

MRI Safety Considerations in the Perspective of MRI Technologist

Nisha T K

Assistant Professor, Mangester College of Paramedical Science, Ettumanoor, Kottayam District, Kottayam, Kerala-686631, India

DOI: <https://doi.org/10.5281/zenodo.15658844>

Published Date: 13-June-2025

Abstract: Magnetic Resonance Image is a commonly used diagnostic technique recognized for its non-ionizing properties and exceptional image quality. The MRI environment presents several intrinsic safety hazards that must be meticulously handled to safeguard both patients and healthcare staff. This paper analyzes essential MRI safety factors from the viewpoint of MRI technicians, emphasizing issues such as Specific Absorption Rate, time-varying magnetic fields (MFs), acoustic noise, and radiofrequency (RF) exposure. It examines actual case studies of MRI-related incidents and underscores the need of stringent safety standards, equipment compatibility, and awareness of implanted medical devices. The assessment also addresses patient preparation, environmental safety in MRI suites, and the changing responsibilities of technicians in maintaining operational safety. The results emphasize the need for continuous education, uniform methods, and interdisciplinary cooperation to improve safety standards in MRI settings. The research highlights the essential role of MRI technicians in promoting a safety culture within contemporary imaging practices via an integration of current literature, regulatory standards, and incident evaluations.

Keywords: MRI Safety, MRI Technologist, Specific Absorption Rate, Radiofrequency Burns, Ferromagnetic Projectiles, Patient Safety.

1. INTRODUCTION

MRI is a potent diagnostic instrument extensively used in contemporary medical practice as seen in figure 1. Nonetheless, despite its non-ionizing characteristics, MRI poses many safety problems that must be meticulously managed to safeguard the health of both patients along with healthcare providers. From the perspective of an MRI technician, comprehending and alleviating these hazards is essential for ensuring a secure imaging environment (Korutz et al., 2017).

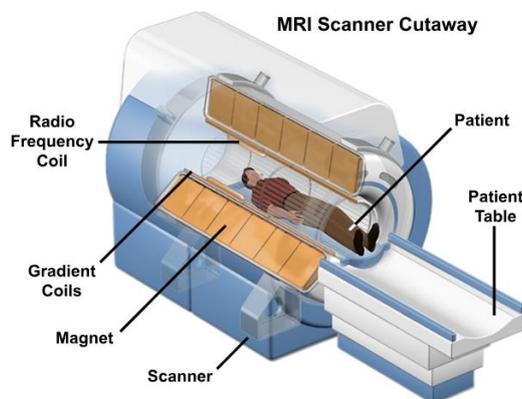


Figure 1. Magnetic Resonance Imaging¹

¹ <https://nationalmaglab.org/magnet-academy/read-science-stories/science-simplified/mri-a-guided-tour/>

This review paper examines essential safety considerations during MRI scanning, emphasizing critical factors such as the Specific Absorption Rate (SAR), time-varying magnetic fields, acoustic noise, and radiofrequency (RF) irradiation, are all critical factors that can affect patient safety during MRI. Each of these components contributes to potential biological effects or physical risks, and they are closely monitored and regulated in clinical MRI settings. All of which may result in thermal injuries, peripheral nerve stimulation, and auditory damage if inadequately addressed. The study also includes real-world case studies of accidents that underscore the repercussions of safety protocol violations and emphasize the need of rigorous compliance with safety rules (Sammet, 2016).

Patient safety measures are analyzed, distinguishing between closed and open MRI systems, since the scanner's physical layout might affect patient comfort, risk exposure, and procedural planning. The environmental safety of the MRI suite is a critical priority, emphasizing equipment compatibility, the safe handling and storage of cryogenic chemicals like helium, and stringent regulation of ferromagnetic (FM) materials inside the MF environment.

This paper looks to thoroughly examine and stress the main safety concerns regarding MRI from the viewpoint of MRI technicians. It emphasizes technical and procedural elements, assesses dangers related to MRI settings, and examines ways for improving safety via education, policy, and practical measures. This research utilizes a review technique to analyze existing scientific literature, clinical recommendations, safety standards, and case studies. Sources were chosen from reputable medical imaging publications, regulatory organizations counting the American College of Radiology (ACR), and event registries that record MRI-related mishaps (Cross et al., 2018).

2. OVERVIEW OF MRI TECHNOLOGY

Magnetic Resonance Imaging (MRI) was widely recognized for its diagnostic efficacy and non-ionizing nature; however, its operational environment presents numerous safety challenges that have been well-documented in the literature. Panych and Madore (2018) comprehensively analyzed the primary risks associated with MRI, such as the transformation of everyday objects into projectiles, RF-induced burns, gradient-induced nerve stimulation, and auditory damage from brash acoustic noise. Their review emphasized the need to bridge the gap between practical clinical protocols and the underlying electromagnetic physics, arguing that enhanced intuition in electromagnetic principles can support safer practices in MRI environments. The authors structured their work around the hazards posed by the three main electromagnetic fields (EMFs) involved in MRI: the static MF, the RF excitation field, along with the gradient fields (GFs). The static MF (B_0), typically ranging – 1.5T - 7T or even higher, exerts strong forces on ferromagnetic objects, which can turn everyday items into dangerous projectiles, and can interact with metallic implants, leading to displacement or malfunction. The RF excitation field, used to flip hydrogen nuclei during imaging, contributes to specific absorption rate (SAR) and can cause tissue heating or burns, particularly in patients with conductive materials like implants or loops formed by cables or body posture. The GFs, which are time-varying MFs used for spatial encoding, can induce peripheral nerve stimulation (PNS), discomfort, and even muscle contractions, while also generating acoustic noise levels that may lead to hearing damage. These electromagnetic fields, though essential for image acquisition, can interact with biological tissues and medical devices in potentially harmful ways.

Similarly, Cross et al. (2018) emphasized that MRI, particularly due to its reliance on superconductivity to generate strong and uniform magnetic fields, presents considerable safety risks. These include magnetic forces on ferromagnetic materials, RF-induced heating and burns, peripheral nerve stimulation, along with acoustic noise hazards. A notable concern outlined in their study was the inadvertent exposure of a diverse group of individuals—patients, staff, and physicians—to the MRI environment, increasing the likelihood of accidents due to external metallic objects or implants.

In the context of ultra-high field MRI, Hoff et al. (2019) investigated the safety challenges associated with 7-Tesla (7T) MRI systems, which, despite gaining clinical approval, introduced heightened risks due to stronger magnetic fields. These included intensified interactions with metallic implants and increased RF energy deposition, leading to a greater prevalence of physiological effects such as vertigo, dizziness, and magnetophosphenes. The study called attention to the urgent need for safety strategies tailored to ultra-high-field environments to protect patients and healthcare professionals.

Mittendorff et al. (2021) discussed MRI technologists' evolving role in ensuring safety, particularly as rapid advancements in imaging and implant technologies demanded a broader and deeper knowledge base. Their review highlighted the critical need for MRI technologists to understand MRI operations' physical principles and to stay informed about emerging technologies and safety standards. The paper underscored the importance of continuous education to meet growing safety expectations and ensure best practices in the MRI suite.

Expanding on individual safety in the workplace, Almalki et al. (2022) focused on the occupational hazards faced by lone MRI technologists inside Southern Saudi Arabia. Through a cross-sectional study involving 73 technicians across 23 hospitals, the authors found a significant correlation between lone working conditions and elevated rates of accidents and errors. Their findings revealed that 84% of technicians had experience working alone, with a higher incidence of adverse events in private hospitals.

Building on the theme of professional readiness, Mittendorff et al. (2023) assessed MRI technologists' preparedness inside New Zealand along with Australia to manage safety challenges amidst technological advancements. Through a comprehensive questionnaire distributed to over 300 MRI professionals, the study revealed that while most respondents exhibited confidence in their decision-making, discrepancies existed in the accuracy of safety knowledge across subgroups. The research affirmed that formal education had generally prepared MRI technologists to operate safely, though ongoing professional development was deemed essential for maintaining high safety standards.

Collectively, these studies underscore the multidimensional nature of MRI safety, encompassing both technical and human factors. The literature highlights a recurring theme: the critical importance of integrating theoretical knowledge, regulatory frameworks, and practical training to foster a culture of safety in MRI environments. As MRI technology continues to evolve, so too must the approaches to risk management, technician education, and institutional protocols to safeguard both patients and healthcare professionals.

A comparative table summarizing and the key aspects of the literature reviewed as seen in table 1.

Table 1. Comparative study

Study	Focus Area	Identified Risks	Key Findings	Recommendations / Conclusions
Panych & Madore (2018)	MRI safety hazards based on electromagnetic principles	Projectile objects, RF burns, nerve stimulation, auditory damage	Emphasized the gap between practical risk management and fundamental physics; provided insight into hazards from static, RF, and gradient fields	Recommended cultivating intuition about electromagnetism; bridging physics and clinical practice
Cross et al. (2018)	Risk management and safety programs in MRI environments	Magnetic attraction, heating, nerve stimulation, noise, contrast agents	Documented frequent incidents; emphasized exposure of patients and staff to continuous magnetic fields	Advocated for strict protocols, structured supervision, and adherence to regulatory standards (e.g., ACR, The Joint Commission)
Hoff et al. (2019)	Safety issues in 7T ultra-high-field MRI	Metallic implant interactions, RF heating, vertigo, dizziness, nausea, visual effects	Identified heightened bioeffects at 7T compared to lower fields	Called for specific safety strategies for ultra-high-field MRI environments
Mittendorff et al. (2021)	MRI technologist responsibilities and safety knowledge	General MRI-related hazards; evolving technology risks	Highlighted increased responsibility of MRI technologists; noted need for expanded knowledge base	Stressed ongoing education in MRI physics and emerging technologies
Almalki et al. (2022)	Risks of lone MRI technicians in Saudi Arabia	Projectiles, burns, human error	Lone workers experienced higher accident/error rates; many lacked proper safety training	Suggested policy changes, better training, and discouragement of solitary work environments
Mittendorff et al. (2023)	Readiness of MRI technologists inside NZ and Australia	Inconsistent safety knowledge, confidence gaps	Education prepared most techs, but accuracy of safety decision-making varied	Encouraged continuous education; pointed out need for targeted improvements in training accuracy

3. KEY MRI SAFETY CONCERNS

Lowering Burn Incidence

The FDA identifies second-degree burns as the most often reported MRI safety concern. Burns related to the MRI's RF field may manifest in many ways, the most apparent being when a patient contacts the bore throughout scanning. A lone bedsheet is insufficient to shield a patient directly from near-field burns; included insulated pads about one inch thick must be used to prevent burns caused by dangerous bore closeness. This is particularly critical if patient is anesthetized. If insulating padding dislodges as patient is moved into the magnet, then a body component may come into contact with the bore, potentially causing a serious burn, particularly because the patient may not respond to the heat. Patients' thighs or other body regions must not make contact, since places of skin-to-skin contact may serve as loci for heating along with burns resulting from RF energy-triggered current loops inside the body (Sotardi et al., 2019).

Avoiding Projectile Incidents

Projectiles provide a further source of MR-linked injuries and fatalities. This happens when FM items, such as oxygen canisters, are rapidly drawn crossways the room towards the MRI scanner (MRIS) and then collide with an individual present in the vicinity. An MRIS is a very strong magnet that remains activated regardless of whether the unit is operational. This is a crucial awareness and safety principle that must be understood by all those operating in the imaging suite. The ACR has delineated four safety zones inside MRI facilities. So, they are designated as Zones 1 to 4 (Z1, Z2, Z3, Z4), according to raising degrees of MF exposure. Z4 contains the MRI apparatus, serving as both the 'magnet chamber' and the 'projectile zone.' Dr. Watson said that if a someone enters Zone 3 with a hazardous ferromagnetic item while the entrance to Z4 remains open and unguarded, it creates the potential for a significant projectile event. The judicious use of ferromagnetic detecting technologies may mitigate this danger (Korutz et al., 2017).

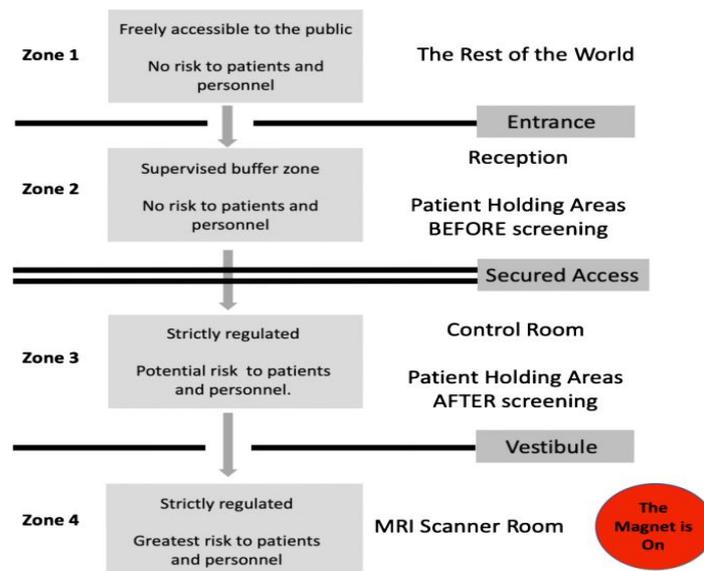


Figure 2. MRI Safety program (Sotardi et al., 2019)

Understanding Recommendations on Implanted Devices

Radiologists must be cognizant not only of external metallic objects on the patient's body but also of the internal contents inside the patient. Certain implanted devices may jeopardize a patient's life if scanning is conducted improperly. Implanted devices are classified into three classes: MRI safe, then MRI unsafe, or even MRI conditional. It is predicted that around 75% of patients having CIEDs, including pacemakers along with defibrillators, will require an MRI at some stage in their lives. Although previously deemed dangerous for MRI, several contemporary cardiovascular implantable electronic devices (CIEDs) along with intracardiac leads now include MRI conditional labeling. Recent evidence, endorsed by various organizations such as the International Society for Magnetic Resonance in Medicine, and the Heart Rhythm Society, along with the ACR MR Safety Committee, indicates that patients having cardiac devices designated as MRI unsafe could still undergo scanning safely inside a controlled setting. This entails appropriately configuring the CIED, doing scans under the correct MR circumstances, and continuous patient monitoring (Mervak et al., 2019).

Focusing on MRI Safety Awareness

Although burns, and projectiles, along with implanted devices ubiquitously documented reasons for MRI-linked injuries along with fatalities, several radiologists concur fundamental danger lies in insufficient education, communication, and standardization about MRI safety. In response, several organizations along with societies, counting RSNA, include specialized MR safety seminars into their yearly meetings. So, the ACR MR Safety Committee regularly revises the Manual on MR Safety, while the American Board of Magnetic Resonance Safety (ABMRS) administers official examinations for applicants to validate their expertise in MR safety responsibilities². Comprehending Z1 - Z4 and establishing thorough procedures is crucial, and there is consensus that employing trained MR medical directors, and MR safety officers, along with MR safety specialists is vital for fostering a secure workplace (Sammet and Sammet, 2015).

Case Studies of MRI-Related Accidents

1. A tragic recent event that garnered attention in several Indian along with international publications was a 32-year-old guy's death who went inside MRI room to see his elderly relative all the while transporting an oxygen cylinder³. Television reports indicated the victim's hand was ensnared inside machine right when the compromised cylinder ruptured, resulting in noteworthy oxygen loss. Despite being sent to the medical hospital within 10 minutes, he was pronounced dead (Malloy, 2018).
2. A recent event inside Sri Lanka included a 5-year-old child's death during an MRI exam. The specialists concluded that the fatality was caused by the release of quench-cryogen gas right into MRI room, which displaced oxygen (Malloy, 2018).
3. Fatal accidents have also been documented in other regions globally. In 2001, a 6-year-old kid was fatally injured in an MRI-linked incident inside New York in USA. The fatality cause – oxygen canister that became guided missile due to MRI magnet. The youngster sustained a fatal head injury, resulting in his death (Millburg, 2018).
4. There has been a noteworthy hike in the incidence of MRI-related mishaps in recent years. Recent database research indicated an 185% increase in MRI incidents likened to prior years. So, this rise was ascribed to the augmented installation of MRI apparatus and the absence of organized training programs for all personnel at MRI imaging facilities (Peck, 2018).
5. A primary problem with MRI safety happens to be the "missile effect. The "missile effect" transpires as a result of the peripheral field constituent of the static MF of an MRI machine, which swiftly draws a FM item inside scanner with considerable force. Said kind of missile impact might render MRI procedures contraindicated for individuals with orthopedic implants, and materials, and equipment. Fortunately, the majority of said devices are constructed from non-FM materials, therefore not disrupting MRI processes (Bloom, 2018).

4. PATIENT SAFETY PROTOCOLS

Safety Instructions for Patients

Patient education is necessary prior to MRI testing. Technologists must educate patients on the technique, anticipated feelings, and the need of remaining motionless. Screening forms must evaluate for implants, foreign objects, and previous surgical procedures. Pre-scan instructions must include the removal of metallic items and the donning of MRI-compatible clothes (Grover et al., 2015).

Closed vs. Open MRI: Risk and Comfort Considerations

Closed MRISs provide high-resolution pictures but may induce claustrophobia. Open MRI systems provide enhanced comfort for some individuals; nevertheless, they may exhibit worse picture quality. Technologists must evaluate patient tolerance and clinical needs to choose the suitable modality.

MRI Safety for Ancillary Equipment (AE) and Implants

AE must satisfy one of three criteria: a manufacturer's safety statement, FDA clearance, or prior testing. "Manufacturer declaration" signifies that the producer has evaluated AE for safety. Metallic implants may attain considerable torque inside

² <https://www.rsna.org/news/2022/june/mri-safety-issues>

³ <http://www.telegraph.co.uk/news/2018/01/29/indian-man-dies-freak-mri-machine-accident-mumbai-hospital>

MFs, presenting hazards if not securely fastened. The kind of metal influences the MF's impact on the implant. Intense MFs may induce considerable deflection inside ferrous metals. Simultaneously, nonferrous metals are prone to heat accumulation in the MRI setting as a result of RF absorption (Jabehdar Maralani et al., 2020).

Comprehending the interplay between diverse medical implants along with the MRI setting may assist healthcare practitioners in improving patient safety while preserving imaging standard. Presented below are essential deliberations for many categories of implants along with devices.

1. Aneurysm Clips (ACs)

The substance of the AC mostly influences its safety in the MRI setting. FM clips, such as those composed of certain stainless-steel varieties, provide significant hazards and are contraindicated. Non-FM or weakly FM clips, such as certain metals or titanium, are often considered safe. An MRI utilising ACs should only be conducted after verifying that the clip type is nonferrous (Hofman et al., 2024).

2. Hemostatic Vascular Clips

Hemostatic clips, often composed of non-FM materials, exhibit no deflection inside MFs and are deemed safe inside MRI settings (Peschke et al., 2021).

3. Intravascular Coils, Filters, and Stents

Certain intravascular devices are FM and may get entrenched in vessel walls over time, therefore dropping the danger of dislodgement. MRI is generally safe for individuals using said devices after an adequate post-implantation interval.

5. CONCLUSION

The safety of MRI is a crucial and complex issue requiring continuous monitoring, comprehensive understanding, and strict compliance with established guidelines. This study highlights the crucial function of MRI technicians in recognizing and addressing safety risks, such as burns from RF exposure, injuries from ferromagnetic projectiles, and issues related to implanted medical devices. The study identifies deficiencies in training, communication, and enforcement of safety measures via a thorough investigation of recorded accidents and existing safety policies. Establishing a secure MRI environment requires a cooperative strategy, including revised regulations, ongoing professional advancement, and technical cognizance. As MRI technology advances, safety standards must also progress, supported by knowledgeable and well-trained technicians who are at the forefront of patient care and operational management.

REFERENCES

- [1] Sammet S. Magnetic resonance safety. *Abdom Radiol (NY)*. 2016 Mar; 41(3):444-51.
- [2] Korutz AW, Obajuluwa A, Lester MS, McComb EN, Hijaz TA, Collins JD, Dandamudi S, Knight BP, Nemeth AJ. Pacemakers in MRI for the Neuroradiologist. *AJNR Am J Neuroradiol*. 2017 Dec; 38(12):2222-2230.
- [3] Mittendorff, L., Young, A., Lee, A., & Sim, J. (2023). New Zealand and Australian MRI technologists' (radiographers) MRI safety knowledge and confidence levels.. *Radiography*, 29 4, 697-704.
- [4] Mittendorff, L., Young, A., & Sim, J. (2021). A narrative review of current and emerging MRI safety issues: What every MRI technologist (radiographer) needs to know. *Journal of Medical Radiation Sciences*, 69, 250 - 260.
- [5] Almalki, M., Shubayr, N., Alomair, O., Alkhorayef, M., Alashban, Y., Alamari, D., & Alghamdi, S. (2022). Safety related for lone working magnetic resonance technologists in southern saudi arabia. *Journal of King Saud University - Science*.
- [6] Hoff, M., McKinney, A., Shellock, F., Rassner, U., Gilk, T., Watson, R., Greenberg, T., Froelich, J., & Kanal, E. (2019). Safety Considerations of 7-T MRI in Clinical Practice.. *Radiology*, 182742.
- [7] Cross, N., Hoff, M., & Kanal, K. (2018). Avoiding MRI-Related Accidents: A Practical Approach to Implementing MR Safety.. *Journal of the American College of Radiology: JACR*, 15 12, 1738-1744 .
- [8] Panych, L., & Madore, B. (2018). The physics of MRI safety. *Journal of Magnetic Resonance Imaging*, 47.
- [9] Malloy M. (2018) Indian Man Dies after Freak MRI Machine Accident at Mumbai Hospital The Telegraph.

- [10] Millburg S. (2018) 5-Year-Old Girl Dies during MRI in Sri Lanka Diagnostic Imaging, Medical Ethics, Neuroradiology, Pediatric Radiology.
- [11] Peck P. (2018) Fatal MRI Accident is First of its Kind WebMD Archives.
- [12] Bloom D. (2018) Two Hospital Workers Spend FOUR HOURS Pinned to MRI Machine by Metal Oxygen Tank that was Catapulted across Room when Device's Giant Magnet was Turned on.
- [13] Grover VP, Tognarelli JM, Crossey MM, Cox IJ, Taylor-Robinson SD, McPhail MJ. Magnetic Resonance Imaging: Principles and Techniques: Lessons for Clinicians. J Clin Exp Hepatol. 2015 Sep; 5(3):246-55.
- [14] Jabehdar Maralani P, Schieda N, Hecht EM, Litt H, Hindman N, Heyn C, Davenport MS, Zaharchuk G, Hess CP, Weinreb J. MRI safety and devices: An update and expert consensus. J Magn Reson Imaging. 2020 Mar; 51(3):657-674.
- [15] Hofman MBM, Lavini C, van der Zwan A, van Pul C, Muller SH, Stam MK, van der Graaf M, Kloeze C, van Nierop BJ, Kappert P, Kuijer JPA. MRI in patients with a cerebral aneurysm clip; review of the literature and incident databases and recommendations for the Netherlands. Phys Med. 2024 Jan; 117:103187.
- [16] Peschke E, Ulloa P, Jansen O, Hoeverner JB. Metallic Implants in MRI - Hazards and Imaging Artifacts. Rofo. 2021 Nov; 193(11):1285-1293.
- [17] Sammet S, Sammet CL. Implementation of a comprehensive MR safety course for medical students. J Magn Reson Imaging. 2015 Dec; 42(6):1478-86.
- [18] Mervak BM, Altun E, McGinty KA, Hyslop WB, Semelka RC, Burke LM. MRI in pregnancy: Indications and practical considerations. J Magn Reson Imaging. 2019 Mar;49(3):621-631.
- [19] Sotardi, S.T., Degnan, A.J., Liu, C.A. *et al.* Establishing a magnetic resonance safety program. *Pediatr Radiol* 51, 709–715 (2021).