BS”D

American Board of Magnetic Resonance Safety
MRMD ,MRSO, MRSE
Examination Content Syllabus

Version 1.5
Friday, February 06, 2015

A. Basic underlying MR safety principles and building blocks

1. Static magnetic field (B_0, dB_0/dx)

a. Basic Physics
   i. Quantities and units
   ii. Field lines/gradients
   iii. Magnetic properties of matter

b. Biological Effects
   i. Magnetophosphenes
   ii. Magnetohydrodynamic effect
   iii. Flow potentials/EKG perturbations
   iv. Vertigo, dizziness/nystagmus, nausea with motion in the static field
   v. Teratogenesis?
   vi. Pregnancy-related issues: Spontaneous abortion, premature delivery, gender of offspring, low birth weight, infertility

c. Mechanical Forces
   i. Translational Forces (Missile Effect)
      1. Magnetic spatial gradient exposure (dB_0/dx)
      2. Static field exposure (B_0)
      3. Spatial and force-related effect of magnetic shielding
         a. Active
         b. Passive
      4. 3D location of maximal translational force (i.e., force product; location of maximum $(dB_0/dx)(B_0)$)
   ii. Rotational Forces (Torque)
      1. 3D location of maximal rotational force (i.e., location of maximum B_0)
      2. Field orientation (horizontal, vertical)
   iii. Lenz’s Forces
      1. Dependence predominantly on:
         a. Static field B_0 and static field gradient dB_0/dx
         b. Orientation of electrical conductor relative to the lines of magnetic force
         c. Rate of motion of electrical conductor relative to B_0
         d. Dimensions of moving electrical conductor

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2. **Time varying magnetic fields**
    a. Basic physics
        i. Induction –Faraday’s law
        ii. E field, Current density J
        iii. Near and far field
        iv. Tissue properties – conductivity, dielectric constant
    b. Rapidly changing - RF magnetic fields (B_1)
        i. Potential biological concerns
        ii. Potential thermal concerns; multifactorial determinants, including among others:
            1. SAR and energy deposited
                a. SAR modes
                    i. Normal
                    ii. First level controlled
                    iii. Second level controlled
            2. Rate of exposure
            3. Route of exposure
            4. Transmitting RF coil
                a. Proximity of patient tissue/device to transmitting RF coil
            5. Diameter of induced current loop
            6. Orientation of induced current loop relative to transmitted RF power
            7. Concentration of induced voltages/currents
                a. Predominantly in leads, wires, devices with sharp edges/points
                b. Field strength/transmitted RF frequency relative to the object in which there is an induced voltage/current
                c. “Hot spots”
                d. Resonant conditions, critical lengths relative to field strength/frequency dependence
            8. Presence/absence of heat sink (other than patient tissue!)
            9. Use of padding/insulation
                a. Between patient and bore (cylindrical magnets)
                b. Skin to skin contact avoidance vis à vis large caliber induced loops

c. Slowly changing - Gradient magnetic fields (dB/dt)
    i. Acoustic/auditory considerations
    ii. Direct neuromuscular stimulation potential
        1. Muscular twitching, fasciculations
        2. Arrhythmogenesis potential
d. Very slowly changing magnetic fields (dB_0/dt)
    i. System quench
    ii. Movement/motion within the static magnetic field

3. Gadolinium based contrast agents (GBCA)

a. Short term adverse effects
    i. Non-allergic type: Nausea, emesis, headache, local injection site adverse reactions, etc.
    ii. Allergic type: Hives, sneezing, swelling, etc.
    iii. Anaphylaxis/anaphylactoid reactions
    iv. Risk assessment
        1. Previous adverse event with a GBCA
        2. Previous adverse event with iodinated agents
        3. History of allergies or allergic respiratory disorders
b. Long term adverse effects
    i. Nephrogenic Systemic Fibrosis
    ii. Dose related dentate/globus pallidus T1 shortening; retained gadolinium
    iii. Gadolinium Associated Plaques (GAP)
    iv. Anthropogenic gadolinium
    v. Self-published patients with normal renal function and complaints since GBCA administration; elevated 24 hour urinary gadolinium excretion?

4. Cryogen safety considerations

a. Quench vent pathway considerations
b. Hypothermia/frostbite
c. Asphyxia
d. Changing magnetic fields
e. Explosive/flammable risk
f. Pressure related risks (if quench vent pathway failure)
    i. Ruptured eardrums
    ii. Pressure "locking" of doors/access

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5. **Claustrophobia/Anxiety**

6. **Monitoring**
    a. MR environment effects on ability to accurately monitor
    b. Effects of the monitoring device(s) on MR imaging (artifacts)

B. Clinical situations and considerations

1. **ACR Guidance Document for Safe MR Practices: 2013**

2. **General implant safety considerations**
    a. Maximum spatial gradient (clinical application and decision making)
        i. System maximum (may be behind system shroud/enclosure)
        ii. Maximum exposure to the patient and health care personnel
    b. Thermal (clinical application and decision making)
    c. Induced voltages
    d. Artifact induction (clinical application and decision making)

3. **Specific implant/device safety considerations**
    a. Patient implants/devices
        i. Ferromagnetic risk
            1. Magnetic implants (dental, breast implants, ICP monitors, etc.)
            2. Intraocular or adjacent to other delicate tissues/organs
            3. Artifact consideration
        ii. Active implants/devices (specific examples follow)
            1. Device interfering with the MR scanner/artifact
            2. MR fields interfering with the implanted device function
            3. Pacemakers
                a. Classical, one or more leads
                b. Newest intracardiac, "leadless"
            4. ICDs
            5. Depth electrodes
            6. Neurostimulators (including deep brain stimulators)
            7. Bone growth stimulators

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iii. Passive implants/devices (specific examples follow)
1. Wires/leads/sutures
2. Special consideration/circumstances
a. Copper 7/copper T
b. Foreign bodies (bullets, shrapnel, BBs, etc.)
c. Tattoos
i. Thermal
ii. Migration
d. Foil backed (i.e., electrically conductive) medication patches
e. Multiple adjacent or contiguous implants (e.g., skin staples, multiple dermal anchors, piercings)

b. Fixed Parameter Option:B Operating Mode
c. Healthcare worker implants
d. Device labeling and proper use of terminology
i. MR Safe
ii. MR Unsafe
iii. MR Conditional

4. Pregnancy MR safety considerations

a. Patient pregnancy issues
i. Unenhanced
ii. Enhanced
b. Research subject pregnancy considerations
i. Risk-benefit assessments we use in clinical scanning do not apply, as the individual undergoing the risk is not the same as the one receiving the potential benefit
ii. Unenhanced
iii. Enhanced
c. Healthcare pregnancy issues
i. Risk-benefit assessments we use in clinical scanning do not apply, as the individual undergoing the risk is not the same as the one receiving the potential benefit

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5. **Limits and standards**
    a. IEC, FDA, ICNIRP
        i. Static field, movement in static field
        ii. Time varying gradients
        iii. RF
    b. Occupational exposure

6. **Non-MR personnel in the MR environment**
    a. Anesthesiologists
    b. Referring physicians (neurosurgeons, neurologists, cardiologists, etc.)
    c. ICU personnel (nursing, respiratory)
    d. Patient transport
    e. Security
    f. Housekeeping/maintenance
    g. Firefighters, police, first responders
        i. Training content, frequency
    h. Accompanying family/friends/guardians
    i. Prisoners
        i. House arrest bracelet
        ii. Handcuffs, other restraining device(s)

7. **Screening considerations**
    a. Standardization
        i. By whom?
        ii. Of whom?
        iii. How many times?
        iv. Written? Oral? Both?
    b. Ferromagnetic detection; pros and cons, advances (far fewer false positives)
    c. Standard conventional "airport style" metal detectors are NOT recommended
    d. Gowning considerations
        i. Decrease risks from ferromagnetic and thermal considerations
        ii. Whom? (patient? Accompanying family? Accompanying healthcare workers?)
        iii. How much? (i.e., what constitutes gowning? Top? Whole body? Underwear/socks?)

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8. Handling codes in the MR environment

a. Prospective designation outside of Zone IV (except anesthesia)
   i. Location
   ii. Events/steps to execute
b. Prospective site design (oxygen, suction, location with ability to safely and reliably defibrillate)

9. 4 Zones concept

a. Site access restriction for:
   i. Humans
   ii. Ferromagnetic devices/objects
   iii. Ferromagnetic devices/objects
      1. Ancillary equipment in Zone 4 (MRI scanner room)
b. Site access restriction relative to:
   i. The MR magnet room/Zone IV
   ii. The quench vent exhaust port
c. Signage
   i. Relative to the MR magnet room/Zone IV
   ii. Relative to the quench vent exhaust port
d. Authority and responsibility for enforcement

10. Siting considerations for MR safety

a. Defined at least in part by the patient population to be scanned (e.g., in-patient versus out-patient, pediatric versus adult, sedation, anesthesia and recovery, monitoring, how will codes be handled, etc. etc. etc.)
b. Diagnostic versus interventional (intraoperative) care
c. Hybrid scanners (PET/MR, etc.)
d. Access control, line of sight from MR Technologist/Operator, etc. (4-zone integration)
e. Siting of ferromagnetic detection units
f. Patient screening areas
g. Area for running codes
h. Area for running induction/recovery (if/as applicable)
i. Metal/ferromagnetic material storage/quarantine area (e.g., lockers)

j. Site planning for gases, suction, etc. access
k. Proper quench venting pathways
    i. Design
    ii. Maintenance
    iii. The entirety of the cryogen vent pathway falls with Zone III definitions and as such requires physical restriction from inadvertent access by non-MR personnel, even though it may be physically removed from the MR suite itself

11. Infection control (cleaning, venting between patients, etc.)

C. Medicolegal implications of MR safety

1. Legal foundations and building blocks
    a. Standard of care
        i. This is the basis of it all
        ii. Expectation of how another similarly trained individual would have behaved in the same clinical situation
        iii. HOWEVER, defined by the *patient's* expectation
    b. Medical malpractice
        i. Breach of standard of care = Negligence
        ii. The breach of the standard of care was a proximate cause of an injury
    c. "Captain of the ship" doctrine for medical malpractice in US
    d. There can be multiple parties responsible/liable for an injury
    e. Vicarious liability
        i. NOT determined by who hires/fires the employee
        ii. If they respond to your guidance, you can be held vicariously liable for their actions/inactions