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Authors

Watson, Robert E

Tesfaldet, Mussie

Warren, Julee

et al.

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MR Imaging Safety Events Analysis and Improvement

Robert E. Watson Jr, MD, PhD^{a,*}, Julee Warren, RT (R)(MR)MRSO(MRSC)^a,
Mussie Tesfaldet, RT (R)(MR)MRSO(MRSC)^b, Michael Hoff, PhD^b

Q5Q4
Q7Q6
Q1Q8
Q2

KEYWORDS

• MR imaging safety • MR imaging burns • MR imaging projectiles

KEY POINTS

- Contemporary MR imaging practices face increasing safety risks associated with tight patient scheduling, relative shortfalls in MR imaging technologist availability, complex implantable devices, and increasing MR imaging environment complexity.
- By analyzing MR imaging safety events with debriefings and root cause analyses, specific gaps and conditions that led to the events can be identified and provide a basis for improved policies and procedures to prevent similar incidents from occurring going forward.
- Recent revisions to the American College of Radiology Guidance document on safe MR practices propose improvements to standards of care that can decrease chances that incidents, similar to those described in this article, will occur.
- Standardization of MR imaging safety organization by appointing MR safety Medical Directors, MR Safety Officers, and MR Safety Experts can be expected to ensure best practices.

INTRODUCTION

There are many ongoing efforts to improve the state of MR safety. There have been substantial revisions to the American College of Radiology (ACR) MR safety guidance document and increasing efforts to standardize operational infrastructure around MR imaging safety with named individuals serving as MR Medical Directors (MRMDs), MR Safety Officers (MRSOs), and MR Safety Experts (MRSEs).¹ The American Board of Magnetic Resonance Safety now exists with the aim of credentialing individuals in these positions through role-specific examinations. Despite incremental gains in MR safety, many evolving challenges remain in the field that are related to increasingly fast MR imaging workflow and time pressure, complex and evolving information sources including electronic medical records, frequent MR imaging technologist staff shortages

associated with rapid MR imaging practice growth and a competitive job market,² complicated patients with ever-increasing numbers of implanted devices, as well as increasingly complex intraoperative and hybrid procedural practices.

As detailed in this article, multiple factors associated with contemporary clinical MR imaging create distinct patient and MR imaging personnel safety risks. There is great awareness in the MR imaging community of the need to improve MR imaging safety practices.³ Strong attractive forces associated with the main magnetic field create the possibility of dangerous projectile incidents if ferromagnetic objects are inadvertently allowed to enter into Zone IV. Because of the spatial gradient magnetic field,⁴ an unsuspecting individual transporting a ferromagnetic object may initially detect virtually no force on the object until it is suddenly and forcefully drawn toward the magnet. Time-varying gradient magnetic fields

^a Department of Radiology, Mayo Clinic, 200 First Street Southwest, Rochester, MN 55905, USA; ^b Department of Radiology, University of Washington, 4245 Roosevelt Way Northeast, Seattle, WA 98105, USA

* Corresponding author.

E-mail address: watson.robert16@mayo.edu

and radiofrequency (RF) magnetic fields can interact with implanted or on-planted devices and result in patient harm if not correctly recognized and accounted for. RF fields can also cause burns, which may be exacerbated by poor patient positioning or MR unsafe patient garments, jewelry, and other adornments.

Q10 In an effort to learn from past MR safety events,⁵ this report describes several MR imaging safety incidents from the authors' institutions. Contributing factors are detailed, and responses to these incidents that strive for safer practices going forward are described. These illustrative cases are of interest to the MR imaging safety community, especially in the context of new recommendations included in the ACR MR imaging safety committee document on MR safety.¹ For other pertinent incidents, the most commonly reported patient safety events are reported to the Manufacturer and User Facility Device Experience (MAUDE) database.⁶

Avoid Zone IV Doorway Ferromagnetic Object Breaches with a Barrier

Incident 1a

A wheelchair-bound, small-stature, low-weight outpatient child was to receive an MR imaging. The patient was changed into an MR imaging safe gown. The father wheeled the patient into Zone III in the patient's MR imaging unsafe wheelchair. The wheelchair was securely tethered to the wall with dedicated straps and clasps well away from the Zone IV door. The father, who was appropriately screened for MR imaging safety, was granted permission to stay with the child in Zone IV while the scan was being performed. The father carried the child from the tethered wheelchair to the docked MR imaging table. The scan was performed uneventfully. Although the technologist came into Zone IV at the conclusion of the study to attend to the child, the father, without being asked to do so, left Zone IV through the open door, untethered the wheelchair, and wheeled it back toward Zone IV. As he was crossing the threshold, the technologist noticed his presence and shouted for him to stop. A clinical assistant in the area heard this and guided the father and the wheelchair back to Zone III to retether it. An MR imaging conditional wheelchair was then used to remove the patient from Zone IV.

Incident 1b

A full-spine MR imaging examination was completed. The technologist entered Zone IV and began disconnecting monitoring leads from the patient. A second technologist was distracted by a physician phone call. At that time an emergency room float nurse entered the MR imaging

room through the open door with an MR-unsafe stretcher for patient transfer. The technologist attending to the patient was facing away from the nurse and stretcher but on turning around noticed it. The technologist quickly pushed the stretcher out of the magnet room.

Incident 1c

An incarcerated patient was admitted for MR imaging. The patient was waiting to be scanned while on the MR imaging table in Zone IV as the scanning technologists were making phone calls to the radiologist for protocol-related queries. During this time the corrections officer responsible for the patient, equipped with a firearm, restraining devices, and various other metallic devices attached to his person, walked into Zone IV through the open door to talk to the patient. One of the technologists saw the officer in the room and quickly followed and requested that he step out of the room due to the various potential projectiles. The corrections officer stepped out of the MR imaging room and when queried admitted that he had been told not to enter but had forgotten. The patient was removed from Zone IV and overseen by the corrections officer in the Zone III area while the technologists completed their remaining tasks. The patient was then scanned and left the department without further incident. Multiple corrections officers, the covering physician, and family members of the prisoner were made aware of this near miss that could have had serious consequences.

Learning points Additional instances of less ferromagnetic materials crossing the Zone IV threshold through an open Zone IV door while attending to patients have occurred, all without injury. In the aforementioned scenarios, had any of the ferromagnetic objects become projectiles, there was substantial risk of significant injury or death. A common factor in these events was while attending to their duties, technologists left the Zone IV entry point open to free passage, without any physical barrier. As a result, the authors' institutions have implemented new departmental policies for ensuring that free access through the Zone IV entry point is always restricted. This entails that either the Zone IV door is closed, that a barrier such as a bright yellow retractable safety strap or plastic chain is affixed, or responsible level 2 personnel are physically stationed at the doorway. This, along with appropriate updates to MR imaging safety training, are essential to reduce the chances of unintentionally bringing unsafe ferromagnetic objects into Zone IV. A common scenario is that despite being told repeatedly not to enter Zone IV, non-MR imaging personnel in

Zone III frequently forget, and a physical barrier at the door can prevent entry.

Since this policy was enacted it has been well received by MR imaging staff and compliance has been excellent. There was initial concern that technologists and others would resist taking the time to close the door or deploy the strap, but this has not been the case, and MR imaging staff seem to appreciate the augmented safety margin that this practice provides. Importantly, the update to the ACR MR imaging safety committee document on MR safety has specifically recommended the following:¹

Zone IV

The entry door to Zone IV (MR system room) should be closed except when it must be open for patient care or room/MR system maintenance. During the times that the door to the MR system room must remain open, a "caution" barrier is recommended at the entry to Zone IV to inhibit unintended passage of personnel and/or materials from Zone III to IV. Examples of caution barriers include easily adjusted straps or plastic chains secured across the scanner room doorway.

The institutions have also adjusted policy to ensure enhanced vigilance with regard to prisoners and corrections officers. As a preliminary measure, nonferrous restraining devices are requested of the corrections department for the MR imaging scan. Thorough MR screening of the patient and the accompanying correctional officer occurs in Zone II. All efforts to restrict ferrous materials from entering Zone III are made to avoid the possibility that they could become projectiles, and the officer is educated on this possibility with additional emphasis if the ferrous objects, including firearms, are absolutely essential in Zone III to maintain security. This conforms with recommendations in the update to the ACR MR imaging safety committee document on MR safety:¹

Patient and Non-MR Personnel Screening

Guidance on the management of prisoners with restraints undergoing MR examinations has also been previously detailed.⁷⁻¹⁰ However, guidance on prison or security personnel weapons (ie, firearms) has not been previously mentioned. Ferromagnetic firearm weapons should not be permitted into Zone III unless deemed absolutely essential for maintenance of security due to the design of the facility. Furthermore, ferromagnetic firearms that are loaded pose a serious threat in Zone IV (the MR system room) due to the possibility of inadvertent discharge.¹¹

A Full-Stop/Final Check at the Zone IV Door Can Ensure Unwanted Metals Are Restricted Access

Incident 2a

A patient was brought from the emergency room with a leg in traction for an MR imaging scan. Orthopedics was called to remove the traction device from the patient before entry in Zone IV. The apparatus that hooks to the Steinman Pin was removed from the patient, wrapped in a towel, and left within blankets between the patient's legs. The admitting technologist did not notice this apparatus as the patient was brought into Zone IV. The patient was positioned on the MR imaging table, and when brought toward the scanner, the device was pulled from the blankets toward magnet, striking the patient's perineal area before becoming affixed to the magnet. The patient was not significantly injured.

Incident 2b

An intubated inpatient was transported from the emergency department to MR imaging room for a brain scan. Multiple staff in Zone III, including nurses, technologists, assistants, and an interpreter in Zone III engendered a complicated patient preparation scenario. In the process of screening and bringing the patient into Zone IV, an MR imaging unsafe intravenous (IV) pole was brought into the scan room by an MR imaging technologist. The pole was pulled away from the technologist and patient toward the magnet, becoming affixed to the magnet bore. The lines from the IV pole were carefully removed from the pole, and the patient was removed from the scan room safely. The patient was unharmed. The magnetic field needed to be ramped down by vendor service engineers until the pole could be safely removed from Zone IV.

Incident 2c

An interventional MR imaging site has a 3T magnet MR imaging separated by laterally sliding doors from an operating room (OR). In addition to laser ablation and focused ultrasound cases, the site is used frequently to assess for extent of tumor resection. Patients are MR scanned with the surgical wounds still open, and the patient may return to OR if imaging demonstrates subtotal resection.

One complex tumor resection case lasted in excess of 12 hours. The patient was being readied for transfer to MR imaging to assess extent of tumor resection. Some personnel had left for the day, including those associated with electromyography (EMG) monitoring of the patient. Leads attached to the patient that are normally removed by the EMG personnel had remained in place. A

certified registered nurse anesthetist (CRNA), working well beyond normal working hours, assisted by finding a pair of small scissors and cutting the leads near the patient's skin surface. The patient was prepared for transfer into Zone IV by OR staff, and a time-out, controlled by a level 2 technologist serving as the MRSO, was performed on the CRNA before crossing the threshold into Zone IV. All pockets were patted down and the CRNA was deemed safe to proceed. The CRNA was wheeling anesthesia equipment into Zone IV ahead of the patient, and it was at this time that a projectile was seen flying into the bore of the magnet. The CRNA and MRSO found the small scissors in the bore, and with considerable effort, pulled them off the bore and walked them out of the room, well away from the patient and other personnel. The patient was then scanned uneventfully and returned to the OR for wound closure.

Root cause analysis revealed that the CRNA had mistakenly placed the scissors in a top front pocket of their scrubs, behind folded papers with patient notes. The pocket was patted down during the time out before crossing the threshold into Zone IV, but due to the papers in front of the scissors, the scissors were not detected.

Learning points These 3 events shared the common theme of projectile events occurring in the context of scanning complex, nonroutine patients. Evolving and improving MR imaging safety practices, along with awareness of the significantly increased risks in such scenarios, can be anticipated to lessen the chances of similar incidents going forward. Although MR imaging personnel clearly understand the risks of unsafe ferromagnetic materials entering Zone IV, and generally are excellent at screening for such unsafe items, in complex situations, safety gaps can occur. For this reason, strict procedures and checklists should be implemented and adhered to. In especially challenging scenarios, as in intraoperative MR imaging settings, and in hybrid procedural suites, identifying a designated MRSO as the point person whose role it is to ensure safety of the team and the patient should be strongly considered. This can address distractions and unusual circumstances that could derail MR safety efforts if not approached in a systematic manner.

The updated ACR guidance document on MR safe practice now recommends that there be a "full-stop and final check" before patients, staff, and equipment can access Zone IV.¹ This states:

Full-Stop and Final Check

Some instances where the patient is sedated or anesthetized, an inpatient, or an

emergent case, a "full-stop and final check" performed by the MR imaging technologist along with support staff is recommended to confirm the completion of MR safety screening for the patient, support equipment, and personnel MR screening immediately prior to crossing from Zone III to Zone IV. "Full-stop and final check" may also be useful for non-sedated outpatients and inpatients prior to movement from Zone III to Zone IV. The purpose of this final check is to confirm patient name, ensure that all screening has been appropriately performed, and that there has been no change in patient and/or equipment status while in Zone III.

In addition to the full-stop and final check, extensive testing of any equipment in the MR environment and appropriate MR safety labeling should be performed. Any materials needed that are MR imaging unsafe, such as the IV pole in case 2b, should be removed from the department and replaced with MR imaging safe or conditional ones.

The intraoperative MR imaging environment requires constant assessment to identify additional essential safety measures. MR imaging personnel now wear pocketless scrubs. Ferromagnetic detector screening of personnel traversing from Zone III to IV has been implemented. For excessively long surgical cases, if the neurosurgeon does not expect to resect additional tumor, regardless of what an MR imaging would show, MR imaging is being deferred until the next day to minimize chances that fatigue could play a contributory role in an MR imaging safety incident.

Finally, in situations where ferromagnetic material is affixed to the bore, special safety considerations should be undertaken before attempts to remove the object. Moving a ferromagnetic object across the rapidly changing spatial magnetic gradient field near the opening of the magnet bore can cause unpredictable torque and force on an object. This creates a risk that the object may break free from the individual's grasp and become a dangerous projectile *once again*, with risk of injury to personnel or a patient in proximity. At the authors' institutions, MR imaging service personnel are consulted in such a situation and they handle rare removal of ferromagnetic objects from the bore.

Appropriate Transmit Coil Insulation Is Essential to Avoid Radiofrequency RF Burns

Incident 3a

An outpatient was to receive an elbow MR imaging examination. The patient had a prosthetic leg

and was wearing athletic stretch leggings. The medical assistant (MA) directed the patient to a changing room to remove all clothing and put on a gown, per protocol. Patient changed as directed but did not remove the athletic leggings. The MR imaging technologist and MA brought the patient into the examination room to be positioned for the elbow examination following safety screening. It became clear later that the patient's lower back was in proximity to the bore with apparently only a bedsheet between the patient and the bore. The scan commenced, and the scanning MR imaging technologist handed off the case to another technologist midway through the case. The patient was verbally checked 3 times during the examination without reported issue. The patient began to move toward the end of the last MR imaging sequence and mentioned that it was warm, but the technologist did not hear this. The technologist asked the patient to keep still, stating that it was almost over. Patient complied and, again, never mentioned warmth or discomfort. When the technologist came to remove the patient from the scanner, the patient was sweaty and mentioned a burning sensation perceived as friction around the upper margin of the leggings that had caused motion during the scan. The supervising technologist was alerted, and a radiology nurse and fellow determined the area of warmth to be a burn posterior to the patient's left hip. A follow-up visit was arranged by the MRMD for the patient to be examined by a dermatologist. It was not clear if the leggings contained metallic fibers potentially contributing to the burn or if the mechanism was solely a result of proximity to the bore, being separated only by the sheet.

Incidents 3b

Several additional skin burns have occurred in a similar fashion to the one described in incident 3a related to improper pad positioning. Notably, in one case, a burn resulted despite proper positioning of a pad that was subsequently found to be worn out, permitting skin to be in unsafe proximity to the bore wall.

Learning points Burns are the single most common adverse event reported to the Food and Drug Administration MAUDE database,⁶ and there are many actions that should be followed to avoid their occurrence. For most MR imaging examinations, the transmitting RF coil is housed within the magnet bore and can induce electrical currents in any conductive substance nearby. Excessive heating can occur in subcutaneous fat, where there is a relative paucity of pain

receptors, such that significant burns may be evolving before being detected by the patient. There are even greater risks in the setting of anesthetized patients who cannot sense a burn in progress. The patient should be separated from contact or proximity with the magnet bore with an appropriately thick layer of padding to prevent burns, as discussed in the updated ACR guidance document on MR safe practices.¹

Burn Prevention

To help safeguard against thermal injuries or burns, insulating pads should be placed between the patient's skin and any transmit RF coil located behind the walls and ceiling of the bore of the magnet system, especially the area of the transmit RF body coil, to ensure spacing between the bore wall and the patient's skin. A single-layer bed sheet is insufficient insulation or spacing. It is also important to recognize that large conducting loops may be created within the patient's own tissues by points of skin-to-skin contact, such as thigh-to-thigh contact. Thus, providing insulation in such areas may also be required to prevent burns. To prevent excessive heating and possible burns in patients in association with MR procedures, the previously published guidelines are recommended.¹²

Also, in an effort to prevent patient burns, it is essential that patients remove clothing and be fully gowned before entry into Zone IV due to the increasing prevalence of metallic fibers in clothing.¹³ The updated ACR guidance document on MR safe practices now makes explicit gowning recommendations that warn about new synthetic types of clothing that use metallic thread.¹

Patient and Non-MR Personnel Screening

Some materials used in clothing have been increasingly associated with thermal injury and/or burns in patient's undergoing MR imaging. Additionally, recent trends in the manufacturing of clothing and other related products have incorporated ferromagnetic and/or conductive materials (eg, antimicrobial silver and copper) that are not reliably disclosed in labeling.¹³ Such clothing products include, but are not limited to, sportswear (including underwear), brassieres, orthotic-related items (eg, stump covers or stump shrinkers), and blankets.¹⁴ Reliance on clothing labeling is not sufficient, as the Federal Trade Commission (FTC) "guidelines"

allow clothing to contain as much as 5% impurities, which could be significant for a patient undergoing an MR imaging examination.¹⁵ For areas in or around the volume of transmitted RF power, we recommend patients wear only MR-Safe gowns or scrubs supplied by the imaging facility.

Screening Considerations and Potential Utility of Ferromagnetic Detection

Incident 4a

A research subject reported to MR imaging mid-morning for a noncontrast head scan. Before reporting, there was awareness of an implanted and inflatable penile prosthesis identified to be MR imaging conditional, requiring no special scanning that would affect the planned research scan. No other special notations were included on the patient's written MR imaging safety screening form that was completed immediately before the scan. The patient is changed out of street clothes into the required MR imaging safe hospital gown, leaving underwear on. Because no contrast was being administered, there was no assessment by Radiology Nursing before the MR imaging. On verbal screening by the technologist, the patient again noted the presence of the penile prosthesis but disclosed nothing else of concern. The MR imaging scan was performed uneventfully. When the technologist went into the room following the scan, a lump at the waistline under the patient's gown was noted and the technologist discovered the presence of an insulin pump. The patient was removed carefully from the room, ensuring that the pump would not become a projectile. The patient examined the pump, stated that they had forgotten about it at the time of screening, and noted that it seemed to be functional. The technologist released the patient without notifying a radiologist who was immediately available and on site.

Late in the afternoon of the same day, the patient reported to the emergency department with a chief complaint of severely fluctuating blood glucoses, being intermittently markedly hyperglycemic with blood glucose in the 400s mg/dL, as well as hypoglycemic, with a reading in the low 30s mg/dL. At this time, it was recognized that the insulin pump that had been exposed to the MR imaging environment was no longer reliable. The patient was admitted to hospital to ensure medical stability while a new pump was obtained. The following day the patient was released in good condition.

Incident 4b

A 65-year-old patient was admitted for an abdomen MR imaging. The patient had been screened multiple times for metallic devices, although none were reported aside from an insulin pump on the right side of the abdomen. This was removed before scanning, leaving only the port. During the first scout, image distortion and signal loss reminiscent of metal artifact was observed on the patient's left side, which did not correspond to the location of the insulin port. The technologist queried the patient as to whether there was anything unreported during screening that was brought into the scanner room. The patient stated that there were no pumps, belts, or other devices brought into the scan room, aside from a wedding ring on the left hand. The technologist entered the scanner room, removed the ring, palpated the region around the left iliac wing, and felt nothing of concern. The technologist then ran another scout and observed that artifacts remained in the images. Technologist then inspected a recent computed tomography image of the patient and noticed metallic artifact on the lower left abdomen region, just above the left iliac wing. The technologist again queried the patient, and the patient responded that there was indeed a glucose monitor on the left side. The technologist removed the glucose monitor, and the scan was completed without further incident. The supervising technologist was alerted to the incident.

Learning points Not only are electronic implanted devices becoming more prevalent, but on-planted devices are as well. These cases highlight potentially dangerous consequences of inadvertently scanning patients with insulin pumps and associated glucose monitors. Insulin pump exposure to the MR imaging environment can alter the pump's functionality in unpredictable and hazardous ways, potentially causing life-threatening scenarios. The literature associated with the specific pump in the first incident, a Medtronic MiniMed Paradigm Revel 723 insulin pump, states that the pump should not be exposed to MR imaging or other devices that generate strong magnetic fields since the motor could be damaged and should be removed and kept outside the magnet room. It also noted that inadvertent exposure to MR imaging requires that device usage be discontinued and a 24-hour manufacturer hotline contacted. The glucose monitor in the second incident was also a concern, as it slipped by the various screening procedures undetected, and in addition to subsequent reliability concerns, could potentially cause heating or force hazards on top of the artifacts observed.

Root cause analysis of these events demonstrated a relative lack of awareness of potential severe consequences of inadvertently scanning patients with glucose monitoring equipment among technologists and radiologists. Hazard avoidance includes enhanced MR imaging safety educational efforts and augmented screening procedures. Improved screening includes updated screening forms, inclusion of device-specific information in electronic medical records, ferromagnetic-sensitive detectors, visual inspection, pat-downs, and additional verbal queries before entering the scan room. The MR imaging safety screening forms for both sites were changed to include specific questions querying the presence of insulin pumps and glucose meters, and plans were made to inquire as to whether the patient is diabetic to further identify such devices. Preliminary evidence suggests that ferromagnetic detectors can be valuable in identifying the presence of on-planted insulin pumps.

SUMMARY

As MR practices become increasingly complex, MR safety practices must continue to evolve to meet the associated challenges. It has been the intent of this article to describe real clinical scenarios that are being addressed with improved safety procedures that are in accordance with updates to the ACR guidance document on MR safe practices.¹ Sites that implement restricted access of the Zone IV doorway, a full-stop/check before entering Zone IV, screening for on-planted devices, proper separation from the bore wall, and appropriate patient gowning can help maintain a safe MR environment, benefiting patients and staff alike.

Clinics Care Points

- In the typically relatively short time that the entry door to Zone IV (MR system room) must be open (eg, for patient care), a physical "caution" barrier can help prevent unintended passage of unsafe personnel or ferromagnetic materials.
- Particularly in the acute or intraoperative environment, a full-stop/final check at the Zone IV door can help ensure unsafe items are identified and prevented from entering.
- Proper padding between the bore wall and potentially points of conductive skin to skin contact can prevent radiofrequency burns. A single bed sheet is not sufficient to prevent bore wall RF burns.

- In addition to surgically implanted devices, it is essential to recognize important MR imaging safety issues associated with "on-planted" devices, such as insulin pumps and continuous glucose monitors. There can be significant damage to the devices if exposed to MR imaging, potentially putting the patient at risk.

DISCLOSURE

The authors declare that they have no conflicts of interest or funding to disclose.

REFERENCES

1. ACR Committee on MR Safety, Greenberg TD, Hoff MN, et al. ACR guidance document on MR safe practices: updates and critical information 2019. *J Magn Reson Imaging* 2020;51(2):331–8.
2. Occupational Outlook Handbook: Radiologic and MRI Technologists. US Bureau of Labor Statistics. 2019. Available at: <https://www.bls.gov/ooh/healthcare/radiologic-technologists.htm>. Accessed March 28, 2020.
3. Cross NM, Hoff MN, Kanal KM. Avoiding MRI-related accidents: a practical approach to implementing MR safety. *J Am Coll Radiol* 2018;15(12):1738–44.
4. Shellock FG, Kanal E, Gilk TB. Regarding the value reported for the term "spatial gradient magnetic field" and how this information is applied to labeling of medical implants and devices. *AJR Am J Roentgenol* 2011;196(1):142–5.
5. Watson RE. Lessons learned from MRI safety events. *Curr Radiol Rep* 2015;3:37.
6. Delfino JG, Krainak DM, Flesher SA, et al. MRI-related FDA adverse event reports: a 10-yr review. *Med Phys* 2019;46(12):5562–71.
7. Expert Panel on MR Safety, Kanal E, Barkovich AJ, et al. ACR guidance document on MR safe practices: 2013. *J Magn Reson Imaging* 2013;37(3):501–30.
8. Kanal E, Barkovich AJ, Bell C, et al. ACR guidance document for safe MR practices: 2007. *AJR Am J Roentgenol* 2007;188(6):1447–74.
9. Kanal E, Borgstede JP, Barkovich AJ, et al. American College of Radiology White Paper on MR Safety: 2004 update and revisions. *AJR Am J Roentgenol* 2004;182(5):1111–4.
10. Kanal E, Borgstede JP, Barkovich AJ, et al. American College of Radiology White Paper on MR safety. *AJR Am J Roentgenol* 2002;178(6):1335–47.
11. Kanal E, Shaibani A. Firearm safety in the MR imaging environment. *Radiology* 1994;193(3):875–6.
12. Shellock FG, Cruess JV. MR procedures: biologic effects, safety, and patient care. *Radiology* 2004;232(3):635–52.

13. Pietryga JA, Fonder MA, Rogg JM, et al. Invisible metallic microfiber in clothing presents unrecognized MRI risk for cutaneous burn. *AJNR Am J Neuroradiol* 2013;34(5):E47–50.
14. Bertrand A, Brunel S, Habert MO, et al. A new fire hazard for MR imaging systems: blankets-case report. *Radiology* 2018;286(2):568–70.
15. Federal Trade Commission. Threading Your Way Through the Labeling Requirements Under the Textile and Wool Acts. Federal Trade Commission. 2020. Available at: <https://www.ftc.gov/tips-advice/business-center/guidance/threading-your-way-through-labeling-requirements-under-textile>. Accessed March 20, 2020.

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electronic medical records, and increasing numbers of implanted devices, increase chances of MR imaging safety event occurrence. Several MR imaging safety incidents are described in this article, including the safety conditions and other factors that contributed to the events. MR imaging safety policy and procedural improvements that address these are also described. Specific revision points in the American College of Radiology Guidance document on MR safe practices are viewed in the context of these events, with emphasis on how their implementation could reduce probability of similar event recurrence.

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