Impact of Ferromagnetic Detection on MRI Safety

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Ferromagnetic projectile incidents
Small ferromagnetic objects that have caused projectile injuries
Occurrence Rate of Projectile Incidents

- FDA MDR data base focused on clinical and not operational incidents¹
- VA National Center for Patient Safety²
- Chaljub Survey³
- Pennsylvania Patient Safety Reporting System⁴
- Experts statements
VA NCPS Alert observed risk factors

- Invisible magnetic field extends in 3 dimensions
- Impossible to tell if the magnet is “on”
- Many objects contain ferromagnetic material that do not appear to (*sand bags, wooden chair*)
- Labeling on devices or in documentation is confusing
VA NCPS Alert observed risk factors (continued)

• Combination of complacency, work-arounds for speed and diffuse responsibility

• Equipment and consumables that are “safe” 99% of the time become “unsafe” near the MRI

• People and equipment that are “new” to the MRI suite (*more interventions and surgeries*)

• It is difficult and inaccurate to make “simple” lists of unsafe materials
Chaljub Survey

- 52% of the respondents had incidents involving airborne objects including: a defibrillator, wheelchair, respirator, ankle weights, IV pole, toolbox, sandbags containing metal pellets, vacuum cleaner, and mop buckets.

- Survey conclusion: “Our experience suggests that despite MR safety education, projectile cylinder accidents and other incidents are on the increase. More sick patients are undergoing scanning while on life support equipment, as evidenced by four of the five accidents occurring within the past 3 years at our institution.”
Pennsylvania Patient Safety Reporting System

88 incidents reported by ECRI\textsuperscript{7} from June 2004 to September 2005

- 33 screening error (e.g., wrong form used)
- 28 contraindications discovered during screening
- 12 contraindications discovered during or after MR exam
- 12 incompatible equipment in MR (i.e., potential projectiles)
- 3 potential burns (patient loops, redness)
Expert Quotations

• “Close calls in M.R. centers probably happen once a month.”
  Dr. John Gosbee - Director of patient safety information systems at the VA NCPS

• “It's my opinion that the majority of the incidents that have occurred ... have been as a result to what I referred to as pilot error or how the procedure was performed. I believe there is a strong ‘it couldn't happen here’ mentality. I don't believe people are quite aware of the potential problems that can occur, the substantial severity that could occur.”
  Dr. Emanuel Kanal - Director of MR Services and Professor, Department of Radiology at the University of Pittsburgh, a Chair of the ACR Blue Ribbon Panel on MR Safety

• “MRI Scanners’ Strong Magnets Are Cited in a Rash of Accidents”
  Front Page New York Times August 19, 2005
Why are Incidents increasing?

- VA NCPS Points\(^9\)
- Shared staff and facilities between modalities
- Magnet design – shorter bores, higher fields, active shielding of magnetic field
Comparison
Active shielded – unshielded

CONTROL OF MAGNETIC STRAY FIELD

Actively Shielded

Unshielded

Typical 1.5T magnet

Courtesy of Siemens Medical

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Typical active shielding
Local spatial gradient

Distance from the isocenter of the magnet

- $30,000 \text{ G}^*$
- $10,000 \text{ G}^*$
- $1,000 \text{ G}^*$
- $100 \text{ G}^*$
- $50 \text{ G}^*$
- $30 \text{ G}^*$
- $10 \text{ G}^*$
- $5 \text{ G}^*$
- $3 \text{ G}^*$
The Force, \( \mathbf{F} \) on an object depends on
- the magnetic field strength, \( B \)
- the magnetic field gradient, \( \frac{dB}{dz} \)
- the object’s susceptibility and shape

\[ F \propto B \frac{dB}{dz} \]

NO Translational force at isocenter

Distance from the isocenter of the magnet
Effect of active shielded magnets on Projectile risk

• No gentle, slowly increasing pull to provide feedback of ferromagnetic properties.

• Maximum force much greater than for the same field strength unshielded magnet.

• Distance / time to react to force can be shorter than reaction time

• A 3 T magnet with the same magnetic footprint as a 1.5 T has four times the force
What affects an object’s potential as a ferromagnetic threat?

- The **ferromagnetic mass**
- The **shape** of the object
- The ratio of **ferromagnetic mass** to **non-ferromagnetic mass** of the object
What affects ferromagnetic mass?

- How much ferromagnetic material (weight)
- The type of ferromagnetic material (permeability)
Why does the shape of an object effect its ferromagnetic threat potential?

• A pointed object of a given mass and composition will be attracted to the magnet more strongly than a round object of the same mass and composition.

• The long (pointed) dimension will line up with the bore of the magnet causing greater damage and risk of injury.
Conventional “airport type” Detector
Conventional Metal detector efficacy

- Alarms for *ALL* conductive objects
- *False Positives* for non-ferromagnetic objects (*aluminum, brass, titanium etc.*)
- *False Negatives* for non-conductive ferromagnetic projectiles (*ceramic magnets*)
- Alarm sensitivity *not* related to threat potential
- Transmitter source of potential interference
- Both ACR and ECRI recommend against use
Ferromagnetic detection efficacy

- Responds *only* to ferromagnetic threats
- Response proportional to threat potential
- Can detect ferromagnetic material buried inside of any other material
- No electromagnetic transmitter to interfere with MRI
- Greatly reduced false positives and negatives
Two detection applications

• Prevent ferrous material from accidentally entering the magnet room. Reduce the risk of an ordinary object, thought to be OK, from suddenly becoming an unintended missile

• Reduce the risk for personnel bringing undiscovered objects that can become dangerously magnetically attracted
SAFESCAN Ferromagnetic MR Target Scanner™

- Passive device
- Handheld
- Generates local magnetic field (100 gauss @ 1 inch)

MEDNOVUS • SAFESCAN® Imaging Systems
SAFESCAN ferromagnetic screening instruments are developed by Mednovus, Inc. in alliance with Quantum Magnetics (a GE Infrastructure Security company) and the National Research Council, Canada
SAFESCAN® Portal 9000-C

- Passive device
- Separate portal and control console
- Generates local magnetic field (50 gauss inside portal)

MEDNOVUS • SAFESCAN® Imaging Systems

SAFESCAN ferromagnetic screening instruments are developed by Mednovus, Inc. in alliance with Quantum Magnetics (a GE Infrastructure Security company) and the National Research Council, Canada.
QinetiQ Ferroguard® MRI System

- Passive system
- Boxes mount on opposite walls
- Generates no local magnetic field
Ferromagnetic Detection System

- Passive Device
- *NO* magnetic field generated
- **Green GO**, Amber **STOP** with Audio
- High Output Audio Alarm for Unattended periods
- Activated by motion sensor

FerrAlert™ Entry

Development Inc.
FERRALERT™ ENTRY
Ferromagnetic Detection System
DISPLAY CONSOLE
Proprietary Ferromagnetic Sensors

Sensor Array Portal

Signal Processor / Alarm Generator w/ Visual and Audio Alarms

Operator’s Display Console

Sensor Array Preamplifier / Preprocessor w/ Visual and Audio Alarms
Passive Device

NO magnetic field generated

Green GO, Amber STOP w/Audio Alarm

Sensitive to *very small* objects

Activated by motion sensor
Ferromagnetic Detection – A part of the MR safety puzzle

- Safety Procedures
- Training
- Facility Layout
- Attitude
- Imaging Room Ferromagnetic Control
- Ferromagnetic Prescreening

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Conclusion

- Ferromagnetic risks are increasing
- Ferromagnetic detection systems when used to supplement a comprehensive screening procedure have the potential of significantly reducing the risk of a projectile incident.
- “These detectors at least have the potential to reduce the risk of patient injury and damage to equipment, as well as to reduce MR downtime that could occur as a result of an incident”

ECRI Guidance Article 2005\textsuperscript{10}
References

1. Medical Device Reporting (MDR) database. (The reports are accessible through FDA's Web site [http://www.accessdata.fda.gov/scripts/cdrh/cfdocs/cfmdr/search.CFM]
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