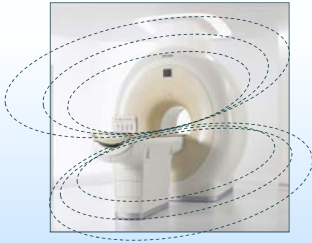
- a. Establish, implement & maintain safety policies & procedures
- b. "Name" MRI medical director
- c. Report incidents
- d. **Optimize scan protocols**

If you had difficulty answering this "Magnetic Moment" question correctly, or if you would like to re-review this concept: Click back to [slide 9](#) on the table of contents.
Remember, you are NOW on [slide 14](#). Click [slide 14](#) to continue with this lecture.

Slide - 14

MRI Safety Update – Hardware


- Magnetic fields
 - Time varied magnetic fields (TVMF)
 - Radiofrequency Fields (RF)
 - Gradient fields
- Static magnetic field
- Fringe field



Slide - 15

RF Field Safety

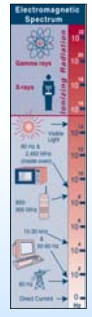
- RF
 - Power
 - Wavelength
- Bio-effects
 - RF Heating
 - More problematic when dealing with metallic materials within the imaging volume of the magnet
 - Different issues with higher field strengths
 - Varies with system
 - SAR
- FDA Regulations



Slide - 16

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 (°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



Slide - 17

SAR Limits for RF Fields

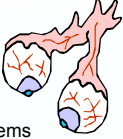
Food and Drug Administration (FDA) /
 Criteria for Significant Risk Investigations of Magnetic Resonance Diagnostic Devices (CDRH)
 Issued – 07/14/03

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

Slide - 18

Increased ... RF Effects

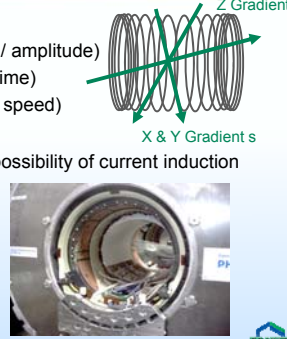
- Scans & options
 - Magnetic Transfer (MTI)
 - Fast Spin Echo (FSE)
 - More heat / more RF pulses
 - Double the flip, 4X the power
- Patients with compromised thermoregulatory systems
 - Higher risk for RF effects
- Patients with higher risk include:
 - Cardiovascular disease
 - Hypertension, diabetes,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



Slide - 19

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



Slide - 20

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”.

Slide - 21


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

Slide - 22

Gradient Magnetic Fields

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

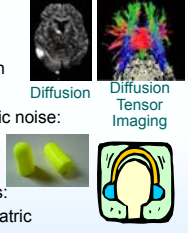
Criteria for Significant Risk Investigations of
Magnetic Resonance Diagnostic Devices, Issued on 07/14/03

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

Slide - 23

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.



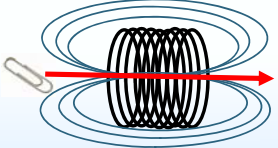
ACR Guidance Document for Safe MRI Practices 2007

Slide - 24

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!”




Slide - 25

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



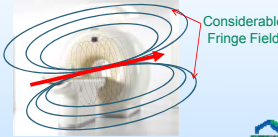
Slide - 26

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



Permanent Magnet Vertical Field Limited Fringe Field



Solenoid Magnet Horizontal Field Fringe Field Considerable Fringe Field

Slide - 27

Siting Issues Magnetic Field Shielding

- Passive
 - Metal in scan room walls
 - Steel
- Active
 - Implies current
 - Other magnets within
- 5 g within the wall
 - General public
 - De-activates pacer





Image Courtesy Lindgren



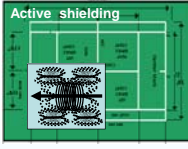
metronix

American College of Radiology
White Paper on MR Safety

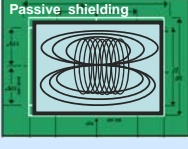
Slide - 28

Active Shielding – Tennis Anyone?

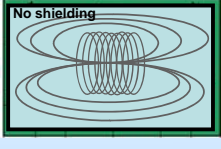
- Active shield
 - 1/4 of a doubles tennis court
- Passive shield
 - Steel within scan room walls
- Non-shielded
 - The entire tennis court



Active shielding



Passive shielding



No shielding

Slide - 29

Magnet Configurations




Image courtesy of Hitachi Medical

Permanent Magnet 0.3T




Image courtesy of Philips Medical

Resistive Magnet 0.3T




Image courtesy of Siemens Medical

Superconducting Magnet 1.5T

Permanent Magnet	Resistive Magnet	Superconducting Magnet
Ferromagnetic material	Coils of wire	Coils of wire
Magnetized	Current creates magnet	Superconducting
Low cost (purchase)	Low cost (purchase)	Low cost (purchase)
Low cost (operation)	High current cost (operation)	Zero current cost (operation)
Heavy in weight	Light in weight	Cryogen cost
Low field strength	Low field strength	Medium in weight
MAGNET IS ALWAYS ON!	MAGNET CAN TURN OFF!	High field strength
		MAGNET IS ALWAYS ON!

Slide - 30

Quench: Superconducting Magnets

- Uses cryogenens
 - 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

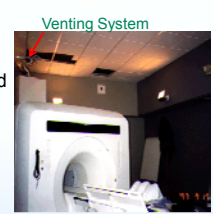


Slide - 31



Ramp Down vs. Quench

- Ramp down
 - Controlled removal of cryogenens
 - Controlled reduction of magnetic field
- Quench
 - Uncontrolled removal of cryogenens
 - Cryogenens 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.



Slide - 32



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



Slide - 33



Magnetic Moment...



Slide - 34



Magnetic Moment...

The FDA limit for RF exposure is:

- 0.4 w/kg
- 4.0 w/kg
- 8.0 T
- Until the patient feels discomfort

Slide - 35



Magnetic Moment...

The FDA limit for RF exposure is:

- 0.4 w/kg
- 4.0 w/kg**
- 8.0 T
- Until the patient feels discomfort

If you had difficulty answering this "Magnetic Moment" question correctly, or if you would like to re-review this concept: Click back to **slide 17 & 18** on the table of contents.
Remember, you are NOW on **slide 36**. Click **slide 36** to continue with this lecture.


Slide - 36



Magnetic Moment...

The FDA limit for static magnetic field strength is:

- a. 2.0 T for all patients
- b. 4.0 T for all patients
- c. 6.0 T for infants
- d. Until the patient feels discomfort




Slide - 37

Magnetic Moment...

The FDA limit for static magnetic field strength is:

- a. 2.0 T for all patients
- b. **4.0 T for all patients**
- c. 6.0 T for infants
- d. Until the patient feels discomfort

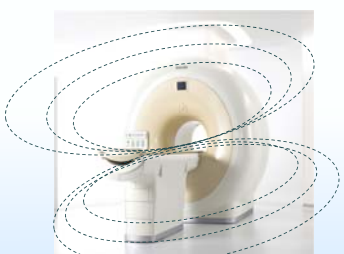

If you had difficulty answering this "Magnetic Moment" question correctly, or if you would like to re-review this concept: Click back to [slide 26](#) on the table of contents.
Remember, you are NOW on [slide 38](#). Click [slide 38](#) to continue with this lecture.



Slide - 38

MRI Safety Update – Levels, Siting & Zones


- Magnetic fields
 - Static field
 - Within the bore
 - Outside the bore
 - TVMF
 - RF
 - Gradients
- Site considerations
 - Zones
 - Shielding
 - Signs

Slide - 39

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




Slide - 40

ACR Recommendations – Zones

- Zoning 2002
 - Zone I
 - Zone II
 - Zone III
 - Zone IV
- Zoning 2004 & 2007
 - Zone I
 - Zone II
 - Zone III – Modified
 - Zone IV




Zones
2002



Zones
2004 &
2007

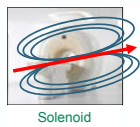

ACR Guidance Document for Safe MRI Practices 2007

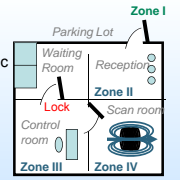


Slide - 41


Imager Considerations – Zoning

- **Zone I:**
 - This includes all areas that are freely accessible to the general public.
- **Zone II:**
 - This area is the interface between the publicly accessible uncontrolled Zone I and the strictly controlled Zone III.
- **Zone III:**
 - This area is the region in which free access by unshielded non-MRI personnel and/or ferromagnetic objects and equipment can result in serious injury or death. All access to at least Zone III is to be strictly restricted, with access.
- **Zone IV:**
 - This area is synonymous with the MRI scanner magnet room itself.



* Based on the ACR white paper, The concept of designating various zones to help control site access relative to the static magnetic field of the MRI system*.



Slide - 42

Levels of MR Personnel – Who Goes Where?

- Non-MRI Personnel**
 - Patients, visitors or facility staff who do not meet the criteria of level 1 or level 2 MRI personnel.
 - Examples of non-MR personnel
- Level 1 Personnel**
 - Individuals / minimal safety educational efforts to ensure their own safety as they work within Zone III regions (e.g., MRI department office staff, patient aides)
 - Examples of Level 1 personnel
- Level 2 Personnel**
 - Individuals / more extensively trained and educated in the broader aspects of MRI safety issues including issues related to the potential for thermal loading/burns, direct neuromuscular excitation from rapidly changing gradients, etc., (e.g., MRI technologists, radiologists, radiology department nursing staff)
 - Examples of Level 2 personnel

Note the locations of various categories of personnel relative to MR imager.

Slide - 43

Annual MRI Safety Training for Everyone!

- Who needs MRI safety training?
 - Level 2 – Extensive training
 - Technologists
 - Radiologists
 - ALL healthcare professionals
 - Level 2 or level 1
 - Nurses
 - Doctors
 - Level 1 – Limited training
 - Ancillary staff (aides, clerical)
 - Transporters
 - Others
 - Non-MRI personnel
 - Fireman
 - Police
 - Visitors

From the ACR Guidance Document for Safe MRI Practices 2007

Slide - 44

Non-MRI Personnel - Who Goes Where?

“Non-MRI personnel should be...

- Accompanied by, or under the immediate supervision of, and
- In visual or verbal contact with, one specifically identified level 2 MRI person for the entirety of their duration within Zone III or Zone IV restricted regions.
- However, it is acceptable
 - To have non-MRI personnel in a changing room or restroom in Zone III without visual contact
 - As long as the personnel and the patient can communicate verbally with each other.”

Non-MRI personnel must be in contact with Level 2 personnel at all times while in Zone III and Zone IV

Unacceptable for Level 1 to escort non-MR personnel

Level 2 to monitor non-MR personnel while in Zone III & Zone IV

From the ACR Guidance Document for Safe MRI Practices 2007

Slide - 45

Zone I – Accessibility

“Zone I: This region includes all areas that are freely accessible to the general public. This area is typically outside the MRI environment itself and is the area through which patients, health care personnel, and other employees of the MRI site access the MRI environment.”

It is acceptable for Non-MRI personnel to be within Zone I without escort from Level 2 personnel

From the ACR Guidance Document for Safe MRI Practices 2007

Slide - 46

Level 1 Personnel

Level 1 MRI Personnel: Those who have passed minimal safety educational efforts to ensure their own safety as they work within Zone III.

Level 1 personnel can include ancillary MR staff such as transporters, technologist aides, clerical staff, nurses, physicians and even technologists from radiography – to name a few

From the ACR Guidance Document for Safe MRI Practices 2007

Slide - 47

Zone II – Patients Greeted


“Zone II: This area is the interface between the publicly accessible, uncontrolled Zone I and the strictly controlled Zones III and IV. Typically, patients are greeted in Zone II and are not free to move throughout Zone II at will, but are rather under the supervision of MRI personnel. It is in Zone II that the answers to MRI screening questions, patient histories, medical insurance questions, etc. are typically obtained.

It is acceptable for Level 1 personnel to ‘greet’ Non-MRI personnel within Zone II.

From the ACR Guidance Document for Safe MRI Practices 2007


Slide - 48

Level 1 Personnel - Who Goes Where?



Level 2 MRI Personnel

Level 1 MRI Personnel are permitted unaccompanied access throughout Zones III and IV. Level 1 MRI personnel are also explicitly permitted to be responsible for accompanying non-MRI personnel into and throughout Zone III, excluding Zone IV. However, level 1 MRI personnel are not permitted to directly admit, or be designated responsible for, non-MRI personnel in Zone IV.



Level 1 MRI Personnel may not monitor patient while in Zone I or IV

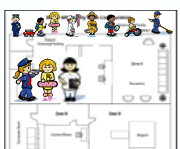
In the event of a shift change, lunch break, etc., no Level 2 MRI personnel shall relinquish their responsibility to supervise non-MRI personnel still within Zone III or Zone IV until such supervision has been formally transferred to another of the site's level 2 MRI personnel.

Slide - 49 From the ACR Guidance Document for Safe MRI Practices 2007

Zone III – Accompanying Personnel

“Zone III: This area is the region in which free access by Unscreened non-MRI personnel or ferromagnetic objects or equipment can result in serious injury or death

- These interactions include, but are not limited to, those involving the MRI scanner’s static and TVMF.
- **All access to Zone III is to be strictly restricted.**
 - With access to regions within it (including Zone IV) controlled by, and entirely under the supervision of, Level 2 MRI personnel.



Level 1 personnel may ‘greet’ Non-MRI personnel within Zone II.


- Specifically identified MRI personnel (typically, but not necessarily only, the MRI technologists) are to be charged with ensuring that this MRI safe practice guideline is strictly adhered to for the safety of the patients and other non-MRI personnel, the health care personnel and the equipment itself. This function of the MRI personnel is directly under the authority and responsibility of the MRI medical director or the level 2 MRI personnel-designated physician of the day for the MRI site.”

Slide - 50 From the ACR Guidance Document for Safe MRI Practices 2007

Level 2 Personnel - Training

Level 2 MRI Personnel:

- Those who have been more extensively trained and educated in the broader aspects of MRI safety issues, including, for example, issues related to the potential for thermal loading or burns and direct neuromuscular excitation from rapidly changing gradients.
- It is the responsibility of the MRI medical director not only to identify the necessary training, but also to identify those individuals who qualify as level 2 MRI personnel.
- It is understood that the medical director will have the necessary education and experience in MRI safety to qualify as level 2 MRI personnel.

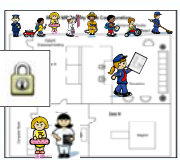


Slide - 51 From the ACR Guidance Document for Safe MRI Practices 2007

Zone III – Locked Access

Zone III regions should be physically restricted from general public access by

- **Key locks, passkey locking systems, or any other reliable, physically restricting method that can differentiate between MRI personnel and non-MRI personnel**
- **The use of combination locks is discouraged as combinations often become more widely distributed than initially intended,**
- Only MRI personnel shall be provided free access, such as the access keys or passkeys, to Zone III



Location of lock outside Zone III and/or Zone IV

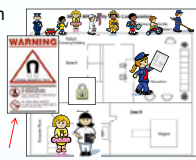
*There should be no exceptions to this guideline. Specifically, this includes hospital or site administration, **physician, security, and other non-MRI** personnel. Non-MRI personnel are not to be provided with independent Zone III access until such time as they undergo the proper education and training to become MRI personnel themselves.

Slide - 52 From the ACR Guidance Document for Safe MRI Practices 2007

Zone III – Signs

Signs should be posted outside the MR imager room. Bear in mind that, Magnetic fields are three-dimensional volumes,

- Zone III controlled access areas may project through floors and ceilings of MRI suites, imposing magnetic field hazards on persons on floors other than that of the MRI scanner.
- Zones of magnetic field hazard should be clearly delineated (with signs) even in typically non-occupied areas such as rooftops or storage rooms, and access to these Zone III areas should be similarly restricted from non-MRI personnel as they would be inside any other Zone III region associated with the MRI suite.
- Magnetic field strength plots for all MRI systems should be analyzed in vertical section as well as in horizontal plan, identifying areas above or below



Location of signs posted outside Zone IV – May be recommended to post in 3 dimensions.

Slide - 53 From the ACR Guidance Document for Safe MRI Practices 2007

Warning vs. Danger Signs

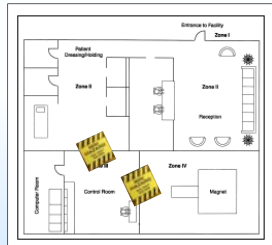





Courtesy: Anne Marie Sawyer @ Stanford

Slide - 54

Warning vs. Danger vs. Hazard Signs



Courtesy: Christiana Imaging

Slide - 55

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.

Slide - 56

From the ACR Guidance Document for Safe MRI Practices 2007

MRI Technologists

“**MRI Technologists** should be American Registry of Radiologic Technologists (ARRT)–registered technologists (RTs).

- All MRI technologists must be trained as level 2 MRI personnel prior to being permitted free access to Zone III.
- All MRI technologists will maintain current certification in American Heart Association basic life support.
- Except for emergent coverage, there will be a minimum of 2 MRI technologists or one MRI technologist and one other individual with the designation of MRI personnel in Zone II through Zone IV
- For emergent coverage, the MRI technologist can scan with no other individuals in their Zone II through Zone IV
 - As long as there is in-house, ready emergent coverage by designated department of radiology MRI personnel (e.g., radiology house staff or attending radiologist).



Slide - 57

From the ACR Guidance Document for Safe MRI Practices 2007

Zone IV – Keep an eye on the Patient!

- **Zone IV = the MRI scanner magnet room itself**
 - The physical confines of the room within which the MRI scanner is located.
 - Zone IV, by definition, will always be located within Zone III,
 - The MRI magnet and its associated magnetic field of Zone IV.
- Zone IV should also be
 - Demarcated and clearly marked as being hazardous due to very strong magnetic fields.
- Zone IV site restriction, all MRI installations should provide
 - **Direct visual observation by level 2 personnel to pathways to Zone IV.**
 - **By means of illustration only, the MRI technologists would be able to directly observe and control, via line of sight or via video monitors.**
 - The entrances or access corridors to Zone IV from their normal positions when stationed at their desks (at the console) in the scan control room.”



Video Monitor Video Camera

Slide - 58

From the ACR Guidance Document for Safe MRI Practices 2007

Pregnant Healthcare Workers

“**Healthcare Practitioner Pregnancies**

- Pregnant healthcare practitioners are permitted to work in and around the MRI environment
- Throughout all stages of their pregnancy.
- Acceptable activities include, but are not limited to,
 - positioning patients, scanning, archiving, injecting contrast material,
 - and entering the MRI scan room in response to an emergency.
- Although permitted to work in and around the MRI environment, pregnant healthcare practitioners are requested
 - Not to remain within the MRI scanner bore or Zone IV
 - During actual data acquisition or scanning.”



Slide - 59

From the ACR Guidance Document for Safe MRI Practices 2007

MRI and Pregnant Patients

According to the...

Society for Magnetic Resonance (SMR) Safety Committee:

“MRI imaging may be used in pregnant women

- If other non-ionizing forms of diagnostic imaging are inadequate
- – or –
- If the examination provides important information that would otherwise require exposure to ionizing radiation.”



Coronal single shot (T2WI) Fetal Imaging

Slide - 60

From the ACR Guidance Document for Safe MRI Practices 2007

MRI & Pregnancy – Patients (ACR)

- To date, no conclusive documentation of any deleterious effects of MRI exposure on the developing fetus
 - Pregnant patients can be accepted to undergo MRI scans at any stage of pregnancy.
 - No special consideration is recommended for the first, versus any other, trimester in pregnancy.
 - The information requested from the MRI study cannot be acquired via non-ionizing means (e.g., ultrasonography).
 - The data are needed to potentially affect the care of the patient or fetus *during* the pregnancy.
 - The referring physician does not feel it is prudent to wait until the patient is no longer pregnant to obtain these data.
- It is prudent to screen women of reproductive age for pregnancy prior to permitting them access to MRI imaging environments.
 - Risks versus benefits of the pending study
 - The risk–benefit ratio to the patient
 - The radiologist should confer with the referring physician.

Slide - 61

From the ACR Guidance Document for Safe MRI Practices 2007



MRI & Pregnancy – Gadolinium (ACR)

- MRI contrast agents should *not* be routinely provided to pregnant patients. However, the decision to administer Gd...
 - Case-by-case basis by the level 2 MRI personnel-designated attending radiologist who assesses the risk–benefit ratio for that particular patient.
 - A well-documented and thoughtful risk–benefit analysis.
 - This analysis should be able to defend a decision to administer the contrast agent based on...
 - Overwhelming potential benefit to the patient or fetus
 - Outweighing the theoretic, but potentially real, risks of long term exposure of the developing fetus to free gadolinium ions.
- Studies have demonstrated that gadolinium-based MRI contrast agents pass through the placental barrier and enter the fetal circulation.
 - From there, they are filtered in the fetal kidneys and then excreted into the amniotic fluid, and may remain in this amniotic fluid for an indeterminate amount of time before finally being reabsorbed and eliminated.

Slide - 62

From the ACR Guidance Document for Safe MRI Practices 2007



Magnetic Moment...



Slide - 63



Magnetic Moment...

The ACR recognizes the “level” of training for MRI personnel, whereby:

- a. Level 1 is extensively trained
- b. Level 1 is not trained
- c. Level 2 is minimally trained
- d. Level 2 is extensively trained

Slide - 64



Magnetic Moment...

The ACR recognizes the “level” of training for MRI personnel, whereby:

- a. Level 1 is extensively trained
- b. Level 1 is not trained
- c. Level 2 is minimally trained
- d. **Level 2 is extensively trained**

If you had difficulty answering this “Magnetic Moment” question correctly, or if you would like to re-review this concept: Click back to [slide 40, 43](#) on the table of contents.

Remember, you are NOW on [slide 65](#). Click [slide 65](#) to continue with this lecture.

Slide - 65



Magnetic Moment...

The ACR designates “Zones” whereby:

- a. Zone I is the location within the scan room
- b. Zone II is the location within the scan room
- c. Zone III is the location within the scan room
- d. Zone IV is the location within the scan room

Slide - 66



Magnetic Moment...

The ACR designates "Zones" whereby:

- a. Zone I is the location within the scan room
- b. Zone II is the location within the scan room
- c. Zone III is the location within the scan room
- d. **Zone IV is the location within the scan room**

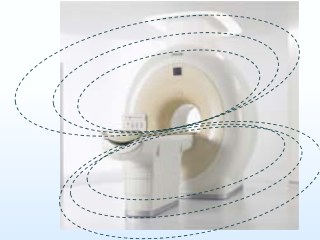
If you had difficulty answering this "Magnetic Moment" question correctly, or if you would like to re-review this concept: Click back to [slide 41, 42](#) on the table of contents.
Remember, you are NOW on [slide 67](#). Click [slide 67](#) to continue with this lecture.

Slide - 67



MRI Safety Update – Devices & Terminology

- Safety terminology
 - MRI compatible
- MRI terms
 - MRI safe
 - MRI unsafe
 - MRI conditional



Slide - 68



ACR Recommendations – Compatibility

- MRI safe
- MRI unsafe
- MRI conditional

"With the increasing advent and use of 3.0-Tesla and higher strength magnets, users need to recognize that one should never assume MRI compatibility or safety information about a device if it is not clearly documented in writing.



Decisions based on published MRI safety and compatibility claims should recognize that all such claims apply only to specifically tested conditions, such as static magnetic field strengths, static gradient magnetic field strengths and spatial distributions, and the strengths and rates of change of gradient and radiofrequency (RF) magnetic fields."

Slide - 69

From the American Society for Testing and Materials (ASTM)



MRI "Compatibility"

- **MRI Safe**
 - "an item that poses no known hazards in all MRI environments."
- **MRI Conditional**
 - "an item that has been demonstrated to pose no known hazards in a specified MRI environment with specified conditions of use. Field conditions that define the specified MRI environment include static magnetic field strength, spatial gradient, dB/dt (time varying magnetic fields), RF, and specific absorption rate (SAR). Additional conditions, including specific configurations of the item, may be required."
- **MRI Unsafe**
 - "an item that is known to pose hazards in all MRI environments."
- **NOT ... MRI Compatible**
 - devices that have been previously tested and deemed "MRI Compatible" will not be re-tested / changed. New devices will be deemed **MRI Safe, MRI Unsafe or MRI Conditional**, since 2005.

New Terminology With Regard to MRI and Implants and Devices
 American Society for Testing and Materials (ASTM) International, Designation: F 2503-05, Standard Practice for Marking Medical Devices and Other Items for Safety in the Magnetic Resonance Environment. ASTM International, 100 Barr Harbor Drive, PO Box C700, West Conshohocken, Pennsylvania, 19428, 2005.

Slide - 70



Ancillary Equipment - Testing & Marking

- 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.

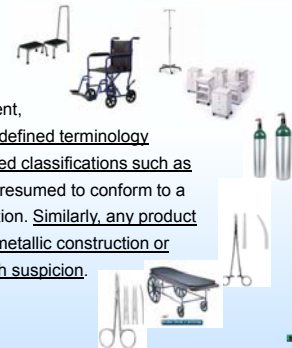


Slide - 71



Non-MRI – Clinical Equipment

Particularly with regard to nonclinical and incidental equipment, current products marketed with ill-defined terminology such as "non-magnetic," or outdated classifications such as "MRI-compatible," should not be presumed to conform to a particular current ASTM classification. Similarly, any product marketed as "MRI safe" but with metallic construction or components should be treated with suspicion.



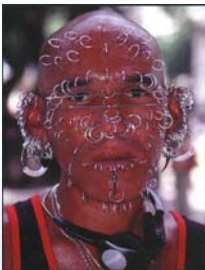
Slide - 72



Why should screening be performed?

To determine...

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


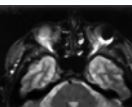


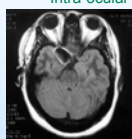
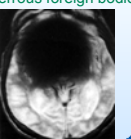
Some Implants are More Obvious Than Others

Slide - 73

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

Slide - 74

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
- They follow strict criteria, listed on www.mrisafety.com

EXPEDITED REVIEW

Magnetic Resonance Imaging and Cardiac Pacemaker Safety at 1.5-Tesla

Edward T. Moran, MD, FACC, FJACC, A. Carter, MD, FACC, FJACC, G. Stubbins, PhD, Christopher C. Pollock, MD, Robert Fox, MREDT, MRC, Ken Jackson, MREDT, MRC, Dale Robinson, MD, Diploid, Cardiology and Neurology, Minnesota


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


Slide - 75

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

Slide - 76


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

Slide - 77

Additional Conditions for Revo™ System

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



MRI SureScan Settings		MRI SureScan Parameters		Page 1
MRI SureScan	ON	Device	Revo MRI RV0801	Date of Impl: 02-Jan-2010
Mode	SD00	Model	5086MRI CapSureFix	IME13 Software Version 1.0
Lead Rate	800pm	Serial Number	FFA807728	Copyright © Medtronic, Inc. 2010
Paced AV	110 ms	Implanted	LF900555V	
A. Amplitude	3.0 V	Implanted	LF900556V	
A. Pulse Width	1.0 ms			
RV Amplitude	3.0 V			
RV Pulse Width	1.0 ms			

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

Slide - 78

MRI/Radiology Specific Education



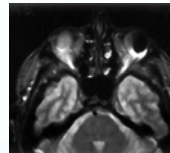

www.mrisurescan.com

Slide - 79

Intraocular Ferrous Foreign Bodies (IFFB)

One Theory...

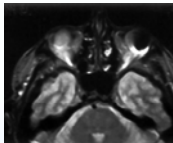
- American Journal Neuroradiology (AJNR); 2000 Feb; 21(2):426-33
- Cost utility analysis of radiographic screening for an orbital foreign body before MRI imaging
- Seidenwurm DJ, McDonnell CH 3rd, Raghavan N, Breslau
CONCLUSION: Clinical screening before radiography increases the cost-effectiveness of 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.



Slide - 80

Intraocular Ferrous Foreign Bodies (IFFB)

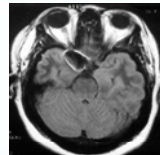
- All such patients should also undergo plain film imaging of the skull or orbits and chest to exclude metallic foreign objects (if recently obtained plain films or CT or MRI studies of such areas are not already available).
- Should it be determined that non-MRI personnel wishing to accompany a patient 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.



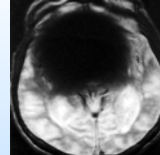
Slide - 81

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

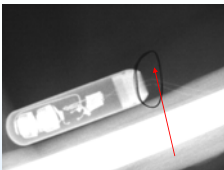


More Ferrous

Slide - 82

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

Slide - 83

Deep Brain Stimulators (DBS)




MRI GUIDELINES FOR MEDTRONIC DEEP BRAIN STIMULATION SYSTEMS

www.mrisafety.com

Prior to the MRI examination, a responsible individual such as an MRI radiologist or MRI physicist must ensure 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 Active System to MRI under conditions other than described in the guidelines can induce excessive heating of 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-bore or other field-strength MRI systems).
- Use only a nonmetallic head coil.
- Contraindication: Implantation of an Active Brain Stimulation System is contraindicated for patients who are using a full body transmit radio-frequency (RF) coil, a head-only head coil, or a head transmit coil that extends over the chest area. Performing MRI with this equipment can cause tissue lesions from conducted heating, especially if the lead electrodes, resulting in serious and permanent injury including coma, paralysis, or death.
- Before the (closed) patient enters the MRI to ensure the head SAR is estimated correctly.




- Use MRI examination parameters that limit the displayed average head SAR to 1.0 (0.1) W/kg or less for all RF pulse sequences unless the applied SAR is known. If known, an applied SAR up to 1.0 (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 pre-scan, 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 Active System, particularly at the lead electrodes.
- Limit the gradient dB/s field to 20 Tesla/second or less.

Slide - 84

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 Intracranial pressure (ICP) catheter



Slide - 85

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.



Slide - 86

Other 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.

Slide - 87

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?**


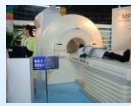
Metallic ballistic fragments: MRI imaging safety and artifacts
 GP Teitelbaum, CA Yee, DD Van Horn, HS Kim and PM Colletti
 Department of Radiology, LAC-USC Medical Center 90033.

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

Slide - 88

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.

Slide - 89

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.



Slide - 90

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

Slide - 91

From the ACR Guidance Document for Safe MRI Practices 2007



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

Slide - 92

From the ACR Guidance Document for Safe MRI Practices 2007

Magnetic Moment...



Slide - 93

Magnetic Moment...

Terminology with respect to MRI devices, includes all of the following EXCEPT:

- MRI compatible
- MRI safe
- MRI unsafe
- MRI conditional

Slide - 94

Magnetic Moment...

Terminology with respect to MRI devices, includes all of the following EXCEPT:

- MRI compatible**
- MRI safe
- MRI unsafe
- MRI conditional

If you had difficulty answering this "Magnetic Moment" question correctly, or if you would like to re-review this concept: Click back to [slide 68 - 70](#) on the table of contents.
Remember, you are NOW on [slide 95](#). Click [slide 95](#) to continue with this lecture.

Slide - 95

Magnetic Moment...

Contraindications for MRI imaging, may include any of the following EXCEPT:

- Patients with certain types of intracranial vascular clips
- Patients with claustrophobia
- Patients with certain types of cardiac pacemakers
- Patients with intra-ocular ferrous foreign bodies

Slide - 96

Magnetic Moment...

Contraindications for MRI imaging, may include any of the following EXCEPT:

- a. Patients with certain types of intracranial vascular clips
- b. **Patients with claustrophobia**
- c. Patients with certain types of cardiac pacemakers
- d. Patients with intra-ocular ferrous foreign bodies

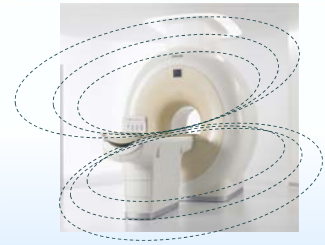
If you had difficulty answering this "Magnetic Moment" question correctly, or if you would like to re-review this concept: Click back to **slide 73** on the table of contents.
Remember, you are NOW on **slide 97**. Click **slide 97** to continue with this lecture.

Slide - 97



MRI Safety Update – Patient Care & Screening

- Patient screening
- Patient preparation
- Screening devices



Slide - 98



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



"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

Slide - 99

From the ACR Guidance Document for Safe MRI Practices 2007



Recommended Screening Forms – ACR

Forms available at www.acr.com

Slide - 100



Recommended Screening Forms

Forms available at www.mrisafety.com

- Forms for patients
- Forms for individuals

Screening Form for Individuals

Side 1

Side 2

Screening Form for Patients

Slide - 101



Who performs the screening ?

- Screened by level 2 personnel
- More than once
- Verbally & visually
- Written
 - or –
- X-rays



Slide - 102

From the ACR Guidance Document for Safe MRI Practices 2007



Non-MRI Personnel

All non-MRI personnel wishing to enter Zone III must first pass an MRI safety screening process. Only MRI personnel are authorized to perform an MRI safety screen before permitting non-MRI personnel into Zone III.

Slide - 103 From the ACR Guidance Document for Safe MRI Practices 2007

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."

Slide - 104 From the ACR Guidance Document for Safe MRI Practices 2007

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.

Slide - 105 From the ACR Guidance Document for Safe MRI Practices 2007

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.

Slide - 106

Patient Preparation for MRI

- Remove metal
- Change patient gown

"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."

Slide - 107 From the ACR Guidance Document for Safe MRI Practices 2007

Patient Considerations

- Emergency care
- Claustrophobia
- Sedation
- Monitoring
- Pregnancy
- Contrast agents

Slide - 108

ACR Recommendations for Claustrophobic Patients

1. Prepare the patient (explain the exam)
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 desensitization
16. Hypnosis

K. Claustrophobia, Anxiety, Sedation, Analgesia, and Anesthesia
 Adult and pediatric patient anxiety, sedation, analgesia, and anesthesia for any reason should follow established ACR [24, 25], American Society of Anesthesiologists (ASA) [26–29], and JCAHO standards [29].

Slide - 109



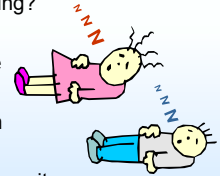
Patient Monitoring

Who should be monitored?

All patients should be monitored verbally & visually.

Who would require additional monitoring?

1. Patients who cannot communicate
2. Patients with weak voices
3. Patients who do not speak English
4. Patients who are sedated
5. Patients with diminished mental capacity
6. Patients at risk for contrast reaction



Slide - 110

From the ACR Guidance Document for Safe MRI Practices 2007



Monitoring Devices

MRI compatible monitors & devices

- ECG
- Pulse oximeters
- Blood pressure
- Respiratory & apnea
- Temperature
- Multi-parameter monitoring systems
 - The potential for thermal injury from excessive RF power deposition exists.
 - Sedated, anesthetized, or unconscious patients may not be able to express symptoms of such injury.
 - This potential for injury is greater on especially higher-field whole-body scanners (e.g., 1 Tesla and above).
 - Patients who require ECG monitoring and who are unconscious, sedated, or anesthetized should be examined after each imaging sequence, with potential repositioning of the ECG leads and any other electrically conductive material with which the patient is in contact.
 - Cold compresses or ice packs could be placed upon all necessary electrically conductive material that touches the patient during scanning.



Slide - 111

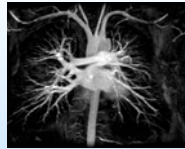
From the ACR Guidance Document for Safe MRI Practices 2007



Magnet – Hemodynamic Effect



Blood Flowing in the Aorta

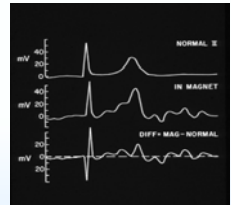


MRA of the Thoracic Vasculature

ECG of Patient Outside the Bore

ECG of Patient Within The Bore

ECG of Patient Within The Bore Fixed



Distortion of the electrocardiogram within the magnetic field makes interpretation of the ECG complex unreliable, even with filtering used by contemporary monitoring systems. However, routine monitoring of heart rate and rhythm may be accomplished using pulse oximetry, which also eliminates the risks of thermal injury from electrocardiography.

Slide - 112

From the ACR Guidance Document for Safe MRI Practices 2007



Emergency Treatment

All MRI personnel should be familiar with the procedure for removing a patient from the MRI scan room in the event of a medical emergency.

- MRI "safe" supplies for imaging
- Non-ferrous IV poles
- Non-ferrous wheel chairs
- Non-ferrous IV poles
- Stretchers
- Non-ferrous IV poles
- MRI "safe" monitoring devices & more!



According to the ACR white paper on MRI Safety, "Zone III & Zone IV site access restriction must be maintained during resuscitation and / or other emergencies."

Slide - 113



Magnetic Moment...




Slide - 114



Magnetic Moment...

The following patients **MUST** be screened prior to entering the MRI environment:

- a. Patients with implants
- b. Patients without implants
- c. Parents of pediatric patients
- d. Anyone who intends to enter the scan room




Slide - 115

Magnetic Moment...

The following patients **MUST** be screened prior to entering the MRI environment:

- a. Patients with implants
- b. Patients without implants
- c. Parents of pediatric patients
- d. **Anyone who intends to enter the scan room**

If you had difficulty answering this "Magnetic Moment" question correctly, or if you would like to re-review this concept: Click back to **slide 99** on the table of contents.
Remember, you are NOW on **slide 116**. Click **slide 116** to continue with this lecture.




Slide - 116

Magnetic Moment...

When hand-held magnets are used in MRI for screening patients:

- a. The screening is more efficient
- b. The screening is less efficient
- c. There can be a false sense of security
- d. The implant is undetectable




Slide - 117

Magnetic Moment...

When hand-held magnets are used in MRI for screening patients:

- a. The screening is more efficient
- b. The screening is less efficient
- c. **There can be a false sense of security**
- d. The implant is undetectable

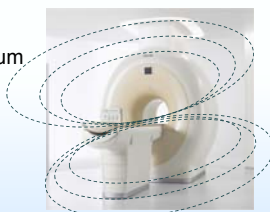
If you had difficulty answering this "Magnetic Moment" question correctly, or if you would like to re-review this concept: Click back to **slide 105** on the table of contents.
Remember, you are NOW on **slide 118**. Click **slide 118** to continue with this lecture.




Slide - 118

MRI Safety Update – Contrast Media

- Contrast Media in MRI
- Venipuncture
- Safety associated with CM
- Contraindications for Gadolinium






Slide - 119

Contrast Administration – ACR White Paper

- ***"No patient is to be administered prescription MRI contrast agents without orders from a duly licensed physician."***
- *Intravenous injection-qualified MRI technologists may start and attend to peripheral IV access lines if they have undergone the requisite site-specified training in peripheral IV access and have demonstrated and documented appropriate proficiency in this area.*
 - *IV-qualified MRI technologists may administer FDA-approved gadolinium-based MRI contrast agents via peripheral IV routes as a bolus or as a slow or continuous injection as directed by the orders of a duly licensed site physician.*
 - *Administration of these agents is to be performed according to the ACR policy. **The ACR approves of the injection of contrast material and diagnostic levels of radiopharmaceuticals by certified and/or licensed radiologic technologists and radiologic nurses under the direction of a radiologist or his or her physician designee who is personally and immediately available,** if the practice is in compliance with institutional and state regulations.*
 - *There must also be prior written approval by the medical director of the radiology department or service of such individuals.*
 - *Such approval process must follow established policies and procedures, and the radiologic technologists and nurses who have been so approved must maintain documentation of continuing medical education related to materials injected and to the procedures being performed"*





From the ACR Guidance Document for Safe MRI Practices 2007

Slide - 120

Avoid Extravasation



- Animal studies do show moderate necrosis
- Osmolality a consideration
 - More problematic with ionic agents

Investigative Radiology 2002 July;37(7):393-8

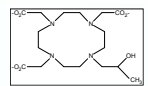

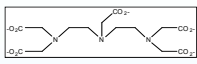

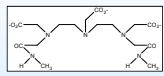

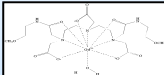





Gadolinium Toxicity

- Rare earth metal ion (as a contrast agent)
- Heavy metal (toxic) – as an element
- To remove toxicity – chelate "claw"
 - Non toxic!
 - Ligand
 - Ionic vs. non-ionic
 - Can be excreted

Gadolinium Chelates


	Gadoteridol (Gd HP-DO3A) ProHance by Bracco	
	Gadopentetate Dimeglumine (Gd DTPA) Magnevist by Bayer / Berlex	
	Gadodiamide (Gd DTPA-BMA) Omniscan by GE / Nycomed	
	Gadoversetamide Optimark by Covidien / Malinkrodt	



Adverse Reactions





- Minor reactions occur with all agents in a low percentage of cases.
 - The current 5 agents have similar safety profiles.
- Anaphylactoid reactions are rare.
 - Have occurred with all agents
- Sites should be prepared to treat a reaction.

V. Runge, *Topics in Magnetic Resonance Imaging*, 2001, Aug; 12(4):309 - 14



Adverse Reactions

- Mild transitory headaches (HA)
- Slight increase bilirubin & blood iron
- Nausea / vomiting
- Urticaria / rash
- Less than 1% anaphylaxis or death

Be Prepared!


Top Magn Reson Imaging 2001 Aug; 12(4):309-14

Safety of magnetic resonance contrast media.

Runge VM.

Department of Radiology, Scott and White Clinic and Hospital, Texas A&M University Health Science Center, Temple, Texas, USA.

Intravenous contrast media, specifically the gadolinium chelates, are well accepted for use in the clinical practice of magnetic resonance imaging. The gadolinium chelates are considered to be very safe and lack (in intravenous use) the nephrotoxicity found with iodinated contrast media. Minor adverse reactions, including nausea and hives, occur in a low percentage of cases. The four agents currently available in the United States cannot be differentiated on the basis of these adverse reactions. Review abstracts.



Gd Side Effects - Signs vs. Symptoms


- Standard IV use/doses
 - Not nephrotoxic (usually)
- Iodinated contrast equivalent doses or intra-arterial (IA) use for digital subtraction angiography (DSA)
 - Nephrotoxicity has been reported
 - Debatable if gadolinium performs better than low osmolar iodinated agents
- Patients in renal failure ... 1998
 - Nephrogenic fibrosing dermopathy
 - Nephrogenic systemic fibrosis

NDT

Nephrogenic Systemic Fibrosis: a specific trigger for the development of arthropathy, fibrosing dermopathy and angiodysplasia of skin? Blumst

Reference:

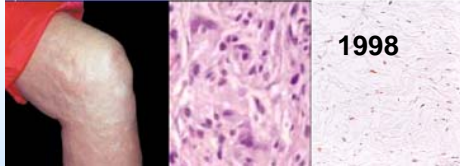
Book of Radiology from April 2005, 10, 11, 12, 13



New Disease – What is it?

Scleromyxoedema-like cutaneous diseases in renal-dialysis patients

Shawn E Cowper, Howard S Robin, Steven M Steinberg, Lyndon D Su, Samardeep Gupta, Philip E LeBoit



Slide - 127

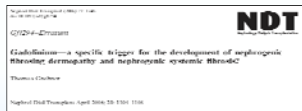
What's in a name? What is it called?

- First described in 1997, in 15 dialyzed patients
- Resembled scleromyxedema
- So ... mislabeled at first
- First named...
 - NFD – nephrogenic fibrosing dermopathy (skin)
- Then...
 - NSF – nephrogenic systemic fibrosis
 - Circulating fibrocytes
 - Systemic nature
- Should be diagnosed by skin biopsy
 - Generally is not

Slide - 128

NFD / NSF

- NFD – nephrogenic fibrosing dermopathy
- NSF – nephrogenic systemic fibrosis



"It has been recently noted that over a 4-year period, 20 patients in Denmark and five in Austria developed a very rare disease that is seen only in patients with severely impaired renal function [32, 33]. Each of these patients had been administered Omniscan (gadodiamide, GE Healthcare), a gadolinium-based MRI contrast agent (GBMCA), for an MRI imaging or angiographic examination within a few weeks or months prior to the onset of the disease. Roughly 17,500 patients are examined using Omniscan in Denmark each year. Since January 2002, about 400 patients with severely impaired renal function had been examined, of which 20, or 5%, to whom Omniscan had been administered, eventually were diagnosed with this disease in that country."

Slide - 129

ACR Manual on Contrast Media Version 7, 2010

Group I: Agents associated with the greatest number of NSF cases:

Gadodiamide (Omniscan® – GE Healthcare)
 Gadopentate dimeglumine (Magnevist® – Bayer HealthCare Pharmaceuticals)
 Gadoversetamide (OptoMARK® – Covidien)

As of December 2009, according to data provided by the Food and Drug Administration (FDA) [4], the approximate number of administered doses and the number of NSF cases associated with these three agents were as follows:

Agent	Approximate # of doses (in millions)	# of reported NSF cases (single-agent nonconfounded)
Gadodiamide	13	282
Gadopentate dimeglumine	23	195
Gadoversetamide	4.7	35

While various factors may have influenced the number of cases reported with each of these agents, investigators believe that intrinsic properties of these three agents increase the relative likelihood of NSF developing following exposure in at-risk patients.

Slide - 130

ACR Manual on Contrast Media Version 7, 2010

Group II: Agents associated with few, if any, unconfounded cases of NSF:

Gadobenate dimeglumine (MultiHance® – Bracco Diagnostics)
 Gadoteridol (ProHance® – Bracco Diagnostics)
 Gadoteric acid (Dotarem® – Guerbet) - as of this writing not FDA-approved for use in the United States.
 Gadobutrol (Gadovist® – Bayer HealthCare Pharmaceuticals) – as of this writing not FDA-approved for use in the United States.

Group III: Agents which have only recently appeared on the market in the US:

Gadofosveset (Ablava® – Lantheus Medical Imaging)
 Gadoteric acid (Eovist® – Bayer HealthCare Pharmaceuticals)

There is limited data for these agents, although, to date, few, if any, unconfounded cases of NSF have been reported.

Slide - 131

ACR Manual on Contrast Media Version 7, 2010

- Risk Factors**
- Chronic kidney disease
 - Acute kidney injury
 - High dose
 - Multiple exposures

Slide - 132

ACR Manual on Contrast Media Version 7, 2010

Identifying Patients at Risk

- eGFR within 6 weeks of procedure in patients with suspected kidney disease
- > 60 years of age
- Hx of renal disease
- Diabetes, hypertension

If possible, avoid administration in patients with $eGFR < 30 \text{ mL/min/1.73 m}^2$.



Slide - 133

Magnetic Moment...



Slide - 134

Magnetic Moment...

If possible, avoid administration in patients with $eGFR < 30 \text{ mL/min/1.73 m}^2$:

- True
- False

Slide - 135

Magnetic Moment...

If possible, avoid administration in patients with $eGFR < 30 \text{ mL/min/1.73 m}^2$:

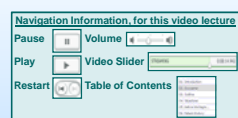
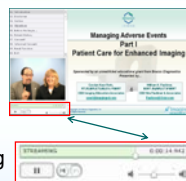
- True**
- False

If you had difficulty answering this "Magnetic Moment" question correctly, or if you would like to re-review this concept: Click back to [slide 133](#) on the table of contents.
Remember, you are NOW on [slide 136](#). Click [slide 136](#) to continue with this lecture.

Slide - 136

Outline

- ACR guidelines & recommendations
- Considerations for hardware
- Site considerations ... zoning
- Personnel considerations
- Device considerations ... safety testing
- Patient considerations ... screening
- Gadolinium considerations



Slide - 137

Objectives

Upon completion of this course, the learner should be able to:

- Describe the importance of safety in Magnetic Resonance Imaging (MRI).
- Recognize the American College of Radiology (ACR) recommendations associates with MRI safety.
- Explain magnetic field considerations with MRI safety.
- Describe static field (known as B_0), radiofrequency [RF, a time varied (oscillating) magnetic field known as B_1] field and gradient field [a time varied magnetic field (TVMF)] considerations.
- Demonstrate appropriate patient screening techniques in MRI.
- Identify safety considerations associated with contrast media (CM), typically gadolinium (Gd) in MRI.

Slide - 138

Thank you for your attention! Update on MRI Safety

Presented by

Carolyn Kaut Roth	William H. Faulkner
RT (R)(MRI)(CT)(M)(CV) FSMRT	BSRT (R)(MRI)(CT) FSMRT
CEO, Imaging Education Associates	CEO, Wm. Faulkner & Associates
candi@imaginged.com	Faulkner@t2star.com

*Produced by Imaging Education Associates
Sponsored by an unrestricted educational grant from Bracco Diagnostics*

If you are viewing this presentation as an on-line (self study) module,
be sure to complete the post test to claim your credits.



Slide - 139