MR Safety: Case Review of Real MRI Safety Incidents

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Outline

- MR Safety Considerations
  - B0, dB/dt, RF, Acoustic
  - Assessment strategy
- Case reviews
  - Shocked (or not?)!
  - Sacral stimulator (sans wires) - head/ spine
  - Chest expander
  - Tanked (a zone 3 phenomena!)
  - Cochlear implant
  - Stapes Implant

MRI Safety Considerations

- B0
- dB/dt
- RF
- Acoustic

- Can we simplify?
- When faced with a patient exam, how do we get started?

ACR Guidance Document on MR Safe Practices: 2013 M. Kanal et. al, J. Magn. Reson. Imaging 2013;37:501–530.

MRI Safety: Assessment Strategy

- Know what device is in your patient
  - Manufacturer
  - Model
  - Serial number (if possible)
- Does your patient have an information card?
- Talk to patient, care provider, manufacturer 's rep
- Look in medical notes
- Use internet for:
  - Information from the manufacturer
  - Search device name + " MRI safety"
  - Safety web sites
- Assess risk and benefit with Radiologist

MRI Safety: Assessment Strategy (2)

- Assess your device against MRI safety considerations
  - B0 (attractive force, torque)
  - dB/dt (peripheral nerve stimulation)
  - RF (heating)
  - Acoustic (Loudness)
- Which are relevant to your situation?
- Talk to technologist and Radiologist to assure everyone is understanding and in agreement
- Review plan with Radiologist and Technologist
- Oversee exam, if needed, at the scanner

When imaging devices within a patient in MRI, which of the following is the best first step ?

17% 1. change the acquisition to normal mode to reduce dB/dt

13% 2. assess whether the device is effected by B0, dB/dt, RF

13% 3. conduct a search on the web to determine safety aspects of the device

43% 4. know exactly what is in your patient - investigate so that the exact device name, model, and serial number (if available) are known to you

13% 5. reduce the RF power (SAR)

Answer

- know exactly what is in your patient - investigate so that the exact device name, model, and serial number (if available) are known to you
- The above allows you to develop a plan

Reference: ACR Guidance Document on MR Safe Practices: 2013 M. Kanal et. al, J. Magn. Reson. Imaging 2013;37:501–530.

MRI Safety Case Review #1

- Physics contacted by MR technologist, patient reports feeling an electric shock during third series of an MRI exam
- Patient removed from 1.5 T MRI scanner
- Patient's vital signs monitored, unstable progression noted, and taken to emergency room
- Patient recovered, and returned for scanning at a later date

- Is this a B0, dB/dt, RF, or acoustic issue?

MRI Safety Case Review #1: What did we do?

- Physics reviewed imaging parameter settings with MR technologist
- Noted Patient issue developed during "T2w GRE"
- "T2 w GRE" used EPI readout*
- MRI Scanner evaluated by service personnel
- Series repeated using same parameters, swapped phase and frequency axes, and Normal mode
- Discussed with Radiologist and with patient (via phone, after the fact)

* Things that make us think, hmmmm

MRI Safety Case Review #1 : What did we find?

- MRI Scanner evaluated by service personnel: RF and electric isolation, humidity
  - RF and isolation - No problem found (NPF)
  - Humidity – high, out of spec due to construction in adjacent room
- "T2 w GRE"
  - Very Low SAR*
  - EPI readout*
- Series repeated using same parameters, swapped phase and frequency axes, and Normal mode
  - Same parameters: Freq. encoding along Y*
  - Peripheral nerve stimulation (PNS) occurred*
  - No PNS in other acquisitions*

MRI Safety Case Review #1 : What did we find?

- Discussed with Radiologist and with patient
- Results so far:
  - Very Low SAR (not RF)
  - EPI readout (gradient dB/dt possible)
  - Significant sensations replicated, but not a "shock"
- Patient was an Electrician and Electrical Engineer
  - Described: sensations start and stop with scan
  - Not electrostatic but patient's context is important!
- Determination: Peripheral Nerve Stimulation - PNS
- Subsequent scans "successful" using Normal mode with frequency encoding along X (revised protocol)

When faced with a patient complaint of a "shocking" sensation during gradient intensive scans such as DWI or DTI imaging, which of the following is the most likely cause?

10% 1. B0, the static magnetic field induced eddy currents

13% 2. gradient dB/dt inducing peripheral nerve stimulation

20% 3. RF energy causing heating in tissue and devices

30% 4. acoustic energy causing a pressure wave in the magnet bore

27% 5. phosphine discharge due to static discharge

Answer

- gradient dB/dt inducing peripheral nerve stimulation
- The DWI and DTI scans are low SAR and high dB/dt making PNS a likely event.

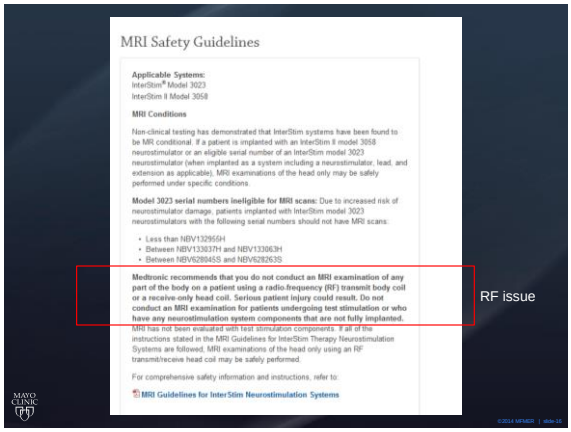
MRI Safety Case Review #2 A

- Physics contacted by technologist
- Patient called one day prior to brain MRI
- Patient reports having sacral nerve stimulator that has had wires removed
- Patient requests discussion with physicist prior to exam
  - Expressed multiple concerns (Safety, anxiety)*
  - MRI important for care plan*
- Is this a B0, dB/dt, RF, or acoustic issue?

InterStim® Therapy for Urinary Control is indicated for the treatment of urinary retention and the symptoms of overactive bladder

- Neuromodulation sends electrical stimulation to the sacral nerve
- The sacral nerve, in particular, influences pelvic floor behavior and is believed to modulate neural reflexes[1]

References: 1. Buback D. *AORN J.* 2001;73(1):176-190.
https://professional.medtronic.com/pt/uro/snm/edu/presentations-downloads/index.htm



MRI Safety Case Review #2A : What did we find?

- RF issue associated with wires
- Patient had wires explanted, generator still in place
- Generator unaffected by B0
- Generator unused, dB/dt effects of battery depletion or programming issues not relevant
- Plan discussed with Radiologist and patient:
  - Normal imaging mode
  - Patient awake
  - Physicist on site to assess protocol
- Scanning completed successfully

MRI Safety Case Review #2 B

- After ~ 6 weeks, physicist contacted by same patient
  - Two days prior to spine MRI
  - Similar concerns as before
- Same imaging plan put in place
  - (Normal mode, physicist present)
- Upon arrival, patient reports having entire sacral nerve stimulator removed (no documentation)*
- Presence or absence of generator did not affect imaging plan
  - Image artifacts indicated presence of generator
- Imaging completed successfully

Which of the following is a concern in MRI when wires are known to be implanted within your patient?

30% 1. B0, the static magnetic field causing attraction of ferromagnetic items

20% 2. gradient dB/dt causing PNS

13% 3. RF energy causing heating

17% 4. loud acoustic noise levels

20% 5. program changes in active devices

Answer

- RF energy causing heating

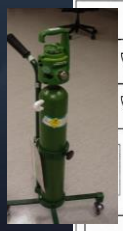
Wires present a real risk of heating in MRI, at high current density points where the end of the wire contacts the patient

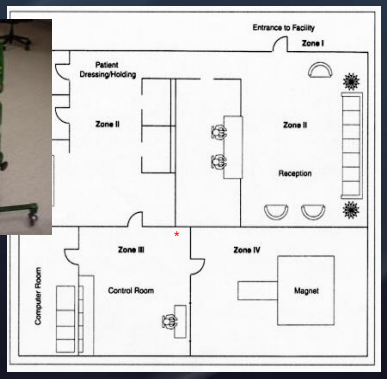
MRI Safety Case Review #3 (Tanked!)

- A green oxygen tank found in zone 3 of MRI area after weekend call at busy hospital

Is this a B0, dB/dt, RF, or acoustic issue?

Tank in zone 3 is too close to zone 4!





MRI Safety Case Review #3 : What did we find?

- Ferromagnetic tank was noted in zone 3, but not removed.
- Weekend patient had brought and exchanged tank at MRI as their oxygen tank was low
  - We found that this is common practice
  - Makes ferromagnetic tank control within hospital very difficult
- Elevated issue as process problem
- Communicated to MR technologists via e-mail and "town hall" meeting
- No injuries , identified a process gap and developed a staff education plan to address issue

Which of the following is a concern in MRI when oxygen tanks are found within zone 3?

20%	1. B0, the static magnetic field causing attraction of ferromagnetic items
17%	2. gradient dB/dt causing PNS
17%	3. RF energy causing heating
20%	4. loud acoustic noise levels
27%	5. program changes in active devices

Answer

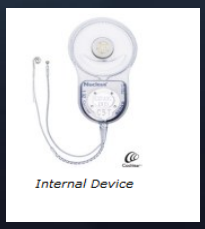
- B0, the static magnetic field causing attraction of ferromagnetic items

Deaths have occurred from ferromagnetic oxygen tanks entering zone 4. An area should be designated for storage of these devices outside of zone 3.

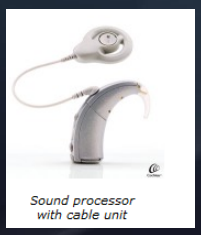
Reference: ACR Guidance Document on MR Safe Practices: 2013 M. Kanal et. al, J. Magn. Reson. Imaging 2013;37:501–530.

MRI Safety Case Review #4

- A patient with cochlear implant presents at MRI, with care plan to wrap the head to stabilize internal magnet



Internal Device



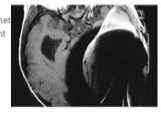
Sound processor with cable unit

Is this a B0, dB/dt, RF, or acoustic issue?

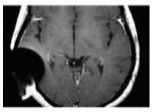
How does a cochlear implant affect MRI?

The internal implant contains a magnet, which holds the external sound processor coil in place. When placed in an MRI scanner, this magnet can cause a blur or 'artifact' over the medical image, which may hinder the Doctor's ability to make an accurate diagnosis of brain scans. As a quarter of all MRI scans are performed on the brain, having the flexibility to remove the internal magnet if required is an important consideration when choosing a cochlear implant.

A 1.5 Tesla MRI scan of a Nucleus® implant recipient with the magnet in place. The yellow line represents implant placement. The implant magnet creates a large blur on the image, hindering an accurate diagnosis.



A 1.5 Tesla MRI scan of a Nucleus implant recipient with magnet removed. The yellow line represents implant placement. The blur on the image is significantly reduced and causes minimal interference with the diagnosis[a]. (Images courtesy of Royal North Shore Radiology (Sydney, Australia)).



Reference: ww.Cochlear.com

MRI Safety Case Review #4

- A patient with cochlear implant presents at MRI
- Care plan and artifacts discussed with Radiologist
  - A cochlear implant patient's head was wrapped at the scanner prior to MRI - wrap maintains internal magnet position
  - External electronics removed
  - SAR limited to safe levels (1 W/kg) * RF issue
  - dB/dt managed using Normal mode
- Imaging completed successfully

Which of the following is a concern in MRI when devices contacting electronic circuitry are known to be implanted within your patient?

27% 1. B0, the static magnetic field causing attraction of ferromagnetic items

13% 2. gradient dB/dt causing PNS

20% 3. RF energy causing heating

17% 4. loud acoustic noise levels

23% 5. program changes in active devices

Answer

- RF energy causing heating

In this case B0 aspects were managed. Gradient induced programming changes are not known to be a problem for this device at this time.

MRI Safety Case Review #5 (Stapes)

- A patient presented with a stapes implant
- Specifics (patient verbal – titanium, had previous MRI)
- Literature and safety web sites show a few implants as unsafe
- One radiologists scanned successfully
- Two radiologists did not scan this patient
- Request for information from surgeon, was inconclusive
- What to do?

Is this a B0, dB/dt, RF, or acoustic issue?

Ferromagnetic Detection

- Ferromagnetic materials perturb the local magnetic field.
- Field perturbations follow the object as it moves.
- A high sensitivity magnetic gradiometer senses the environmental field gradient.
- Ferroguard is sensitive only to changing magnetic field gradients.
- A moving field perturbation triggers a visual/audible alarm.

Slide provided by Metrasens

MRI Safety Case Review #5 (Stapes)

- Ferromagnetic detection was positive, suggesting ferromagnetic metal in the head
- Exact device and history remains unknown
- Future scanning considerations are currently the discretion of Radiologist
- This remains an ongoing investigation …

Summary

- Know basic safety principles (B0, dB/dt, RF)
- Communication is key
  - How many of these situations began with call from technologist?
  - Realize patient anxiety may be beyond exam and related to their disease and ultimately affect their communications
  - Critical thinking and discussion with Radiologist is an expected part of our role on the care team

References

- ACR Guidance Document on MR Safe Practices: 2013 , JMRI 37:501–530 (2013)
- Vendor websites:
  - www.Medtronic.com
  - http://www.cochlear.com
  - https://www.uwhealth.org