Radiologic Technologist Best Practices for MR Safety

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In January 2018, Rajesh Maruti Maru carried an oxygen tank into a magnetic resonance (MR) imaging suite to accompany a relative having an examination in BYL Nair Charitable Hospital in Mumbai. Maru and the oxygen tank were pulled into the MR opening by the powerful magnet inside the equipment. He died within 2 minutes when the tank leaked and emitted a sudden and excessive amount of oxygen, which caused asphyxiation.[1] Investigations into the incident uncovered lapses in safety practices, including a metal detector that was not functional at the time of the man's death and existing piped oxygen in the examination room.[2]

The Mumbai event occurred 17 years after the most well-known MR adverse event in the United States. In 2001, 6-year-old Michael Colombini was killed when an MR-unsafe oxygen tank was brought into the MR examination room while the boy was having an MR examination at Westchester Medical Center in New York. The sentinel event catapulted development of the first national guidelines for MR safety.[3,4]

MR imaging technology was introduced in the 1970s, and MR imaging has been an increasingly important clinical tool since the 1980s.[5] MR imaging assists physicians in diagnosing diseases, injuries, and conditions. The images produced by MR technologists are created by exposing a patient to a strong magnetic field and applying radiofrequency (RF) energies to produce a signal that creates an image from reconstructed data.[6]

National and international standards and guidelines were developed following Michael Colombini's death to improve safety of all patients, visitors, and workers who enter the MR zones (see **Box 1**).[8-10] The American College of Radiology (ACR) released guidance on MR safety in 2002 and updated the guidance a third time in 2013.[8] In the same year, The Joint Commission updated its sentinel alert on MR safety to correlate with the 2013 ACR safety standards.[11] Although safety guidelines and standards lead to improved safety and more consistent practice, no standardized regulations exist with specific requirements for MR safety.[11] MR technologists must understand and apply physics principles and safety standards to ensure a culture of safety in their MR facilities.[5]

Mechanisms of MR Adverse Events

Several risk factors are associated with MR imaging. The first hazard is the powerful magnet housed in most MR equipment; the equipment's static magnetic field remains on continuously and can attract magnetically sensitive (ferromagnetic) objects. However, some systems use resistive magnets that can be turned off. Aside from the static magnetic field, MR equipment has a time-varying gradient and RF magnetic fields. The gradient field provides spatial encoding of the signal, which makes the loud knocking sounds patients hear. Time-varying gradient fields can intensify rapidly and cause electrically induced currents that can cause peripheral nerve stimulation in patients or

Box 1

MR Safety Standards

In the United States, MR imaging facilities must follow strict quality and safety standards for MR equipment, set by the FDA. The FDA places limits on patient safety factors in MR, such as maximum magnetic field strength and noise, as well as the maximum radiofrequency power reaching patients. The FDA approves and regulates MR imaging equipment and handles incident tracking.[5]

Further, the following organizations accredit MR facilities and publish MR quality and safety standards that include minimum staff qualifications, equipment standards, equipment safety, recordkeeping, patient privacy, and patient and family or visitor safety[7]:

- American College of Radiology (ACR)
- Intersocietal Accreditation Commission
- RadSite
- The Joint Commission

Accreditation from 1 of these organizations is required for Medicare reimbursement.[5] It is important for facility leaders and MR technologists to be familiar with the standards required by their accreditors, as well as the requirements of state and federal law. Documents such as the ACR MR Safety Guidelines promote safety and serve as de facto industry standards but are not legally enforced.[8] For this white paper, the ASRT chose to use the ACR recommendations as an example because they are the oldest published MR safety standards. Other organizations provide different guidelines, and each MR facility should ensure compliance with the standards of their own accrediting body.

affect electronic and metallic devices.[5,12,13] The RF field enables technologists to acquire images by applying energy to induce signals to receiver coils, or to antennas; this energy can cause tissues to heat.[5,13]

Adverse events from the gadolinium-based contrast media used in MR scanning can be minor or life-threatening. The risks and benefits of contrast administration have been studied extensively and safety recommendations established for use of the agents.[14] It is within the scope of the MR technologist's practice to determine contrast amount and type based on established protocols and to administer the agent intravenously as prescribed by a licensed practitioner.[14,15] In the 2017 American Society of Radiologic Technologists (ASRT) MR Safety Survey, 74.5% of respondents said a radiologist is responsible for deciding whether to use contrast, and 54.4% said a radiologist is always on site when patients receive contrast injections. Contrast media considerations are within the MR technologist's practice standards but are not within the scope of these best practice recommendations.

MR Utilization

Because of continued technological advancements, and because MR imaging produces detailed images without using ionizing radiation, the use of MR examinations has expanded in purpose, scope, and volume.[5] The number of scans performed in the United States exploded from 7.7 million in 1993 to 22 million by 2002.[16] In 2012, more than 60 million MR examinations were performed around the world.[5] MR examinations are replacing invasive procedures across medical specialties.[17]

As technology has improved and become more available, MR scans are being used more in emergency departments for head and neck injuries. Between 1994 and 2015, use of emergency department MR scans of the head increased 1451%.[18] Among patients admitted for observation in emergency departments, approximately 19% have at least 1 MR scan.[19] Reduced scan times have led to expanded use of MR scanning protocols. For instance, intraoperative MR has led to advanced surgical approaches and improved patient care in hybrid operating rooms.[20]

MR technology also has been combined with other imaging methods, such as positron emission tomography (PET)-MR, to provide physicians images with the detail of MR scans and information on pathological functions in the body.[21] Diffusion techniques and wider availability have attributed to increased use of PET for examining complex neurological disorders.[22] Newer 3-D techniques for radiation therapy have led to increased use of MR imaging to guide radiation treatments.[23] In addition, MR-linear accelerator (MR-LINAC) equipment combines an MR scanner and linear accelerator in a single system. The technology facilitates real-time imaging for adaptive radiation therapy, improving accuracy and treatment efficiency.[22,24]

ASRT Survey of MR Technologists

In 2017, ASRT President Amanda Garlock, MS, R.T.(R)(MR), made technologist-focused MR safety a priority initiative. The ASRT conducted a nationwide survey of MR technologists and convened the MR Safety Best Practices Committee, consisting of MR technologists and safety officers, to create a report on MR safety issues and technologist-driven best practices (see **Appendix A**).

In August 2017, the ASRT invited 22 139 ASRT members employed as MR technologists to participate in an MR safety survey. When the survey closed in October 2017, ASRT had received 2637 responses, for an 11.9% response rate. At its widest, a sample size of 947 yields a margin of error of +3.2% (at the 95% confidence interval).

Most survey respondents (92.5%) were certified in MR imaging, and 3.4% reported having Magnetic Resonance Safety Officer (MRSO) certification from the American Board of Magnetic Resonance Safety (ABMRS). A total of 62.3% of respondents identified as staff technologists, 20.3% stated they were senior or lead technologists, and 7.7% reported that they served as supervisors or managers.

The average survey respondent was aged 47.9 years, worked in radiology for more than 22 years, and worked in MR for 15.4 years. A majority of respondents (58%) indicated they worked in hospitals; 19% worked in clinics, and the remainder listed their primary work environment as physician offices, universities, and other settings. Respondents replied to several questions about staffing and MR safety policies and procedures in their workplaces. The technologists offered insight on safety in some responses. Both quantitative and verbatim responses were incorporated into this best practices report.

Background: MR Technologists

According to the ASRT MR Safety Survey, technologist practice standards and codes of ethics, and national or international MR safety standards, MR technologists must maintain a high degree of accuracy in positioning and technique for optimal care during diagnosis and treatment. According to Kanal et al and the ASRT survey, technologists implement, maintain, and improve MR safety policies to ensure patient, visitor, and colleague safety in the MR environment.[8]

Although technologists conduct MR examinations at the request of referring physicians and under radiologist supervision, technologists are responsible for ensuring adherence to MR safety guidelines and policies.[8,15] To perform their jobs, MR technologists receive training in and demonstrate understanding of[15]:

- human anatomy and physiology
- pathology
- pharmacology
- medical terminology
- MR technique
- patient positioning for MR

MR technologists also must possess knowledge of MR safety and revise their knowledge as technological developments and manufacturing of medical devices evolve. The technologist is the primary contact person for MR patients and a liaison between patients, staff, and other health care professionals. MR technologists have a wide scope of practice (see **Box 2**) and must respond to emergencies as needed. In addition, ACR accreditation recommends that MR technologists who perform cardiac examinations maintain basic life support certification.[25]

Agencies outside the professional discipline further define technologist qualifications. The Medicare Improvements for Patients and Providers Act of 2008 requires providers of outpatient technical components of advanced diagnostic imaging services to be accredited by a Centers for Medicare & Medicaid Services–designated organization to receive Medicare reimbursement.[26] To be ACR-accredited in MR imaging, a facility's MR technologists must be licensed within their state or other jurisdiction, assuming the state has MR-specific licensing for technologists. In addition, MR technologists must meet 1 of the following requirements[25]:

- be registered as an MR technologist with the American Registry of Radiologic Technologists (ARRT), the American Registry of Magnetic Resonance Imaging Technologists (ARMRIT), or the Canadian Association of Medical Radiation Technologists (CAMRT)

Box 2

MR Technologist Scope of Practice[15]

MR technologists' scope of practice includes responsibilities common to all imaging technologists, including but not limited to:

- providing optimal patient care
- receiving, relaying, and documenting patient care orders
- verifying informed consent and corroborating orders or clinical history
- taking care of patient needs during applicable examinations or procedures
- preparing patients for procedures
- performing venipuncture and managing intravenous access or administering medications as prescribed
- evaluating medical images for quality and to ensure patient identification
- identifying and responding to emergency situations
- educating and monitoring students or other health care providers
- performing ongoing quality assurance activities
- applying principles of patient safety throughout all aspects of patient care

In addition, MR technologists:

- perform examinations or procedures (for diagnostic interpretation or therapeutic intervention) under the order of a licensed practitioner
- apply principles of MR safety to minimize risk to patients, self, and others
- research implanted devices
- select appropriate pulse sequences with consideration of established protocols and other factors that influence data acquisition parameters
- assist licensed practitioners with interventional procedures
- perform postprocessing of digital data from patient scans for display or hard-copy records, ensuring patient identification is correct and evident
- maintain archival storage of digital data as appropriate

- be registered with ARRT or have an unlimited state license, along with 6 months' experience in supervised clinical MR scanning
- have an associate or bachelor's degree in an allied health field and certification in another clinical imaging field (such as ARDMS or NMTCB), and 6 months' experience in supervised clinical MR scanning
- have performed MR imaging continuously since 1996 and been evaluated for competence by a responsible physician

MR technologists working in facilities seeking cardiac MR accreditation have additional requirements for supervised experience in clinical cardiac MR and in administering contrast intravenously. ACR accreditation requires facilities to document the qualifications of personnel in the department, including MR technologists.[25] MR technologists who work in specialized areas such as breast imaging, nuclear medicine, interventional radiology, radiation therapy, or hybrid operating rooms also participate in training related to their specialty, such as working in and managing safety in the hybrid operating room environment.[20]

The MRSO is an additional certification available to MR technologists through the ABMRS. The MRSO typically is responsible for implementing all safety procedures and policies in an MR department under the direction of the MR medical director (most often a supervising radiologist).[11] This responsibility includes ensuring that policies and procedures for MR safety are followed every day and that MR technologists and other personnel have access to written instructions, safety procedures, and emergency procedures.[10] The MRSO also helps decide, per MR medical director guidance, whether it is safe to scan a patient in unique and specific situations.[27]

The ABMRS awards MRSO certification to an MR technologist after he or she successfully completes the ABMRS examination, which includes content on[28]:

- magnetic field principles
- cryogen safety
- implant safety
- standards
- non-MR personnel in the MR environment
- screening
- zones
- emergencies
- safety concerns for special populations

The MR safety expert (MRSE) is another designation of the ABMRS, and this professional serves in a technical consulting role. The MRSE designation typically is awarded to medical physicists, although no specific requirements exist for education or experience if a professional passes the MRSE examination.[27]

MR technologists usually are the primary personnel involved in managing patient, visitor, and staff access to safety zones surrounding MR equipment. Under direct authority of the MR medical director, MR technologists are responsible for ensuring adherence to the ACR MR Safety Guidelines. The technologists are charged with tasks such as restricting area access, screening patients and others who need access to the equipment or areas in the magnetic field, and observing and controlling the room (and safety of individuals) in which MR examinations occur.[8]

MR Scanning

MR imaging systems produce images by applying strong magnetic fields and RF energy to the body's atoms. Most clinical MR systems are superconducting systems that use liquid helium to eliminate electrical resistance in the wires that generate the magnetic field. Once the magnetic field is established, it is on continuously, even when not in use. Superconducting magnets can have a cylinder (tube) or open design. Permanent magnets, which do not require electrical current, typically have an open design.

When technologists place a patient in the center of the MR scanner, or bore, a slight majority of hydrogen nuclei align with the scanner's magnetic field. Applying RF energy at the appropriate frequency causes the atoms in the targeted volume to flip out of alignment with the field. When the RF is stopped, the nuclei realign with the magnetic field, producing a signal that is received by the antennas of receiver coils and is then transmitted to a computer.[29] Coils are designed to work with specific sizes and anatomic areas of the body.[5]

Applying other time-varying gradient magnetic fields leads to the spatial localization of the MR scan. These gradient magnetic fields are turned off and on rapidly during MR scanning.[5] Each MR field contributes to safety concerns in patients. MR technologists are educated to understand how the fields affect imaging and safety. Technologists also must be familiar with scanner design.

MR Safety Concerns

Despite its overall safety and effectiveness, MR scanning poses potentially serious risks for patients, their family members, and medical personnel who enter the MR environment if the examinations are not performed by properly educated personnel.[8] MR safety concerns involve several factors not found in other clinical environments. Without strict adherence to safety policies and procedures, the fields or energies used in the imaging process can injure patients, family members, or staff.

Static Magnet

The magnetic field of the static, or primary, magnet used in MR imaging averages a strength of 30 000 to 60 000 times stronger than the magnetic field of Earth.[3,30] The strength of the magnetic field in clinical scanners range from 0.2 Tesla (T) to 7 T. Tesla is the measure of magnetic field strength where 1 T is equal to 10 000 Gauss. For many years, most MR scanners had 1.5 T magnets, but 3 T magnets now are common in hospitals because of the improved diagnostic performance of the stronger systems.[5,31] The first research system with a 10.5 T magnet performed examinations on humans in early 2018.[32] The 5-Gauss line of powerful research magnets can extend outside the scanner magnet's room.[5,13]

Risks of injury or other adverse events often are related to the static magnetic field, which interacts with human tissue and ferromagnetic equipment.[33] Implanted devices or presence of metal materials in MR zone IV can lead to injury for the patient and anyone in the room, as well as damage to the scanner. Further, MR technologists must supervise and control access to zone III or any area physically within the 5-Gauss line.[5] Several adverse events were reported following entry of objects such as ferromagnetic anesthetic gas or oxygen cylinders, beds, chairs, and IV poles. An instance also was reported of a gun being pulled into the MR bore and discharging despite the safety being engaged.[5]

Although modern MR systems have magnetic field shielding to minimize field strength outside the bore, the field strength increases rapidly as a person or object approaches the bore.[5] The magnet rapidly and forcefully can accelerate ferromagnetic objects toward the bore in a missile effect. The magnet can attract metallic objects such as coins, scissors, or hairpins.[13,34] Of all projectiles, heavy objects such as oxygen tanks, stretchers, and wheelchairs can do the most harm to people and the scanner.[17]

If a patient has implanted metal devices or other ferromagnetic materials in the body that enter a static or changing MR magnetic field, the magnet can cause the implanted device to move and twist (torque). Translational and rotational forces can vary depending on factors such as the amount of ferromagnetic material that is in the object and the total mass of the object.[5] Implanted medical devices such as aneurysm clips are attached to soft tissue only, and it is critical to identify clips and other metal devices accurately to determine the amount of ferromagnetic material they contain.[5]

The magnet also can affect the function of critical implanted devices. For example, effects on the function of cardiac implanted electronic devices are among the most common types of adverse events reported in patients who have MR scans. Each device contains a magnetic switch that turns it on or off upon detection of an external magnetic field, which can affect whether the device functions as it should to control heart pacing and detect tachyarrhythmias.[17]

Gradient Field

Time-varying gradient fields are used in MR imaging to spatially localize and encode the MR signal. The changing electrical fields produce a magnetic field that changes in strength depending on position.[5,35] Modern systems carry currents as high as hundreds of amperes that induce voltage and can cause heating in implanted devices.[5,36] Time-varying gradients can interfere with some implants or monitoring devices and can lead to peripheral nerve stimulation (ie, induction of electrical fields in a patient's nerves and muscles).[13,33] The gradient field frequency, flux densities, distribution in the body, and other factors affect the potential for and severity of peripheral nerve stimulation.[13]

Acoustic noise from the gradients requires use of headphones or earplugs for patients having MR scans.[13] Use of 3 T MR scanners is becoming common in the clinical setting as some providers replace aging 1.5 T units with 3 T scanners.[37] A 2018 report from a Chinese study of 3 T MR scanners found that acoustic noise caused temporary hearing loss in patients who had clinical neurological examinations in MR scanners, despite their wearing ear protection.[38] The researchers used 6 techniques, including diffusion tensor imaging and T1-weighted fast spoiled gradient-recalled echo imaging, with an average scan time of 60 minutes. The study found that hearing returned to normal by an average of 25 days after scanning. However, the authors emphasized the crucial nature of hearing protection for patients scanned with 3 T magnets.[38]

Radiofrequency Energy

Radiofrequency waves are created by transmitters integrated into an MR system. Placing an antenna, or receiver coil, in the path of the changing magnetic field induces a current, and the coil then emits an RF pulse.[13] Radiofrequency pulses are present only during scanning, but the pulses can occur hundreds of times per second.[3,5] The RF energy can cause heating in human tissue; the heating effect is measured by a unit called *specific absorption rate* (SAR) and is expressed in watts per kilogram.[5] Different levels of heating can be harmful to infants, small children, or patients who have disorders of their thermoregulatory systems.[13] MR personnel should take special considerations with certain medical or dental implants to reduce the risks of heating and burns.[31,33] Burns of every degree are recorded as MR adverse events.[3]

The RF pulses emitted by MR scanners also can affect nonferromagnetic implants, requiring careful screening by MR personnel. The pulses can induce electrical currents in the leads of cardiac implanted electronic devices, for example, and can affect how the leads sense heart changes and inhibit responses such as pacing; they also can inhibit or induce cardioversion therapy when not approriate.[13,17] Leads on cardiac implanted electronic devices perform like antennas for the pulses and push electrical current through the lead and into surrounding tissues. The tissue resists the current at the site of the lead, causing the tissue to increase in temperature. Temperature increases of 44° F (7° C) to 145.5° F (63.1° C) were documented for cardiac implanted electronic device leads and other types of endovascular wires.[17] Patients also can receive burns on their skin from patches, tattoos, permanent cosmetics, nail polish, and monitoring devices. Zippers, snaps, and metallic microfibers in clothing also can burn patients.[39] In addition, an RF coil and its connecting cables can burn a patient's skin if in direct contact.[5] The risk of

radiofrequency heating increases with longer scan times and higher static field strengths.[13,39]

Safety Zones

The ACR 2002 MR safety documents established 4 demarcated safety zones in MR facilities that become increasingly restricted in relation to MR scanner proximity. The Joint Commission has adopted these zone definitions and safety recommendations.[8,11,40] Managing access to zones is critical to preventing adverse events in the MR department. MR personnel must ensure adherence to zone demarcation, screening, and other safety policies to protect patients and the public. Emergency personnel and non-MR hospital staff might bypass screening steps if they are not trained in MR safety and if an MR technologist is not in the immediate area to control access.[5] A summary of ACR recommended zones follows (see **Appendix B**)[5,8]:

- Zone I – the least restricted and public zone, furthest from the MR equipment. Zone I typically includes the reception area, patient waiting room, restrooms, and admission.
- Zone II – the buffer between public areas and more strictly controlled zones. Zone II typically includes changing and storage areas for patient belongings, patient transfer areas, and patient history and screening. MR personnel should supervise patient movement throughout zone II.
- Zone III – this zone contains potentially hazardous energies, and access to the zone is strictly restricted and controlled by MR personnel as defined by safety guidelines. Entry of unscreened individuals or ferromagnetic materials can result in serious injury or death from the static and time gradient fields. Physical barriers help control entry. Zone III typically includes waiting areas for screened patients, the control room, and the hallways or vestibule leading to the scanner room.
- Zone IV – the most restricted zone; contains the MR scanner room. Zone IV presents the greatest safety risks because of energies associated with MR imaging. Access to zone IV by non-MR personnel is permitted only after proper screening. The area should be marked clearly and entrance allowed only with a badge or passcode. Anyone other than MR personnel must be accompanied or supervised by a staff person designated as trained (level 2) MR personnel while in zone IV.

All zones should be marked clearly with signage.[5] It should not be possible for patients or staff to skip a safety zone by an alternative entrance.[13] Further, magnetic fields extend in all dimensions, not in a single straight line. As a result, safety zones can extend into non-MR areas above, below, or adjacent to the MR scanner room.[13]

In the ASRT MR Safety Survey, 90.3% of respondents said their MR department uses a 4-zone system, and 7.3% said their department does not use the zones. In addition, 2.4% reported that they did not know whether the department used the zone system.

MR Personnel Levels

MR imaging personnel include an MR medical director, medical safety officer, and levels of MR personnel (see Appendix B). These levels and zone access for each level are defined by the ACR as[8]:

- Non-MR personnel – anyone who has not complied with MR safety instruction guidelines, and specifically anyone who has not undergone designated MR safety training within the previous 12 months.
- Level 1 MR personnel – staff members who have passed minimal safety education that ensures their safety while in zone III.
- Level 2 MR personnel – individuals who have completed extensive education in broad MR safety issues related to all MR energy fields.

The MR medical director is responsible for identifying and overseeing the training needs of those in the department who should be educated to qualify as level 2 MR personnel. A department's MR safety officer also is responsible for defining MR safety issues included in training.[8]

The Joint Commission recommends appointing a safety officer who is responsible for implementing and enforcing MR safety procedures.[11] The supervising MR physician should review these written procedures at least once a year.[41] The facility's medical physicist/MR scientist must assess the MR safety program annually, including matters such as access control and cryogen

safety, and inspect the MR equipment for physical and mechanical integrity.[25] The Joint Commission also requires annual training for all MR personnel that informs all non-MR personnel, families, and patients about potential harms of the MR environment.[11] Having a certified MRSO in each department is voluntary.

Screening

Devices

In 1997, the U.S. Food and Drug Administration (FDA) introduced the first standards for terms regarding imaging device safety in MR. In 2005, the American Society for Testing and Materials introduced the following designations, which the FDA later adopted[5,11,42]:

- MR safe – an item that poses no known hazard in the MR environment; typically any items that are not metallic, magnetic, or conductive.
- MR conditional – items that pose no hazard if used as specified. Safety of conditional items is based on specific information such as static field strength, maximum gradient field strength, maximum SAR, and other conditions in which the item was tested. These items should be brought into safety zones III and IV only when using extreme caution.
- MR unsafe – items that pose hazards in all MR environments and are contraindicated for MR examinations.

MR-conditional devices have become increasingly common as manufacturers have made changes to software or hardware to support low-risk use of the devices in MR scanners under specific conditions.[17] Early pacemakers could malfunction and lead to death, especially if a patient was not monitored.[36] The first conditional pacemakers for the MR environment were approved in Europe in 2008 and in the United States in 2011.[42]

Although new implantable devices can be used safely near the MR scanner, many patients still have older devices that are not safe for MR scanning and contraindicate an MR examination.[43] Approximately 2 million people in the United States have implanted devices that are not considered MR conditional; more than half of these people are expected to need an MR examination because of clinical indications.[44] A 2016 study reported that 81% of patients who had a cardiac device when presenting for an MR examination had a conventional device.[42]

Some devices are deemed safe based on known materials. However, any metal or electronic device potentially can cause harm in the MR environment (see **Box 3**).[5] The potential for injury from implants in patients is affected by the implant's proximity to vital tissues (eg, blood vessels or nerves).[13] Further, although some cardiac implanted devices are FDA approved for safe use in the MR setting, neither manufacturers nor the FDA supports MR scans for patients whose devices are not MR conditional or MR safe.[48]

Therefore, approval of some devices for entry into the MR room requires complex and critical decision-making, involving both potential patient injury and device malfunction. However, numerous reports in recent years have shown that conventional devices cause no long-term, clinically significant adverse effects, and that most cardiac implanted electronic devices not labeled MR conditional can be scanned safely if pre-examination evaluation and examination monitoring procedures are followed.[17,49] Strom et al evaluated 123 patients who had 189 MR scans and implanted cardiac devices that were not considered MR conditional.[48] They reported 1 major adverse event and 3 minor adverse events. The authors found a small decline in battery value over years of remaining battery life and effects on right atrial lead threshold potential at 6 months following the MR scan.[48]

Decisions to proceed with examinations for patients should be made individually based on risk vs benefit, with careful consideration of research on specific devices and their reported safety designation.[42] Not all implanted devices are approved or alike, and research typically is conducted on scanners with 1.5 T static magnets.[17,42] Industry-wide and facility-level efforts must balance ensuring patient safety with preventing denial of indicated MR examinations when possible.[8,45] Safety of patients presenting for an MR examination is optimized when risks from devices or other issues are weighed carefully with medical indications for examinations and when all conditions are met for MR-conditional devices.

MR technologists most often research devices for designated safety evidence, and level 2 MR personnel

Box 3

Sample List of Implants and Foreign Objects of Concern in MR Scanning[a]

Policies and procedures should address possible contraindications to MR scanning,[9] including the following devices:

Implanted cardiac devices such as pacemakers and cardioverter defibrillators.[9] Pacemakers received early attention in MR safety. Conventional devices have been associated with adverse events.[3,45] Implanted cardiac devices can lead to adverse events such as ventricular arrhythmias during examinations or problematic changes in pacing and sensing.[45] Also of concern are nearly all prosthetic heart valves, including mechanical valves, and coronary stents. Evaluation of devices at 3 T strength continues.[34]

Other mechanical, magnetic, or electronic devices such as certain neurostimulators and cochlear implants.[9] The FDA has noted incidents of serious injury, including permanent neurological impairment or coma, from implanted neurological stimulators exposed to MR scanning; the electrode tips heated to the point of causing damage to patients.[8] Electrophysiologic monitoring equipment can be used intraoperatively, but surgeons hesitate to use the monitoring with intraoperative MR because of concerns about burning or torque effects on electrodes during MR. Breitkopf et al reported safe use of continuous intraoperative monitoring in intraoperative MR-guided surgery on 110 patients.[46] Cochlear implants can be demagnetized in the presence of an MR magnetic field, depending on the position of the implant in relation to the static field.[31] Breast tissue expanders can have a ferromagnetic port that subjects the expanders to torque forces in the presence of MR magnets that cause pain, burning, or migration of expanders. Some devices are less apt to migrate, and in magnets at 1.5 T strength, filling the device with saline and placing the patient in a prone position can add to procedure safety and image quality.[6]

Medical and dental hardware. Ferromagnetic clips, stents, and ocular implants can move or dislodge during MR scanning.[9] Several types of dental hardware use magnets (a magnetic assembly and keeper). The ability of the dental magnetic assemblies to maintain force and retention is decreased with 3 T scanners. Effects depend on the angle at which magnets are positioned.[31] Brackets are cemented to teeth for some braces or implants. Brackets can be ferromagnetic and cause artifacts on neuroimaging; all removable parts of magnetic dental devices should be removed before MR examinations.[3,31]

Medication patches. Some medication patches contain a metallic foil, which can cause burn injuries when a patch is exposed to the radiofrequency field.[8]

Tattoos and tattooed makeup. These inks can contain metals that heat up when exposed to radiofrequency energy.[8] Makeup and tattoos are not part of typical medical histories, and tattoos located within the region of the body scanned can introduce safety risks.[3]

Body piercing. Piercing hardware can be identified by ferromagnetic detectors and can be partially removed, but hardware might be anchored with a metal post through the skin, which should be identified and assessed for ferromagnetic properties before MR examinations. Multiple body piercings or surgical staples can create a circuit or voltage pathway that causes burning.[3] Patients with staples or superficial metallic sutures can have an MR examination if the materials are deemed not to be ferromagnetic.[8] Heat sinks (ie, materials that disperse potentially hazardous temperature rises, such as ice packs) can be used when they must stay in place and are not in the area of the examination to be performed.

Foreign objects. Some patients are exposed to metal fragments on the job or through injuries. In 1985, there was a report of serious eye injury to a patient who had a small piece of metal move in his eye during an MR scan. Medical history and patient screening forms help reduce risk.[3]

Clothing. Attire and accessories can contain metal snaps or other fixtures. In addition, manufacturers have increased use of metal fibers in clothing, and there have been reports of patients with second-degree burns from metallic threads in clothing worn during MR examinations.[3]

Fitness trackers. Popular step and fitness tracking devices, such as Fitbit, can contain ferromagnetic materials; the Fitbit manufacturer recommends that patients and personnel not wear the device near an MR scanner.[47]

Orthopedic hardware. Orthopedic hardware should be included in screening questionnaires, primarily for concerns about artifacts on images. Most orthopedic hardware is made of nonferromagnetic metals.[3]

[a] *For information only; more complete lists are available from MRISafety.com.*

are among those who can recommend safety of an implant or foreign object based on predetermined criteria. The final decision to proceed with an examination is made by an MR level 2-designated attending radiologist, MR medical director, or specifically designated level 2 MR personnel.[8] MR technologists must carefully follow institutional and ACR recommendations on patient and device screening, consent, and monitoring even in the presence of safe labels or FDA approval.[17,42]

Results of the ASRT MR Safety Survey showed that 94.4% of respondents indicated the MR technologist is responsible for researching implants. In addition, 92.3% said the MR personnel in their facility spend at least 5 minutes researching patients' individual implants, and 48.9% spend more than 15 minutes on the research.

Patient Screening

All nonemergent patients or volunteer research subjects should complete screening questionnaires (see **Appendix C** for a sample form) that are reviewed by registration staff with MR personnel training and later reviewed by MR technologists or MR level 2-trained personnel.[39] Screening recommendations for nonemergent patients also include at least 2 safety screenings on site, 1 of which should be performed by level 2 MR personnel, and 1 of which should be verbal or interactive. Emergent patients and non-MR personnel accompanying them can be screened only once if the single screening is performed by an individual designated as MR level 2 personnel.[8] A total of 55.4% of survey respondents said that, on average, fewer than 2 technologists were scheduled per MR scanner at their facilities. A total of 38.1% reported having 2 technologists scheduled per scanner, and 6.5% reported more than 2 technologists per scanner. Most said 2 or more MR suite personnel are required to screen patients before the patients enter the room with the MR scanner.

MR technologists question patients about any device that could pose a danger in the MR environment. In addition, patients are questioned about any implanted device that is activated magnetically or electrically, such as pacemakers.[11,39] To determine the MR safety of implants and devices, technologists rely on device identification cards, medical records, manufacturer websites, and searchable device lists (see Box 3).[39] Technologists visually should inspect patients for the presence of unsafe items such as metal or conductive attire.[40] Specific procedures for reviewing a patient's answers and investigation should be outlined in department policy before allowing a patient to advance to each corresponding zone and should serve to review and verify information provided by patients or referrers.[11,39,40]

Safety guidelines recommend further investigation for patients who have a history of ferromagnetic foreign object penetration or medical history of orbit trauma from a possible ferromagnetic material. The investigation might include radiography or evaluation of prior CT or MR examinations showing the area of the foreign object.[8] When patients are unconscious or unable to answer screening questions, MR technologists can question family members or surrogate decision makers, examine available patient history, and look for signs (eg, surgery or injury scars) of possible MR-unsafe devices or ferromagnetic materials. When appropriate, use of radiography and ferromagnetic detectors can aid in the investigation.[11]

Personnel Safety and Screening

All non-MR personnel entering the MR environment should be screened through a screening questionnaire and with ferromagnetic detection when available (see Appendix C).[8] Non-MR personnel are subject to injury from projectiles and loud gradient sounds. Thoroughly screening and supervising these personnel help to ensure patient and personnel safety.[3,50]

Radiologic science education program students participate in clinical training in radiology departments. The Joint Review Committee on Education in Radiologic Technology has adopted standard interpretations to promote student and patient safety in the MR environment. The standards state that students will use magnetic field safety measures.[30,51] In addition, students should receive training and supervision by department staff, safety information as part of the classroom training, and a required safety screening protocol by education programs.[30]

Accompanying Family or Personnel, Special Situations

Any family member or caregiver accompanying a patient into the MR scanning room must be screened

using the same criteria for zone IV that are used for patients and personnel. It is recommended that only 1 adult accompany a patient into zone IV. Other situations include prisoners or parolees with metallic restraining devices, RF identification, or tracking devices. Safety recommendations state MR technologists should request appropriate authorities accompany the patient into a designated MR area to remove restraint devices before the study and replace them immediately following the study. These personnel must be screened the same as any accompanying adult or non-MR personnel.[8]

Some patients present special situations. According to a discussion on the online MR forum for ASRT members and to ASRT MR Safety Survey verbatim responses, for example, MR technologists are looking for guidance on the presence of service animals in the MR environment. Although patients with service animals cannot be denied medical service under the Americans With Disabilities Act and must be allowed "anywhere else in a hospital where public and patients are allowed to go,"[52] MR technologists are charged with limiting public access to MR safety zones. This suggests denial of service animal entry when patients, staff, or others are unsafe because of ferromagnetic materials and other MR-unsafe devices. Service dogs have ferromagnetic halters and other metal in collars or leads. Further, hospital staff are not responsible for handling dogs or other service animals. It is the responsibility of the handler to supervise and care for the dog.[52] MR technologists also are concerned about harm to dogs or other animals from the noises generated by MR equipment or by identification chips implanted in dogs (ASRT Communities discussion, December 9, 2016-January 5, 2017).

Emergency Responders

ACR safety recommendations state that all emergency events, such as fire alarms or cardiac arrests, in the MR suite should be managed by a designated MR-trained individual. If possible, designated individuals should be on site before emergency responders arrive to control the responders' access to MR zones III and IV. The guidelines suggest designating MR technologists as security personnel in the facility.[8]

Although MR departments train and assign designated emergency responders from within their facilities in MR safety, training of outside personnel is less frequent or consistent. In the ASRT MR Safety Survey, 15.8% of respondents mentioned failure to limit access as the most frequent type of noncompliance, and 12.4% reported noncompliance with emergency response as most frequent. Respondents reporting annual training of emergency personnel using safety videos and MR technologist presentations covering MR safety annually or at orientations. The range of efforts and requirements varies widely; some emergency responders have no formal training, and other MR departments invite community emergency personnel, but not all attend. Regardless of emergency responder training, physical barriers and MR level 2 personnel supervision should restrict entry to zone IV, according to survey verbatim responses.

ASRT MR Safety Survey respondents described policies that included firefighters and emergency medical services personnel in level 1 MR personnel training and allowing only prescreened staff into zone III. MR technologists should evacuate patients in emergency situations to zone II. Further, some respondents report policies that include ensuring MR level 2 personnel are trained in emergency and evacuation procedures, including annual drills.

Metal Detection

Despite thorough screening, unsuspected ferromagnetic materials might enter MR safety zones.[39] As an additional screening level, guidelines recommend use of a handheld magnet or ferromagnetic material detection device. The detecting magnet should have a strength of at least 1000 Gauss and be designed to detect ferromagnetic objects. Use of ferromagnetic detection systems is demonstrated as highly effective and was evaluated in a 2014 study.[8,53] The author found that the system used in the study (Ferroguard Screener) was 100% sensitive and 98% specific at detecting ferromagnetic objects.[53] Studies show that current ferromagnetic detectors also can detect implanted devices and external metallic objects.[8,40,54]

Ferromagnetic detection is shown to be helpful in screening non-MR personnel from other medical departments who might or might not have MR training.

Staff easily can forget to remove pins, clipboards, or other personal objects and attire before entering the MR safety zones, and a detector serves as a quick reminder and screener.[53]

The ACR suggests use of ferromagnetic detectors in zone II or at the entrance to zone III.[8,53] To date, ferromagnetic metal detectors are not approved by any government entity but are considered a useful tool to assist in MR safety screening.[55] The physical screening for ferromagnetic objects is an adjunct to, but not a replacement for, screening questionnaires, interviews, and visual inspections.[8,40]

Reporting and Documentation

MR technologists are responsible for participating in routine patient care documentation and in documenting adverse events that occur in the department. They follow institutional policies, as well as standards and regulations that pertain to their facility.

Routine Documentation

MR safety standards recommend or require MR personnel to document the examination. They must maintain a permanent record of the full examination in an archive and archive images for a designated period according to procedures. Examination retention must satisfy clinical needs and relevant facility requirements, regulations, or legal needs.[15] The ACR stated in its MR practice parameter that "high-quality patient care requires adequate documentation."[41] Further, ASRT Practice Standards include documentation of orders, corroboration of clinical history, the examination or procedure, and outcome.[15]

MR technologists are responsible for documenting all diagnostic, treatment, and patient data in the medical record in a timely manner.[15] MR technologists who are ASRT members have expressed concerns about the lack of a consistent industry guideline on documentation of screening efforts and device safety research (ASRT Communities discussion, September 1, 2016-December 13, 2017).

Site-specific Documentation

MR facilities must write, enforce, and annually review and document safety guidelines, policies, and practices. The supervising physician must approve the documentation, and the medical physicist/MR scientist must assess MR safety as part of annual performance evaluation. This responsibility also includes matters such as signage, control of access to safety zones, screening procedures used, and cryogen safety policies and practices.[25]

Facilities must have procedures in place for documenting MR personnel qualifications and continuing education. Documented training should include fire and electrical safety, hazard or emergency communication, safety reporting tool training, knowledge of safety manual documentation, and infection control.[8,50] They also must have policies for personnel to report traumas or procedures that might affect their safety in the MR environment. In addition, they must follow documentation requirements related to quality management.[8,25]

Adverse Event Documentation

Intersocietal safety standards require a procedure to identify patients or other individuals who experience an adverse event or complication from an MR examination or from entry into the MR environment. The facility must maintain documentation of the incident.[9]

The ACR safety recommendations state that procedures should be in place for reporting all adverse events, safety incidents, and near incidents to the medical director within 24 hours. Sites also must report adverse events to the FDA.[8] Device-user facilities (eg, hospitals, ambulatory surgical facilities, nursing homes, outpatient diagnostic facilities, and outpatient treatment facilities, but excluding physician offices) must report a suspected medical device-related death to the FDA and the manufacturer. User facilities must report a medical device-related serious injury to the manufacturer, or to the FDA if the medical device manufacturer is unknown.

A user facility is not required to report a device malfunction, but it can voluntarily advise the FDA of such product problems using a voluntary MedWatch form under the FDA's Safety Information and Adverse Event Reporting Program.

The Manufacturer and User Facility Device Experience (MAUDE) searchable database contains mandatory reports filed by device manufacturers and

importers from August 1996 to present, all mandatory user facility reports from 1991 to present, and voluntary reports filed after June 1993. Any information suggesting the device could be likely to cause serious injury or death in a patient must be thoroughly reported by the manufacturer or imported to MAUDE. The MAUDE database houses medical device reports submitted to the FDA by mandatory and voluntary reporters such as health care professionals, patients, and consumers. However, MAUDE does not include events reported through other channels.[56,57]

The ACR has stated that adverse events in MR are under-reported.[8] The Joint Commission's safety policies and procedures state that facilities must report all MR accidents and near misses to the equipment vendor and the FDA.[11]

Summary of MR Technologist Role

Level 2 MR technologists are responsible for:

- ensuring that patients comply with pre-examination preparation instructions
- screening for contraindications
- selecting scanning parameters based on order and protocols
- obtaining images as scheduled and ordered
- assuming the comfort and care of patients in the scanner
- recognizing signs of an emergency

In addition, MR technologists administer first aid or provide life support to patients as needed and monitor patient reactions to contrast media or medications.[15] They are responsible for proactively planning for critical care patients with assigned staff to ensure monitoring and life-sustaining equipment is available and can be used safely.[11,41] MR technologists respond to emergency codes by limiting access to the scanner room and safely and rapidly moving a patient who requires resuscitation out of the scanner and zone IV before resuscitation begins.[11]

MR technologists must prepare and position patients for examinations, placing coils and leads safely as part of the positioning.[15,41] Technologists determine whether services are performed in a safe environment and work to minimize potential hazards,[15] including taking recommended precautions to prevent burns during MR scans. This task can involve ensuring no closed-circuit loops are formed in the MR scanner bore, using nonconducting foam pads between patient skin and the bore, or placing a cold compress on leads, tattoos, and other potentially conductive materials. Technologists also provide ear plugs or headphones for hearing protection.[11]

Level 2 MR personnel also are responsible for ensuring safety of all personnel or family members who enter safety zones; this responsibility includes screening and providing hearing protection and MR-safe or MR-conditional seating for a family member accompanying a patient.[8] In addition, MR technologists usually are the primary people responsible for researching and documenting MR safety of implants under the supervision of the MR medical director.

Staffing

After screening patients and personnel to optimize safety in MR zones III and IV, technologists conduct the MR examination. MR suites are designed so that access is controlled by MR technologists and that technologists can monitor patients continuously. Technologists also must ensure images are acceptable for diagnosis by a radiologist.[15] MR technologists must remain attuned to ferromagnetic detector alarms and respond appropriately, even though false-negative alarms occur.[39]

The ACR recommendations for MR safety state that at least 2 MR technologists or 1 MR technologist and another MR personnel-designated person be in the zones closest to the MR scanner, except in emergent cases, in which case the recommendations state an MR technologist can be alone as long as in-house emergent coverage from a designated department is ready; the recommendations do not require a minimum of 2 technologists at all times.[8] Further, The Joint Commission's performance criteria for MR providers includes the objective of having 1 specially trained MR staff person familiar with MR-specific safety issues accompany "all patients, visitors and other staff who are not familiar with the MR environment" in the 2 zones closest to the MR scanner.[11]

The ASRT MR Safety Survey reported as many as 55% of facilities have fewer than 2 technologists scheduled per MR scanner per day. Only 27.3% of the survey

participants report employment of patient aides who help with patients in the MR department.

The professional ethics of radiologic technologists, per the ARRT, guide the professional behavior and represent the values of MR technologists. The code includes ethical conduct and protecting a patient's right to quality care. In addition, a technologist "assesses situations; exercises care, discretion, and judgment; assumes responsibility for professional decisions; and acts in the best interest of the patient."[58]

MR technologists have reported being torn between administrative policies assigning departmental staffing and a firm resolve to monitor and help patients. They also believe that having fewer MR personnel than recommended on staff compromises patient and personnel safety. For example, the MR technologist on duty must control access to the scanner room and safety zones while simultaneously attending to a patient in the scanner, which can distract from patient monitoring and can be physically impossible to maintain, depending on the layout of an MR department. The technologist should never leave a patient in the MR scanner unattended, yet technologists might be needed to assist in emergency situations requiring more than 1 individual who is level 2 MR personnel, such as removing a patient safely from the room if a patient has a cardiopulmonary arrest. Some MR technologists described nurse-to-patient ratios on inpatient floors as a patient care and safety issue and wondered why a similar policy does not apply industry-wide to MR department staffing (ASRT Communities discussion, February 28-December 29, 2017). New language addressing technologist staffing is included in proposed updates to ASRT practice standards as of May 2018.

Best Practices

Safety guidelines such as those released by the ACR and The Joint Commission serve a broad audience, including supervisors, physicians, physicists, and hospital safety officers. It is clear that managing patient, visitor, and personnel safety falls within the responsibility of MR technologists. Standard guidance lacks recommendations for MR technologists who document device screening, research, and decisions made or precautions taken for MR scanning for patients and personnel. Although guidelines require reviewing and revising departmental or institutional policies and procedures, the MR Safety Best Practices Committee (see Appendix A) recommends the following best practices:

- All individuals in safety zones III and IV must be continuously supervised by MR-trained personnel. Further, MR technologists should never leave the scanner or control room when a patient is in the MR scanner bore or room. This practice requires appropriate staffing support from department and facility administrators.
- Nonemergent patients should be MR safety screened on site by at least 2 MR-trained individuals, at least 1 of which is designated level 2 MR personnel. Level 2 personnel should verbally or interactively screen patients before they enter zone IV. This recommendation requires departmental support for adequate staffing and addressing or revising institutional screening policies.
- All patients should change into facility-provided attire before entering zone III. This ensures no metal objects on clothing or in clothing material enter the magnetic field.
- MR technologists should document all safety screening in a permanent record, such as the patient's electronic medical record. Documentation includes:
  - patients, accompanying individuals, staff screening forms
  - implant documentation (cards, operative reports, vendor information)
  - implant MR safety requirements (SAR, maximum spatial gradient, field strength)
  - summary of interactions between radiologist and MR technologists as to the safety of implant
  - evidence of MR guidelines compliance
  - status of patient pre-examination and postexamination
  - adverse events
- Hospital and community responders, as well as others who might access MR safety zones for emergencies or nonemergencies (eg, nurses, housekeeping staff, or physicians), should receive MR safety training at least annually, and the

training should be documented. MR technologists, supervisors, administrators, and community liaisons should provide appropriate training for staff and local community emergency responders.

- Considering the lack of guidance and information about service animals, MR technologists should refuse entry of service animals to zone IV; the reason includes danger to the animal from acoustic noise. Technologists should ensure appropriate supervision of entry of animals to zone III to follow safety standards regarding public access to the zones. Patients should be advised when making an appointment to bring a handler to the MR facility or department who can supervise the animal. Adhering to this recommendation requires adopting a policy and procedure for service animals and following state regulations and institutional policies that govern the official process.

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Appendix A

MR Safety Best Practices Committee

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Appendix B:

Glossary of MR Safety Terms[8,11]

Personnel:

Non-MR personnel – anyone who has not successfully complied with MR safety instruction guidelines, specifically anyone who has not undergone designated MR safety training within the previous 12 months.

Level 1 MR personnel – those who have passed minimal safety education that ensures their personal safety when in zone III.

Level 2 MR personnel – individuals who have completed more extensive education in broad MR safety issues related to all MR energy fields.

MR medical director – physician responsible for identifying and overseeing training needs of those personnel in the department who should be educated to qualify as level 2 MR personnel.

MR safety officers – certified MR personnel typically responsible for implementing all safety procedures and policies in an MR department under the direction of the MR medical director.

Safety zones:

Zone I – the least restricted zone open to the general public and furthest from the MR equipment. Zone I encompasses areas outside the clinical MR environment through which patients and staff access the MR area, such as the reception area, patient waiting room, restrooms, and an area for patient admission.

Zone II – patients are greeted by MR personnel in zone II, which typically includes changing and storage areas for patient belongings, patient transfer areas, and patient history and screening. MR personnel should supervise patient movement throughout zone II.

Zone III – this zone can contain potentially hazardous energies and access to the zone is strictly restricted and controlled by MR personnel as defined by safety guidelines. Entry of unscreened individuals or ferromagnetic materials can result in serious injury or death from the static and time gradient fields. Physical barriers such as doors with coded access help control entry. Safety zone III typically includes waiting areas for screened patients, the control room, and the hallways or vestibule leading to the scanner room.

Zone IV – the MR scanner room. Zone IV presents the greatest safety risks because of energies associated with MR imaging. Access to the zone by non-MR personnel is permitted only after proper screening and the area should be clearly marked and physically accessible only with a badge or passcode. Anyone other than MR personnel must be accompanied or supervised by a staff person designated as trained (level 2) MR personnel the entire time present in zone IV.

Appendix C:

Screening Form From MRIsafety.com

MAGNETIC RESONANCE (MR) PROCEDURE SCREENING FORM FOR PATIENTS

Date _____/_____/_____ Patient Number _____

Name _____ Age _____ Height _____ Weight _____
Last name First name Middle Initial

Date of Birth _____/_____/_____ Male ❒ Female ❒ Body Part to be Examined _____
month day year

Address _____ Telephone (home) (_____) _____-_____

City _____ Telephone (work) (_____) _____-_____

State _____ Zip Code _____

Reason for MRI and/or Symptoms _____

Referring Physician _____ Telephone (_____) _____-_____

1. Have you had prior surgery or an operation (e.g., arthroscopy, endoscopy, etc.) of any kind? ❒ No ❒ Yes
   If yes, please indicate the date and type of surgery:
   Date _____/_____/_____ Type of surgery _____
   Date _____/_____/_____ Type of surgery _____
2. Have you had a prior diagnostic imaging study or examination (MRI, CT, Ultrasound, X-ray, etc.)? ❒No ❒ Yes

If yes, please list:	Body part	Date	Facility
MRI	_____	_____/_____/_____	_____
CT/CAT Scan	_____	_____/_____/_____	_____
X-Ray	_____	_____/_____/_____	_____
Ultrasound	_____	_____/_____/_____	_____
Nuclear Medicine	_____	_____/_____/_____	_____
Other_____	_____	_____/_____/_____	_____

3. Have you experienced any problem related to a previous MRI examination or MR procedure? ❒ No ❒ Yes
   If yes, please describe: _____
4. Have you had an injury to the eye involving a metallic object or fragment (e.g., metallic slivers, shavings, foreign body, etc.)? ❒ No ❒ Yes
   If yes, please describe: _____
5. Have you ever been injured by a metallic object or foreign body (e.g., BB, bullet, shrapnel, etc.)? ❒ No ❒ Yes
   If yes, please describe: _____
6. Are you currently taking or have you recently taken any medication or drug? ❒ No ❒ Yes
   If yes, please list:_____
7. Are you allergic to any medication? ❒ No ❒ Yes
   If yes, please list:_____
8. Do you have a history of asthma, allergic reaction, respiratory disease, or reaction to a contrast medium or dye used for an MRI, CT, or X-ray examination? ❒ No ❒ Yes
9. Do you have anemia or any disease(s) that affects your blood, a history of renal (kidney) disease, renal (kidney) failure, renal (kidney) transplant, high blood pressure (hypertension), liver (hepatic) disease, a history of diabetes, or seizures? ❒ No ❒ Yes
   If yes, please describe: _____

For female patients:

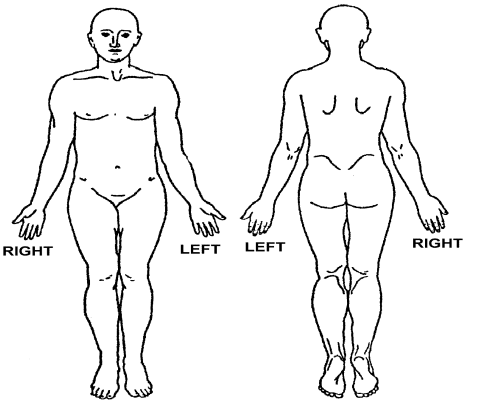
10. Date of last menstrual period:_____/_____/_____ Post menopausal? ❒ No ❒ Yes
11. Are you pregnant or experiencing a late menstrual period? ❒ No ❒ Yes
12. Are you taking oral contraceptives or receiving hormonal treatment? ❒ No ❒ Yes
13. Are you taking any type of fertility medication or having fertility treatments? ❒ No ❒ Yes
    If yes, please describe: _____
14. Are you currently breastfeeding? ❒ No ❒ Yes

WARNING: Certain implants, devices, or objects may be hazardous to you and/or may interfere with the MR procedure (i.e., MRI, MR angiography, functional MRI, MR spectroscopy). Do not enter the MR system room or MR environment if you have any question or concern regarding an implant, device, or object. Consult the MRI Technologist or Radiologist BEFORE entering the MR system room. The MR system magnet is ALWAYS on.

Please indicate if you have any of the following:

- ❒ Yes ❒ No Aneurysm clip(s)
- ❒ Yes ❒ No Cardiac pacemaker
- ❒ Yes ❒ No Implanted cardioverter defibrillator (ICD)
- ❒ Yes ❒ No Electronic implant or device
- ❒ Yes ❒ No Magnetically-activated implant or device
- ❒ Yes ❒ No Neurostimulation system
- ❒ Yes ❒ No Spinal cord stimulator
- ❒ Yes ❒ No Internal electrodes or wires
- ❒ Yes ❒ No Bone growth/bone fusion stimulator
- ❒ Yes ❒ No Cochlear, otologic, or other ear implant
- ❒ Yes ❒ No Insulin or other infusion pump
- ❒ Yes ❒ No Implanted drug infusion device
- ❒ Yes ❒ No Any type of prosthesis (eye, penile, etc.)
- ❒ Yes ❒ No Heart valve prosthesis
- ❒ Yes ❒ No Eyelid spring or wire
- ❒ Yes ❒ No Artificial or prosthetic limb
- ❒ Yes ❒ No Metallic stent, filter, or coil
- ❒ Yes ❒ No Shunt (spinal or intraventricular)
- ❒ Yes ❒ No Vascular access port and/or catheter
- ❒ Yes ❒ No Radiation seeds or implants
- ❒ Yes ❒ No Swan-Ganz or thermodilution catheter
- ❒ Yes ❒ No Medication patch (Nicotine, Nitroglycerine)
- ❒ Yes ❒ No Any metallic fragment or foreign body
- ❒ Yes ❒ No Wire mesh implant
- ❒ Yes ❒ No Tissue expander (e.g., breast)
- ❒ Yes ❒ No Surgical staples, clips, or metallic sutures
- ❒ Yes ❒ No Joint replacement (hip, knee, etc.)
- ❒ Yes ❒ No Bone/joint pin, screw, nail, wire, plate, etc.
- ❒ Yes ❒ No IUD, diaphragm, or pessary
- ❒ Yes ❒ No Dentures or partial plates
- ❒ Yes ❒ No Tattoo or permanent makeup
- ❒ Yes ❒ No Body piercing jewelry
- ❒ Yes ❒ No Hearing aid
  (Remove before entering MR system room)
- ❒ Yes ❒ No Other implant _____
- ❒ Yes ❒ No Breathing problem or motion disorder
- ❒ Yes ❒ No Claustrophobia

Please mark on the figure(s) below the location of any implant or metal inside of or on your body.



IMPORTANT INSTRUCTIONS

Before entering the MR environment or MR system room, you must remove all metallic objects including hearing aids, dentures, partial plates, keys, beeper, cell phone, eyeglasses, hair pins, barrettes, jewelry, body piercing jewelry, watch, safety pins, paperclips, money clip, credit cards, bank cards, magnetic strip cards, coins, pens, pocket knife, nail clipper, tools, clothing with metal fasteners, & clothing with metallic threads.

Please consult the MRI Technologist or Radiologist if you have any question or concern BEFORE you enter the MR system room.

NOTE: You may be advised or required to wear earplugs or other hearing protection during the MR procedure to prevent possible problems or hazards related to acoustic noise.

I attest that the above information is correct to the best of my knowledge. I read and understand the contents of this form and had the opportunity to ask questions regarding the information on this form and regarding the MR procedure that I am about to undergo.

Signature of Person Completing Form: _____ Date _____/_____/_____
Signature

Form Completed By: ❒ Patient ❒ Relative ❒ Nurse _____ _____
Print name Relationship to patient

Form Information Reviewed By: _____ _____
Print name Signature

❒ MRI Technologist ❒ Nurse ❒ Radiologist ❒ Other_____

CUESTIONARIO PREVIO A ESTUDIO CON RESONANCIA MAGNÉTICA (MR) PARA PACIENTES

Fecha _____/_____/_____ Número de paciente_____

Nombre_____ Edad _____ Altura_____ Peso_____
Apellido Primer Nombre Segundo Nombre

Fecha de nacimiento_____/_____/_____ Varón❒ Hembra❒ Parte del cuerpo a ser examinada_____
Mes Día Año

Dirección_____ Teléfono (domicilio) (_____) _____-_____

Ciudad_____ Teléfono (trabajo) (_____) _____-_____

Provincia _____ Código Postal _____

Motivo para el estudio de MRI y/o síntomas_____

Médico que le refirió _____ Teléfono (_____) - _____

1. Anteriormente, ¿le han hecho alguna cirugía u operación (e.g., artroscopía, endoscopía, etc.) de cualquier tipo? ❒ No ❒ Sí
Si respondió afirmativamente, indique la fecha y que tipo de cirugía:
Fecha _____/_____/_____ Tipo de cirugía _____
Fecha _____/_____/_____ Tipo de cirugía _____
2. Anteriormente, ¿le han hecho algún estudio o exámen de diagnóstico (MRI, CT, Ultrasonido, Rayos-X, etc.)? ❒ No ❒ Sí
Si respondió afirmativamente, descríbalos a continuación:

	Parte del Cuerpo	Fecha	Lugar/Institución
MRI	_____	____/____/____	_____
CT/CAT	_____	____/____/____	_____
Rayos-X	_____	____/____/____	_____
Ultrasonido	_____	____/____/____	_____
Medicina Nuclear	_____	____/____/____	_____
Otro_____	_____	____/____/____	_____

3. ¿Ha tenido algún problema relacionado con estudios ó procedimientos anteriores con MR? ❒ No ❒ Sí
Si respondió afirmativamente, descríbalos: _____
4. ¿Se ha golpeado el ojo con un objeto ó fragmento metálico (e.g., astillas metálicas, virutas, objeto extraño, etc.)? ❒ No ❒ Sí
Si respondió afirmativamente, describa el incidente: _____
5. ¿Ha sido alcanzado alguna vez por un objeto metálico u objeto extraño (e.g. perdigones, bala, metralla, etc.)? ❒ No ❒ Sí
Si respondió afirmativamente, describa el incidente: _____
6. ¿Esta actualmente tomando ó ha recientemente tomado algún medicamento o droga? ❒ No ❒ Sí
Si respondió afirmativamente, indique el nombre del medicamento:_____
7. ¿Es Ud. alérgico/a á algún medicamento? ❒ No ❒ Sí
Si respondió afirmativamente, indique el nombre del medicamento:_____
8. ¿Tiene historia de asma, reacción alérgica, enfermedad respiratoria, ó reacción a contrastes ó tinturas usados en MRI, CT, ó Rayos-X? ❒ No ❒ Sí
9. ¿Tiene anemia u otra enfermedad que afecte su sangre, algún episodio de enfermedad de riñón, fracaso de riñón, un transplante de riñón, hipertensión, la historia de la diabetes, relativo al hígado ó de ataques epilépticos?
Si respondió afirmativamente, descríbalos: _____ ❒ No ❒ Sí

Para los pacientes femeninos:
10. Fecha de su último periodo menstrual: _____/_____/_____ En la menopausia? ❒ No ❒ Sí
11. ¿Está embarazada ó tiene retraso con su periodo menstrual? ❒ No ❒ Sí
12. ¿Está tomando contraceptivos orales ó recibiendo tratamiento hormonal? ❒ No ❒ Sí
13. ¿Está tomando algún tipo de medicamento para la fertilidad ó recibiendo tratamientos de fertilidad? ❒ No ❒ Sí
Si responde afirmativamente, descríbalos a continuación: _____
14. ¿Está amamantado a su bebé? ❒ No ❒ Sí

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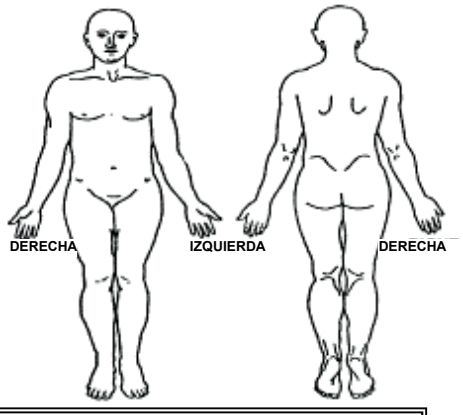
ADVERTENCIA: Ciertos implantes, dispositivos, u objetos pueden ser peligrosos y/o pueden interferir con el procedimiento de resonancia magnética (es decir, MRI, MR angiografía, MRI funcional, MR espectroscopía). **No entre** a la sala del escáner de MR o a la zona del laboratorio de MR si tiene alguna pregunta o duda relacionadas con un implante, dispositivo, u objeto. Consulte con el técnico o radiólogo de MRI ANTES de entrar a la sala del escáner de MR. **Recuerde que el imán del sistema MR está SIEMPRE encendido.**

Por favor indique si tiene alguno de los siguientes:

❒ Sí ❒ No Pinza(s) de aneurisma
❒ Sí ❒ No Marcapasos cardíaco
❒ Sí ❒ No Implante con desfibrilador para conversión cardíaca (ICD)
❒ Sí ❒ No Implante electrónico ó dispositivo electrónico
❒ Sí ❒ No Implante ó dispositivo activado magnéticamente
❒ Sí ❒ No Sistema de neuroestimulación
❒ Sí ❒ No Estimulador de la médula espinal
❒ Sí ❒ No Electrodos ó alambres internos
❒ Sí ❒ No Estimulador de crecimiento/fusión del hueso
❒ Sí ❒ No Implante coclear, otológico, u otro implante del oído
❒ Sí ❒ No Bomba de infusión de insulina ó similar
❒ Sí ❒ No Dispositivo implantado para infusión de medicamento
❒ Sí ❒ No Cualquier tipo de prótesis (ojo, peneal, etc.)
❒ Sí ❒ No Prótesis de válvula cardiaca
❒ Sí ❒ No Muelle ó alambre del párpado
❒ Sí ❒ No Extremidad artificial ó prostética
❒ Sí ❒ No Malla metálica (stent), filtro, ó anillo metálico
❒ Sí ❒ No Shunt (espinal ó intraventricular)
❒ Sí ❒ No Catéter y/u orificio de acceso vascular
❒ Sí ❒ No Semillas ó implantes de radiación
❒ Sí ❒ No Catéter de Swan-Ganz ó de termodilución

❒ Sí ❒ No Parche de medicamentos (Nicotina, Nitroglicerina)
❒ Sí ❒ No Cualquier fragmento metálico ó cuerpo extraño
❒ Sí ❒ No Implante tipo malla
❒ Sí ❒ No Aumentador de tejidos (e.g. pecho)
❒ Sí ❒ No Grapas quirúrgicas, clips, ó suturas metálicas
❒ Sí ❒ No Articulaciones artificiales (cadera, rodilla, etc.)
❒ Sí ❒ No Varilla de hueso/coyuntura, tornillo, clavo, alambre, chapas, etc.
❒ Sí ❒ No Dispositivo intrauterino (IUD), diafragma, ó pesario
❒ Sí ❒ No Dentaduras ó placas parciales
❒ Sí ❒ No Tatuaje ó maquillaje permanente
❒ Sí ❒ No Perforación (piercing) del cuerpo
❒ Sí ❒ No Audífono *(Quiteselo antes de entrar a la sala del escáner de MR)*
❒ Sí ❒ No Otro implante_____
❒ Sí ❒ No Problema respiratorio ó desorden del movimiento
❒ Sí ❒ No Claustrofobia

Por favor marque en la imagen de abajo la localización de cualquier implante o metal en su cuerpo.



¡AVISO IMPORTANTE!

Antes de entrar a la zona de MR ó a la sala del escáner de MR, tendrá que quitarse todo objeto metálico incluyendo audífono, dentaduras, placas parciales, llaves, beeper, teléfono celular, lentes, horquillas de pelo, pasadores, todas las joyas (incluyendo "body piercing"), reloj, alfileres, sujetapapeles, clip de billetes, tarjetas de crédito ó de banco, toda tarjeta con banda magnética, monedas, plumas, cuchillos, corta uñas, herramientas, ropa con enganches de metal, y ropa con hilos metálicos.

Por favor consulte con el Técnico de MRI ó Radiólogo si tiene alguna pregunta o duda ANTES de entrar a la sala de escáner de MR.

NOTA: Es posible se le pida usar auriculares u otra protección de sus oídos durante el procedimiento de MR para prevenir problemas ó riesgos asociados al nivel de ruido en la sala del escáner de MR.

Atestiguo que la información anterior es correcta según mi mejor entender. Leo y entiendo el contenido de este cuestionario y he tenido la oportunidad de hacer preguntas en relación a la información en el cuestionario y en relación al estudio de MR al que me voy a someter a continuación.

Firma de la persona llenando este cuestionario: _____ Fecha____/_____/_____
Firma

Cuestionario lleno por: ❒Paciente ❒Pariente ❒Enfermera _____ _____
Nombre en letra de texto Relación con el paciente

Información revisada por: _____ _____
Nombre en letra de texto Firma

❒ Técnico de MRI ❒Enfermera ❒ Radiólogo ❒ Otro _____

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MAGNETIC RESONANCE (MR) ENVIRONMENT SCREENING FORM FOR INDIVIDUALS*

The MR system has a very strong magnetic field that may be hazardous to individuals entering the MR environment or MR system room if they have certain metallic, electronic, magnetic, or mechanical implants, devices, or objects. Therefore, all individuals are required to fill out this form BEFORE entering the MR environment or MR system room. Be advised, the MR system magnet is ALWAYS on.

***NOTE: If you are a patient preparing to undergo an MR examination, you are required to fill out a different form.**

Date _____/_____/_____ (month day year) Name _____ (Last Name First Name Middle Initial) Age _____

Address _____ Telephone (home) (_____) _____-_____

City _____ Telephone (work) (_____) _____-_____

State _____ Zip Code _____

1. Have you had prior surgery or an operation (e.g., arthroscopy, endoscopy, etc.) of any kind? ❒ No ❒ Yes
   If yes, please indicate date and type of surgery: Date ____/____/____ Type of surgery_____
2. Have you had an injury to the eye involving a metallic object (e.g., metallic slivers, foreign body)? ❒ No ❒ Yes
   If yes, please describe: _____
3. Have you ever been injured by a metallic object or foreign body (e.g., BB, bullet, shrapnel, etc.)? ❒ No ❒ Yes
   If yes, please describe: _____
4. Are you pregnant or suspect that you are pregnant? ❒ No ❒ Yes

WARNING: Certain implants, devices, or objects may be hazardous to you in the MR environment or MR system room. Do not enter the MR environment or MR system room if you have any question or concern regarding an implant, device, or object.

Please indicate if you have any of the following:

❒ Yes ❒ No Aneurysm clip(s)
❒ Yes ❒ No Cardiac pacemaker
❒ Yes ❒ No Implanted cardioverter defibrillator (ICD)
❒ Yes ❒ No Electronic implant or device
❒ Yes ❒ No Magnetically-activated implant or device
❒ Yes ❒ No Neurostimulation system
❒ Yes ❒ No Spinal cord stimulator
❒ Yes ❒ No Cochlear implant or implanted hearing aid
❒ Yes ❒ No Insulin or infusion pump
❒ Yes ❒ No Implanted drug infusion device
❒ Yes ❒ No Any type of prosthesis or implant
❒ Yes ❒ No Artificial or prosthetic limb
❒ Yes ❒ No Any metallic fragment or foreign body
❒ Yes ❒ No Any external or internal metallic object
❒ Yes ❒ No Hearing aid
❒ Yes ❒ No Other implant_____
❒ Yes ❒ No Other device_____

IMPORTANT INSTRUCTIONS

Remove all metallic objects before entering the MR environment or MR system room including hearing aids, beeper, cell phone, keys, eyeglasses, hair pins, barrettes, jewelry (including body piercing jewelry), watch, safety pins, paperclips, money clip, credit cards, bank cards, magnetic strip cards, coins, pens, pocket knife, nail clipper, steel-toed boots/shoes, and tools. Loose metallic objects are especially prohibited in the MR system room and MR environment.

Please consult the MRI Technologist or Radiologist if you have any question or concern BEFORE you enter the MR system room.

I attest that the above information is correct to the best of my knowledge. I have read and understand the entire contents of this form and have had the opportunity to ask questions regarding the information on this form.

Signature of Person Completing Form: _____ (Signature) Date _____/_____/_____

Form Information Reviewed By: _____ (Print name) _____ (Signature)

❒ MRI Technologist ❒ Radiologist ❒ Other _____

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