Safety in the MR Environment: MR Safety Screening Practices

ABSTRACT

Electromagnetic and ferromagnetic materials in close proximity to a magnetic resonance imaging (MRI) scanner can be a hazardous safety risk to any individual near the scanner. To avoid injury from interference and attraction effects, individuals are screened before entering the MRI scan room. The magnetic resonance (MR) screening process typically consists of interviews between MR personnel and patients or other non-MR personnel needing access to the MRI scanner and completion of a questionnaire (MR screening form). The MR screening form contains questions to ask individuals needing access to the MRI scan room in order to identify potential contraindicated objects on or in their bodies, such as an implanted cardiac pacemaker. The magnetic field of the MRI scanner could affect ferromagnetic objects implanted in an individual in such a way as to cause harm. In 2008, the Pennsylvania Patient Safety Authority received approximately 150 reports describing events in which the MR clinical screening process was inadequate and, in some cases, erroneously permitted patients with implanted pacemakers and other ferromagnetic objects into the MRI scanner room. Rigorous MR screening practices will help reduce hazards from contraindicated implants and ferromagnetic objects in close proximity to the MRI scanner. (Pa Patient Saf Advis 2009 Mar;6[1]:20-6.)

Effective screening of patients and nonmagnetic resonance personnel before entering the magnetic resonance imaging (MRI) scanner is an extremely important process in ensuring the safety of individuals in the magnetic resonance (MR) environment. The MR screening process reduces the likelihood of an adverse event while the patient is inside the bore of the MRI system.

In 2008, 148 reports were submitted to the Pennsylvania Patient Safety Authority identifying a variety of problems related to inadequate screening practices of individuals for metal exposure or orders written for MRI scans of patients with MR contraindications (e.g., permanent pacemakers). Most of the reports involved patients with implanted devices such as pacemakers, cardiac defibrillators, and aneurysm clips entering the MRI scanner room or MR personnel realizing just before patients entered the MRI scanner room that the patients had implanted devices. Other reports identified MR screening forms with incorrectly or inadequately answered questions. For inpatient MRI scans, many reports described miscommunication between the referring department (e.g., medical/surgical) and the radiology department about an implant in the patient. For perspective, the following are examples of the narratives of MR screening-related reports submitted to the Authority:

> *An MRI scan of the patient's right knee was ordered; the patient had a pacemaker.*
>
> *Patient was ordered an MRI of the brain. The patient was put on the schedule for 10 a.m. The nurse on the floor called down and said he had a pacemaker. The nurse filled out the [screening] form incorrectly. The physician ordered an MRI on a patient with a pacemaker.*
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> *A patient required an MRI of the head. A technician screened the patient and asked if there was anything in [patient's] sweatpants pockets, to which the patient replied "no." When the [MRI] magnet was started, a knife was pulled out of the patient's pocket by the magnet. It stabbed [the patient] in the [arm]. The injury required staples.*
>
> *A patient developed pain/tingling, during an MRI scan, where a plate and screw were located [implanted]. The patient had been prescreened.*
>
> *A patient was cleared for metal through family interview per ordering resident. The MRI study was started and a metal artifact was identified. The study was immediately canceled. A CT [computed tomography] scan of the head was done instead of the MRI. [The physician was] notified.*
>
> *A patient had a tissue expander noted on [screening form] checklist, but MRI was started. Upon review of initial images, a metal artifact was noticed and the scan was stopped.*
>
> *Patient [was] ordered [an] MRI brain [scan]. The floor [staff] called to verify that patient [was] screened and was told the patient was screened. [The] patient arrived for test, and [staff] found that patient has a pacemaker; a contraindication for the MRI. Patient did not receive MRI.*
>
> *Patient was having an MRI of the left shoulder. [The patient] was wearing a long-sleeve sweater, and during the course of the scan complained of a warm feeling on the right arm. Patient's arm was repositioned away from scanner and a sponge was placed. After the scan the patient showed the right arm [to a registered nurse (RN)], which had a 2-inch by 1-inch red patch with a slightly blistered area in the center. The CT RN looked at the arm and put ice on it. On inspection of the sweater, it [was noted that] it had a makeup of 18% metallic thread.*

Sixty-eight reports (approximately 46%), by far the most frequently reported MR-screening-related event related to implanted clinical devices with ferromagnetic content received by the Authority, described patients with implanted cardiac devices getting past the safeguard of the screening process and entering the

MRI scan room or being stopped from entering the scan room by the final screening process. The next most frequently reported events included five reports of patients with aneurysm clips and four reports of patients with imbedded bullets or BB pellets entering the scan room or being stopped by the screening process before entering the scan room. Data could not be gleaned from 49 of the 148 total reports (approximately 33%) because the reports only indicated that patients were improperly screened. For a comprehensive list of types and frequency of ferromagnetic items reported to the Authority, see the Table.

In the majority of reports, MRI scans were ordered for patients with some type of ferromagnetic or potentially ferromagnetic medical implant. MRI scans are typically contraindicated for patients with ferromagnetic implants because of the potential for injury from forces exerted on the implant by the magnetic field of the MRI scanner and/or magnetic field interferences with the electromechanical operation of the active implant. Another reason for the contraindication is due to radio-frequency (RF) electromagnetic energy used during the scan process inducing electrical currents in electrically conducting implants. The electrically induced currents may result in heating of the implant. Since MRI scans were ordered for those patients, one apparent process breakdown may have been staff not conducting or inadequately conducting patient histories or inadequately reviewing medical records to determine patients' metal exposure histories (e.g., implants). Another breakdown may be in miscommunications between clinicians of patients' histories.

In addition to the reports of implants, one reported event of interest that may not be typically considered by clinical or MR technical staff involved a patient wearing a sweater containing 18% metallic thread. According to the report, the patient experienced erythematous skin with blistering in the center of the mark. While it would be impractical to inspect the clothing of all patients before performing an MRI scan, it may be prudent to perform a quick visual check of patients' clothing for anything out of the ordinary and/or have patients with suspect garments change into gowns or scrubs for their MRI exam.

It should be noted that 74 of 148 reports demonstrated that patients with MR contraindications were identified during MR screening processes and stopped from entering the MRI scan room, potentially preventing injuries.

The information in this article is not comprehensive but is presented as a guide for MR imaging facilities and departments in developing effective MR screening practices. This article will discuss the boundaries and restrictions of the MR environment as they relate to the safety of individuals entering that environment. The article will also discuss the need for and the process of screening individuals for metal exposure, including the clinical implantation of objects or devices that may be ferromagnetic, before entering the MR environment, and the hazards associated with inadequate screening processes. The article will also provide guidance in developing effective MR screening practices.

Table. List of Ferromagnetic Items and Frequency of Reports

FERROMAGNETIC ITEM	NUMBER OF REPORTS
Pacemaker/implanted cardiac device/ heart valve	68*
Aneurysm clip	5
Bullet/BB pellet/gunshot wound	4
Hearing aid/ear implant	3
Orbit (eye) metal	3
Abdominal aortic aneurysm stent	2
Acupuncture needle	1
Inferior vena cava filter	1
"House-arrest" ankle bracelet	1
Knife	1
Metal artifact	1
Metal buckle	1
Metal plate/screw	1
Pain pump (implanted)	1
Sweater (with 18% metal fabric)	1
Tattoo	1
Tissue expander	1
Face mask (with metal nose piece)	1*
Unknown implant	1
Total	**97****

* These two items were recorded on the same Authority report.
** This total number of reports excludes the 49 reports received with descriptions of only improper screening and 2 reports concerning pregnant patients scheduled for MRI scans (148 - 49 - 2 = 97).

MRI Technology

MRI is a noninvasive imaging technology used to image anatomy in multiple planes or slices.[1] An MRI scanner creates cross-sectional images using electromagnetic fields, not ionizing radiation (x-rays) such as in CT scans. MRI scans can image structures that contain air and are not hindered by bone. The MRI scan is conducted with the anatomic structure of interest placed into the center of the bore (i.e., the opening) of the MRI system. The MRI system exposes the subject to electromagnetic fields, then constructs the images by interpreting tissue reactions from the area of interest to the applied magnetic and RF fields.[1] The strength of the static magnetic field of clinical MRI systems is typically between 0.064 and 3 tesla (T), which is measured at the center of the bore of the magnet. However, some MRI systems used for research can have field strengths as high as 9.4 T (Earth's magnetic field varies depending on the proximity to the magnetic poles but averages approximately 0.00005 T, or 0.5 gauss (G) in North America and continental Europe).

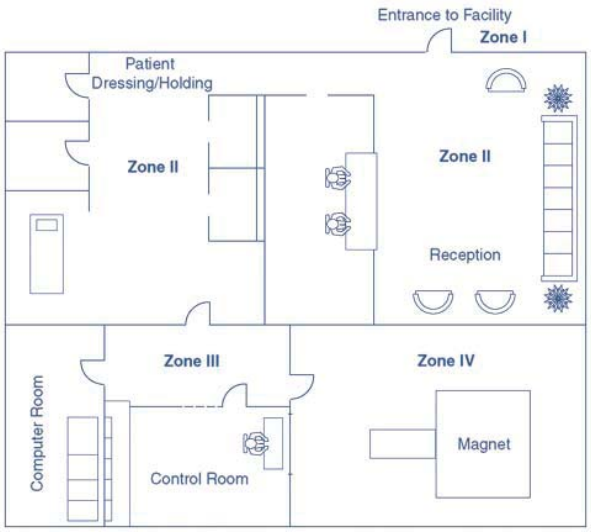
Due to the strong magnetic field of the MRI scanner, ferromagnetic objects external to the body can be pulled into the magnet bore of the scanner, known as the projectile effect. Additionally, the magnetic field can also affect implanted ferromagnetic objects (e.g., permanent pacemaker), applying attractive force even though the object is in the subject's body. The magnetic field may exert forces on an implanted object, potentially causing the object to move in the body, which could result in serious harm to an individual. (A more detailed discussion of the projectile effect will be discussed in an article in an upcoming issue of the *Pennsylvania Patient Safety Advisory*.) MRI systems also incorporate RF electromagnetic fields as part of the scanning process. The RF electromagnetic energy can potentially generate heat in conductive materials in or on the body. (For more information on the hazards during MRI scans, see the section "MR Hazards Associated with Ferromagnetic Implants.")

MR Suite Safety Boundaries

The American College of Radiology (ACR), through the formation of a blue ribbon panel on MR safety, developed the "ACR Guidance Document for Safe MR Practices." The latest revision of the ACR document was published in 2007. While the 2007 ACR MR guidance document is not a regulatory standard for MR safety,[3] at the time of this publication, it is widely used as an industry metric. Among the performance criteria identified by the ACR panel is the designation of a four-zone model of integrated screening and access controls in the MR suite. Each zone in the model represents a different safety level of static magnetic field exposure for the general public. The ACR panel defined the four zones as follows (also see Figure 1):[2]

- Zone 1:
  - All of the areas, outside of the MR environment, that are freely accessible to the general public (e.g., corridors and entrances just outside the MR environment).
- Zone 2:
  - The area between the public accessible zone 1 and the more strictly controlled MR environments (zones 3 and 4). Zone 2 areas typically include reception, waiting, and patient dressing and holding rooms. The general public is generally not free to move throughout zone 2 without the supervision of MR personnel.
- Zone 3:
  - The area in which free access by unscreened non-MR personnel or ferromagnetic objects or equipment is restricted. Serious injury or death could result in zone 3 due to interactions between the individuals, objects, or equipment and the MR environment's static and magnetic fields. Supervision is under the control of the appropriate MR personnel. Access to zone 3 should be physically restricted from the general public through the use of a locking system (e.g., key lock, electronic access control).
- Zone 4:
  - The area containing the MRI scanner (magnet) and is associated with the strongest magnetic fields. Zone 4 should be clearly marked as being potentially hazardous due to the strong magnetic fields. Zone 4 should also be marked with a red light and lighted sign stating "The Magnet Is On."

Figure 1. Model MR Facility Zone Configuration



Sample floor plan illustrating various safety level zones in a typical magnetic resonance suite.

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Figure 2 demonstrate examples of MR zone-level signage. Through colors and text, the signs indicate the level of hazard within each zone.

The boundary in the MR system at which the static magnetic field has diminished sufficiently to pose no physical threat to the general public, but more specifically for individuals with implanted pacemakers, is known as the 5 G line. The 5 G line, which can extend in three dimensions around the magnet bore, defines the boundary of the area at which the magnetic field strength of the MRI system is above or below 5 G (see Figure 3). The strength of the magnetic field increases exponentially approaching the magnet bore. For example, the magnetic field strength at the center of a 1.5 T magnetic bore would be 15,000 G (1 T = 10,000 G). Within a few feet of the magnet bore, some objects could be pulled into the magnet* or may not operate properly.[1] The line may not be limited to the MRI scan room and may vertically extend to the floors directly above and below the MRI system.[1] The 5 G line from the MRI system will

* The topic of ferromagnetic objects and the compatibility of medical equipment in the magnetic resonance imaging environment will be discussed in an article in an upcoming issue of the *Pennsylvania Patient Safety Advisory*.

Figure 2. Examples of MR Zone-Level Signage

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vary depending on the type of MRI system, the field strength of the magnet, and the presence, amount, and configuration of magnetic shielding.[1]

MR Environment Site Access and Restrictions

According to the ACR guidance document, individuals in the MR environment are categorized as either MR personnel or non-MR personnel. MR personnel are individuals working in, at least, zone 3 of the MR environment who have successfully completed MR safety lectures or presentations approved by the MR medical director. MR safety training should be conducted annually and should include documentation upon successful completion of the program by each individual. According to the ACR guidance document, individuals that have not successfully completed the MR safety training within the previous 12 months shall be referred to as non-MR personnel.

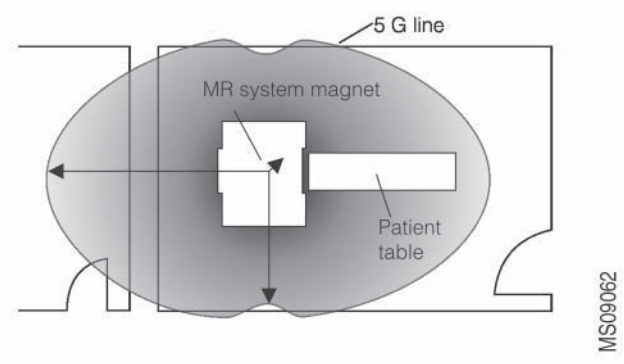
MR personnel can further be broken down into level 1 and level 2 subcategories. Level 1 MR personnel are individuals who have passed minimal MR safety training education to ensure their own safety when working in zone 3 of the MR environment. Level 2 MR personnel undergo more extensive MR safety education in broader aspects of MR safety. For example, level 2 personnel will learn issues related to the potential for thermal loading or burns and direct neuromuscular excitation from rapidly changing gradients.

All non-MR personnel, patients, and visitors must undergo a MR safety screening process before being permitted to enter zone 3 of the MR environment. The safety screening should be performed by level 2 MR personnel only.

MR Safety Screening Process

The MR screening process is typically a multilevel process consisting of the following: a preliminary question-and-answer interview via a telephone call when the appointment is scheduled; an MR screening form filled out by the patient, or patient representative in the event the patient is nonresponsive, impaired, or unable to complete the form (e.g., a child) in the MR reception area at the time of the appointment; and a further screening by level 2 MR personnel before the patient enters the MRI scanner room. The form contains questions to determine the medical history and metal exposure history of the patient in relation to the MRI scan. If the patient's history cannot be obtained, and if the MRI scan cannot be rescheduled until such information can be obtained, then the patient should be physically examined by level 2 MR personnel for signs, scars, or other marks that might be indicative of an implant. If a question exists regarding an implant or potential implant, the MR safety director should decide whether to proceed with the MRI scan. The

Figure 3. Illustration of 5 G Line in MRI Scanner Room



Simplified illustration of an MRI scanner room showing the location of the 5 G line for a typical MRI system. While the illustration is two dimensional, it should be noted that the area of the 5 G line extends in three dimensions around the magnet bore.

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following are examples of the types of questions that may appear on a typical MR screening form:

- Have you ever had a prior diagnostic imaging study or examination (e.g., MRI, CT, x-ray)? ☐ Yes ☐ No
- Have you ever experienced any problem related to a previous MR procedure? ☐ Yes ☐ No
- Have you ever been injured by a metallic object or foreign body (e.g., BB, bullet, shrapnel)? ☐ Yes ☐ No

Facilities can refer to the sample MR screening form available from the Pennsylvania Patient Safety Authority Web site at http://www.patientsafetyauthority.org as a guide in developing a comprehensive MR screening form. All questions on the screening form should be answered completely to avoid confusion or misunderstanding as to the metal exposure history of the patient. The completed screening form should be reviewed with the patient (or patient's representative) by two separate MR personnel to verify completeness and accuracy.

Ferromagnetic detectors (capable of distinguishing between ferromagnetic and nonferromagnetic material), designed specifically for pre-MR screening, may also be used as an adjunct to the MR screening process but should *not* be used in place of the screening process. Ferromagnetic detectors should only be used for detecting ferromagnetic objects external to patients before they can be brought into zone 4. At present, ferromagnetic detectors have not been approved for detecting ferromagnetic objects internal to the patient. Ferromagnetic detectors can be handheld devices, free-standing doorway portals, or pillar systems. Conventional metal detectors (unable to distinguish between ferromagnetic and nonferromagnetic materials) should not be used for several reasons, including the following:

1. Ferromagnetic materials contained in nonferromagnetic metal enclosures may not trigger conventional detectors' alarms.
2. Metals such as aluminum and titanium, which are considered MR-safe, would trigger conventional detectors' alarms.
3. Ferromagnetic objects on the patient could be missed by conventional detectors when the patient is in close proximity to an MR-safe metal such as that found on an MR-safe stretcher.

The ACR guidance document and ECRI Institute recommend against using conventional metal detectors. The ACR guidance document does recommend the use of ferromagnetic-only detectors specifically designed for pre-MR screening.

Before entering zone 3, any individual undergoing an MRI scan must remove all readily removable metallic personal items and devices on or in his or her body (e.g., watches, jewelry, pagers, cell phones, body piercings [if removable], contraceptive diaphragms, metallic drug delivery [transdermal] patches).[2] All metallic items that individuals cannot (or will not) remove before the MR scan must be positively identified for both ferromagnetic and thermal risks before the MR scan. (For more information on patients undergoing MR scans while wearing transdermal drug delivery patches, see the September 2006 Pennsylvania Patient Safety Advisory article "Foiled Again! Risk from Transdermal Patches in MRI Procedures" [http://patientsafetyauthority.org/ADVISORIES/AdvisoryLibrary/2006/Sep3(3)/Pages/18.aspx].) All patients, visitors, and non-MR personnel with a history of potential internal ferromagnetic foreign objects must undergo further investigation before being permitted entrance to zone 3.[2] Acceptable methods of screening for internal ferromagnetic objects include patient history, plain x-ray films, prior CT or MR scans of the anatomic area in question (radiography can only identify radiopaque material and cannot characterize its ferromagnetic or nonferromagnetic properties), or access to written documentation as to the type of implant or foreign object that might be present.[2] Any patients with a history of orbit trauma by a potential ferromagnetic foreign body that required medical attention (or occupational exposure to metal-working) should have their orbits cleared by plain x-ray films.[2] After identifying the presence and type of implant or foreign object in the patient, an evaluation should be undertaken to determine the relative MR safety of the implant or object as it pertains to the particular patient, exam, MRI scanner, and scan parameters. This evaluation should be conducted by level 2 MR personnel, a MR radiologist, or the MR medical director.

Objects That May Be Present on or in the Body

Many ferromagnetic and nonferromagnetic objects could be present on or in the body. Some types of implants and other objects on or in the patient's body that may be encountered in the MR environment include the following (the list is not comprehensive):[4]

- Aneurysm clips

- Biopsy needles
- Breast tissue expanders and implants
- Bullets
- Cardiac pacemakers and implantable cardioverter defibrillators
- Cochlear implants
- Coils, stents, and filters
- Heart valve prostheses
- Orthopedic implants
- Tattoos, permanent cosmetics, and eye makeup
- Transdermal patches

In his book *Pocket Guide to MR Procedures and Metallic Objects: Update 2001*, Frank G. Shellock, PhD, lists more than 900 objects by specific brand, model, and in some cases size that have been evaluated for safety in the MR environment.[4] The list contains objects such as those listed above, the highest magnetic field strength of the MRI system used for testing, and the status of the object when subjected to that magnetic field. The status designations include safe, conditional, and unsafe with substatus designations for conditional and unsafe. The pocket guide is designed as a reference source for MR personnel to ascertain the safety of exposing patients or non-MR personnel with implants, devices, or materials to the MR environment.[4,*]

MR Hazards Associated with Ferromagnetic Implants

Within the MRI system's static magnetic field, ferromagnetic and other magnetic materials can be influenced by rotational (torque) and translational forces. These forces could be dangerous for strongly ferromagnetic implants (e.g., aneurysm clips) by moving or dislodging the implant from its location in the patient. This movement could result in damage to the tissues surrounding the implant, potentially leading to ruptured blood vessels[1] and death. The effect of the rotational force is to align the ferromagnetic, or magnetic, object parallel to the static magnetic field, which results in rotational movement. The amount of the rotational force on an object depends on the object's size, shape, and magnetic properties and on the magnitude of the static magnetic field of the MRI system.[1] The rotational force is greatest at the geometric center of the magnet bore, where the magnetic field strength is greatest. Translational force is a linear force (linear movement), which can draw an object into the magnet's bore. The amount of translational force on an object depends on the object's size, shape, and composition and the static magnetic and spatial gradient fields at the location of the object.[1]

The amount of these forces may change (e.g., potentially increase) with movement of the patient within the magnetic field of the MRI scanner. The rate of change of the forces depends on the rate of motion of patient movement within the field; the greater the patient movement through the magnetic field, the greater the forces acting of the implanted device. Therefore, when removing the patient from the magnet's bore, immobilization of the device and a deliberately slow, cautious, rate of removing the patient may reduce the amount of the forces on the implant.[2]

RF Heating Effect

RF electromagnetic energy, such as that produced during use of an RF coil during MRI scans, can induce electrical currents in electrically conductive materials (e.g., pacemaker lead wires) whether in or on the patient. These induced currents can heat the conductive material, potentially leading to thermal injury where the material is in contact with the patient. The likelihood of thermal injury increases with increasing RF energy and/or with higher-field-strength MRI systems. The heating effect also depends on the distance between the RF coil and the conductive material—for example, the closer the distance is between the RF coil and the conductive material, the greater the likelihood of the patient experiencing thermal injury. Additionally, thermal injury to the patient can occur if the patient is in direct contact with the wall of the magnet bore or the RF coil. Positioning the patient within the magnet bore is such a way as to avoid contact when possible, or positioning conductive leads and cables to avoid contact with the bore can greatly reduce the risk of thermal injury.

MR Image Artifact

Extraneous image information that distorts the accurate depiction of the scanned anatomy is called image artifact. This distortion in image quality affects the diagnostic value of the image. Artifacts typically appear in images as distortions, unwanted signals or patterns, or areas of signal loss, known as signal voids.[1] For accurate image reconstruction, the static magnetic field of the MRI system must be uniform (homogeneity). Disruption in the uniformity of the MRI system's static magnetic field can occur when ferromagnetic materials, and some nonferromagnetic materials—typically less severe—are present near the scanned anatomy.[1] This disruption occurs because ferromagnetic materials will distort the magnetic field of the MRI system.

Distortion can also result from RF energy pulses present in the scanned region, inducing electrical eddy currents in electrically conductive materials, similar to the currents induced in the RF heating phenomenon. Signal voids can be seen in the MR image as a blacked-out portion of the scanned anatomy in the area of the implant. A signal void could be misinterpreted or misdiagnosed as pathologies if the radiologist is unaware of the implant or other conductive material.[1] Signal

* A recent reference publication on MRI safety, implants, and devices is available from Shellock titled *Reference Manual for Magnetic Resonance Safety, Implants, and Devices: 2009 Edition.* However, this reference was not reviewed for this article.

voids are typically a concern with high-field MRI systems (e.g., 3 T). The level of artifact observed on an MR image depends on the magnetic field strength of the MRI system and on the shape, orientation, and position of the material in the body.

Conclusions

Ferromagnetic materials, especially implants, in the presence of the magnetic field generated by an MRI scanner can pose a serious risk to the patient undergoing the MRI procedure. The magnetic field could potentially cause the implant to move or dislodge from its location in the patient, which may result in ruptured blood vessels. Conducting a proper and thorough MR screen for potential ferromagnetic materials of each patient or other individuals entering the MRI scan room will greatly reduce or eliminate the likelihood of adverse events in the MR environment.

As part of a risk reduction strategy to reduce or eliminate adverse events related to MR safety screening processes consider the following:

- Share this article with all staff involved with MR safety.
- Review your facility's MR-related Incident and Serious Event reports to address potential shortcomings in MR screening processes that could affect the safety of individuals entering the MR environment.
- Talk with appropriate staff to identify barriers to effective screening practices.
- Compare your facility's MR screening form against the sample MR procedure screening form, available from the Pennsylvania Patient Safety Authority Web site at http://www.patientsafetyauthority.org, to identify content that current forms may omit.

Notes

1. ECRI Institute. The safe use of equipment in the magnetic resonance environment [guidance article]. *Health Devices* 2001 Dec;30(12):421-44.
2. Kanal E, Barkovich A, Bell C, et al. ACR guidance document for safe MR practices: 2007. *Am J Roentgenol* 2007 Jun;188(6):1447-74.
3. Gilk T. Ferromagnetically naked. Patient Saf Qual Healthc [online]. 2008 Jul-Aug [cited 2009 Jan 6]. Available from Internet: http://www.psqh.com/julaug08/mri-safety.html.
4. Shellock F. *Pocket guide to MR procedures and metallic object: update 2001*. Philadelphia: Lippincott Williams & Wilkins; 2001.

Self-Assessment Questions

The following questions about this article may be useful for internal education and assessment. You may use the following examples or come up with your own.

1. The magnetic resonance imaging (MRI) system static magnetic forces' influence on ferromagnetic objects that are implanted or imbedded in individuals includes all of the following EXCEPT:
   a. Radio-frequency heating
   a. Rotational movement
   c. Translational movement
2. Which of the following mechanisms causes heating of conductive objects in or on an individual in the MRI scan room?
   a. Static magnetic field
   b. Radio-frequency electromagnetic field
   c. Gradient magnetic field
3. The magnetic resonance (MR) screening process is a multilevel process and typically consists of all of the following EXCEPT:
   a. Preappointment phone interview
   b. Interview by level 2 personnel before the patient enters the MRI scan room
   c. MR screening form completed by the patient or patient representative
   d. Interview by level 1 MR personnel while the patient is positioned on the MRI scan table by level 2 MR personnel
4. Conventional metal detectors should not be used to scan objects before entering the MRI scan room because of which of the following?
   a. Ferromagnetic materials contained within nonferromagnetic metal enclosures may not trigger conventional detectors' alarms.
   b. Metals such as aluminum and titanium (considered MR-safe) would trigger conventional detectors' alarms.
   c. Ferromagnetic objects on the patient could be missed by conventional detectors when the patient is in close proximity to a MR-safe metal such as a MR-safe stretcher.
   d. All of the above.
5. An inpatient is scheduled for an MRI scan of his brain. The patient arrives in the MRI department. During the MRI screening process, it is discovered that the patient has an implanted pacemaker.
   The following is a list of statements about the appropriateness of the MRI scan for this patient. Select the statement that promotes the best outcome for the patient.
   a. The MRI scan is of the patient's brain, so there is no risk to the patient from, or damage to, the pacemaker.
   b. The pacemaker can be deactivated or reprogrammed without harm to the patient during the MRI scan.
   c. MRI scans are contraindicated for patients' with implanted pacemakers.
   d. If the pacemaker's programming is altered by the magnetic field, the pacemaker will revert back to original programming once the patient is out of proximity with the field.

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THE PENNSYLVANIA PATIENT SAFETY AUTHORITY AND ITS CONTRACTORS

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The Pennsylvania Patient Safety Authority is an independent state agency created by Act 13 of 2002, the Medical Care Availability and Reduction of Error ("Mcare") Act. Consistent with Act 13, ECRI Institute, as contractor for the Authority, is issuing this publication to advise medical facilities of immediate changes that can be instituted to reduce Serious Events and Incidents. For more information about the Pennsylvania Patient Safety Authority, see the Authority's Web site at http://www.patientsafetyauthority.org.

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ISMP

The Institute for Safe Medication Practices (ISMP) is an independent, nonprofit organization dedicated solely to medication error prevention and safe medication use. ISMP provides recommendations for the safe use of medications to the healthcare community including healthcare professionals, government agencies, accrediting organizations, and consumers. ISMP's efforts are built on a nonpunitive approach and systems-based solutions.