

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 safety⁷:

- 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 of¹⁵:

- 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 requirements²⁵:

- 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 Practice¹⁵

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 on²⁸:

- 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