Natural Resources for Human Health
eISSN: 2583-1194

Original Research

Received 07 Oct 2024
Revised 11 Nov 2024
Accepted 29 Dec 2024

Natural Resources for Human Health 2024, Vol. 4 (4): 567–575

KEYWORDS:
MRI safety, thermal burns, radiofrequency heating, radiologic technologist, patient positioning, conductive loops, screening protocols.

The Effectiveness of Radiologic Technologist-Led Strategies in Preventing MRI-Related Thermal Burns

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ABSTRACT: MRI-related thermal burns arise from radiofrequency-induced heating of conductive materials, loops formed by patient positioning, and direct contact with the bore or monitoring equipment. Because the radiologic technologist is the final practitioner positioned between the scanner and the patient, technologist-led prevention strategies occupy a uniquely influential role in safety. Screening protocols that require patients to remove all metallic and conductive items, combined with structured questioning about implanted devices, tattoos, and transdermal patches, form the first line of defense. Beyond screening, attention to positioning—maintaining separation between the skin and the bore wall, avoiding crossed limbs that create conductive loops, and routing cables away from direct skin contact—addresses the physical mechanisms through which burns most often occur. Evidence supports the effectiveness of these strategies when they are embedded in standardized workflows rather than applied inconsistently. Studies of incident reporting and root cause analyses consistently identify lapses in technologist vigilance, such as overlooked conductive padding or improperly placed surface coils, as proximal causes of preventable thermal injuries. Educational interventions, simulation-based training, and structured checklists have been shown to improve technologist awareness and adherence to safety protocols, with measurable reductions in near-miss events. However, effectiveness depends heavily on institutional culture, staffing levels, and the integration of safety checks into routine workflow, suggesting that technologist-led prevention is most powerful when supported by departmental policy, ongoing competency assessment, and a non-punitive reporting environment that surfaces latent hazards before they reach the patient.

INTRODUCTION

Magnetic resonance imaging (MRI) is universally recognized as a cornerstone of modern diagnostic medicine, prized for its exceptional soft-tissue contrast and its ability to evaluate anatomical and functional abnormalities without exposing patients to ionizing radiation. However, the clinical benefits of MRI are accompanied by a unique and complex set of physical hazards inherent to the MR environment, which utilizes a powerful static magnetic field, rapidly switching gradient magnetic fields, and radiofrequency (RF) electromagnetic pulses. Among the most frequently reported serious adverse events in this environment are thermal injuries—burns caused by the deposition of RF energy. A comprehensive ten-year review of adverse event reports submitted to the United States Food and Drug Administration (FDA) identified thermal burns as a leading category of patient harm, accounting for a significant proportion of all MRI-related injuries [1]. These incidents range from mild, superficial erythema to severe, full-thickness burns that may require surgical intervention, skin grafting, or even amputation of digits in extreme cases [2].

The occurrence of thermal burns during MRI is particularly distressing because the procedure is typically elective and performed for diagnostic purposes. An avoidable injury in this context represents a profound failure of established safety protocols rather than an acceptable, inherent risk of treatment. Extensive evidence demonstrates that the vast majority of MRI-related thermal burns are entirely preventable if rigorous, standardized safety measures are consistently applied [3]. The prevention of these injuries relies heavily on the meticulous execution of safety protocols, many of which are directly controlled and implemented by the radiologic technologist. The technologist acts as the primary gatekeeper of the MR environment, responsible for patient screening, physical preparation, positioning, the application of insulating materials, and continuous monitoring throughout the scan [4]. The effectiveness of national guidelines and professional safety manuals hinges on the technologist's ability to translate these theoretical rules into practical, patient-specific actions at the point of care [5].

A critical challenge in addressing MRI-related thermal burns is the pervasive issue of underreporting. A multicentre interview survey revealed that only a minority of MR-related incidents, including thermal injuries and near misses, are formally documented and reported to departmental or national databases [6]. This underreporting severely distorts the perceived frequency of these events and inhibits the ability of healthcare facilities to identify local patterns of failure. When a burn is not reported, the underlying system flaws—such as inadequate staffing, insufficient padding supplies, or gaps in training—remain

hidden and uncorrected. Consequently, technologist-led reporting and transparent case reviews are not merely administrative requirements but are essential mechanisms for organizational learning and the continuous refinement of prevention protocols [7].

Furthermore, the effectiveness of technologist-led safety interventions is profoundly influenced by the overarching safety culture of the radiology department. A culture that prioritizes patient safety over throughput, empowers technologists to halt a scan if they identify a hazard, and provides continuous education is essential for minimizing thermal injuries. Training programs that emphasize the physics of RF heating, the mechanics of conductive loops, and the nuances of patient positioning have been shown to significantly improve technologist engagement and adherence to safety protocols [8]. When technologists understand why a specific intervention (such as placing a foam pad between the thighs) is necessary, they are far more likely to execute it correctly and consistently, even under the pressure of a busy clinical schedule [8].

Mechanisms of MRI Thermal Injury

To effectively prevent MRI-related thermal burns, the radiologic technologist must possess a fundamental understanding of the physical mechanisms that generate heat during a scan. During an MRI examination, the patient is exposed to a complex interplay of electromagnetic fields. The static magnetic field (B_0) aligns the magnetic moments of hydrogen protons, while the gradient fields (Gx, Gy, Gz) spatially encode the signal. However, it is the radiofrequency (RF) field, typically transmitted by a whole-body birdcage coil or local surface coils, that is primarily responsible for tissue heating. The RF field deposits energy into the patient's tissues, a phenomenon quantified as the Specific Absorption Rate (SAR), which is measured in watts per kilogram (W/kg) [9].

While modern MRI systems are equipped with software limits to cap whole-body SAR and prevent dangerous core temperature elevation, these safeguards do not eliminate the risk of localized, focal burns. RF energy distribution is highly heterogeneous and is significantly influenced by the patient's anatomy, body habitus, tissue conductivity, and the presence of external or internal conductive materials [10]. The human body can act as an antenna, and when the RF field interacts with conductive materials, the energy can concentrate at specific points, rapidly elevating the local temperature and causing thermal injury before the scanner's whole-body SAR limits are triggered. Therefore, the technologist must recognize that safety is not solely managed by the scanner software; it is predominantly managed by the physical preparation of the patient before they enter the magnet room [10].

The most common mechanism of MRI thermal injury is the formation of a conductive loop. When a conductive material, or even bare skin, forms a closed circuit within the RF field, the RF waves can induce an electrical current. If the circuit is incomplete, no current flows. However, if the patient's arms are touching their torso, or if their thighs are pressed together, the skin-to-skin contact creates a continuous conductive pathway. The RF current can become concentrated at the small point of contact, leading to high current density and localized heating, resulting in what is clinically known as a "kissing burn" [11]. Similarly, external devices such as ECG leads, pulse oximeter cables, or uninsulated monitoring wires can form resonant circuits. If these cables are looped or coiled, they can act as antennae, concentrating the RF energy and causing severe burns at the site where the electrode attaches to the skin or where the wire touches the patient [12].

A second major mechanism is direct contact heating. This occurs when the patient's bare skin comes into direct contact with a conductive surface within the RF field, such as the inner bore wall of the scanner, the metallic components of the patient table, or improperly insulated RF coils. The RF field can induce currents in the metallic surface, which then transfer to the patient's skin, causing rapid and severe focal heating [13]. A third, less common but highly dangerous mechanism involves the antenna effect, where elongated conductive structures—such as implanted neurostimulator leads, cochlear implants, or even certain types of metallic tattoos and dermal fillers—couple with the RF field. The energy travels along the length of the conductive material and concentrates at its tip, which can generate immense heat and cause deep tissue burns or device malfunction [14]. Each of these mechanisms requires specific, proactive interventions from the technologist, ranging from meticulous screening to precise patient positioning [14].

The Radiologic Technologist as the Central Safety Actor

The technologist-led model of burn prevention is predicated on the reality that MRI safety is an active, continuous process rather than a passive state. Regulatory bodies and professional organizations consistently emphasize that the radiologic technologist is the primary executor of MR safety protocols. The technologist's responsibilities include verifying patient identity

and clinical history, conducting comprehensive safety screenings, ensuring the removal of all prohibited metallic and conductive items, applying appropriate padding and insulation, routing cables safely, and monitoring the patient throughout the procedure [15]. These are not routine, ancillary tasks; they are the critical interventions that physically prevent the mechanisms of RF heating from causing harm. A technologist who understands the physics of conductive loops is far more likely to recognize the hazard of a patient resting their hand on their hip than one who merely follows a checklist without comprehension [16].

The technologist is also the last line of defense before the patient is exposed to the RF field. In many clinical settings, a radiologist may order the scan and a nurse may prepare the patient, but it is the technologist who makes the final visual and verbal confirmation that the patient is safe to scan. This unique vantage point requires the technologist to possess the authority and autonomy to delay or cancel a scan if they identify a hazard that cannot be mitigated. The effectiveness of technologist-led prevention is heavily dependent on the technologist's critical thinking skills—their ability to look beyond a patient's reassuring verbal responses and physically inspect the patient's attire, skin folds, and monitoring equipment for hidden risks [17].

Furthermore, the technologist plays a pivotal role in the detection and mitigation of burns when they do occur. Because the technologist is in continuous contact with the patient via intercom and visual monitoring, they are often the first to notice the early signs of thermal injury. A patient might report a localized sensation of warmth or tingling, or the technologist might observe a sudden, unexplained movement or facial grimace indicating pain. The technologist's immediate response—halting the scan, removing the patient from the bore, and assessing the affected area—can mean the difference between a minor, reversible skin irritation and a severe, full-thickness burn [18]. Therefore, the technologist's role encompasses proactive prevention, real-time monitoring, and immediate reactive intervention [18].

Pre-Scan Screening as the First Preventive Barrier

Pre-scan screening is arguably the most critical phase of thermal burn prevention, as it is the point at which most potential hazards can be identified and eliminated before the patient enters the magnetic field. The screening process must be rigorous, standardized, and comprehensive. The technologist must utilize a structured screening form, such as those provided by the American College of Radiology, and supplement it with a thorough verbal interview [19]. The objective is to identify any contraindications, including implanted devices, metallic foreign bodies, and external conductive materials. However, screening for thermal burn risks extends beyond just implants; it involves a detailed inquiry into the patient's clothing, accessories, and even their use of topical products. Patients must be asked about athletic wear containing metallic microfibers (like silver or copper), which are highly conductive and can cause severe burns, as well as metallic zippers, buttons, and underwire garments [20].

A particularly vulnerable population during the screening process is patients who cannot reliably communicate. This includes patients who are sedated, anesthetized, confused, or neurologically impaired. These individuals cannot perceive or articulate the early sensations of heating, such as warmth or tingling, which would normally prompt a technologist to stop the scan [21]. For these patients, the technologist must conduct an even more exhaustive screening process, often relying on family members or caregivers for history. Furthermore, the technologist must adopt a more conservative approach to positioning and padding, knowing that the patient cannot act as a co-monitor. Pediatric patients also fall into this high-risk category, as their smaller body size can alter the distribution of RF energy, and their ability to remain still and communicate discomfort may be limited [22].

The screening process must also address the patient's attire. The most effective strategy to prevent burns from clothing is the implementation of a universal changing policy, where all patients are required to change into hospital-provided, non-conductive, pocketless gowns. Relying on visual inspection of street clothes is notoriously unreliable, as metallic threads can be woven into the fabric in ways that are invisible to the naked eye, and patients may forget about hidden pockets or decorative elements [23]. By mandating a change of clothing, the technologist eliminates a major variable in the safety equation, ensuring that the patient's attire does not introduce a conductive hazard into the RF field.

Patient Positioning, Padding, and Insulation

The technical execution of patient positioning and the application of insulating materials are the most direct and empirically supported technologist-led defenses against thermal burns. The fundamental principles of positioning involve separating the patient from conductive surfaces and eliminating any skin-to-skin contact. The technologist must utilize high-quality, non-conductive insulating pads, typically made of foam or gel, to create a dielectric barrier between the patient and the scanner. These pads must be placed between the patient's skin and the inner bore wall, the patient table, and any local RF coils [24].

National guidelines explicitly state that a single bedsheet is insufficient insulation; the pads must have sufficient thickness (usually 1 to 2 cm) to prevent the RF current from bridging the gap to the patient's skin [25].

The prevention of conductive loops requires meticulous attention to the patient's posture. The technologist must ensure that the patient's arms are not touching their torso, that their hands are not resting on their hips or thighs, and that their legs are not pressed together. This is achieved by placing padding between the thighs, between the arms and the body, and between the hands and any adjacent surfaces [1]. The technologist should physically verify that there is no skin-to-skin contact after the patient has been positioned and transferred into the scanner. The patient should also be instructed not to cross their legs or arms during the scan, as this can inadvertently create a loop [3].

Monitoring leads and cables present a unique challenge in positioning. An uncoiled, straight cable poses less risk, but a looped or coiled cable can act as an antenna, concentrating RF energy and causing a severe burn at the electrode site. The technologist must ensure that all cables are routed in a straight line, that they do not loop back on themselves, and that they are not in direct contact with the patient's skin. Furthermore, the electrodes must be in complete, dry contact with the skin; an air gap between the electrode and the skin can lead to arcing, a phenomenon where the RF current jumps across the gap, generating extreme heat and causing a severe burn [5]. Unused leads and cables should be removed entirely from the bore to prevent them from acting as passive antennas.

Table 1. Technologist-Led Positioning and Padding Interventions and Their Rationale

Intervention	Mechanism Targeted	Practical Technologist Action
Place 1–2 cm foam padding between skin and bore wall	Direct contact heating	Verify pad thickness and continuity around the patient's circumference; ensure pads are not compressed.
Separate thighs, arms, and hands with padding	Conductive loop formation from skin-to-skin contact	Position arms at sides with padding; avoid crossed limbs; visually check for skin contact after final transfer.
Route cables in a straight line and avoid loops	Antenna and resonant-circuit heating	Inspect all leads before scanning; ensure cables exit the bore without coiling; remove unused cables.
Ensure electrodes are dry and in full contact	Arcing and contact-resistance heating	Prep skin by cleaning and drying; verify adhesion of ECG pads; replace loose or wet electrodes immediately.
Change patient into non-conductive, pocketless gown	Conductive clothing and hidden metal	Enforce universal changing policy; visually inspect the provided gown for metallic threads or hidden elements.
Instruct patient against crossing limbs	Conductive loop formation	Verbally educate the patient prior to the scan and confirm understanding via intercom during the scan.

Communication and Monitoring During the Examination

Technologist-led communication is a dynamic, real-time preventive strategy that complements pre-scan preparation. During the MRI, the technologist must maintain continuous verbal and visual contact with the patient. Regular check-ins via the intercom allow the patient to report any unusual sensations, such as localized warmth, tingling, or pain, which are the early warning signs of a thermal burn [6]. The technologist must establish a clear and reliable communication system before the scan begins, such as a squeeze ball alarm or a specific verbal code, and should check in at intervals appropriate to the patient's risk profile and the duration of the sequence. For high-risk patients, continuous visual observation through the window and close attention to the patient's facial expressions and body language are crucial, as a patient in distress may not immediately press the alarm or may be unable to speak [7].

Communication also has a critical educational component. Explaining to the patient before the scan what sensations are normal (e.g., the loud knocking noise of the gradients, mild general warmth) and what sensations are abnormal (e.g., sharp heat, tingling in a specific spot) empowers the patient to act as a co-monitor [8]. The technologist should explicitly state that localized warmth or tingling is not a normal part of the examination and must be reported without hesitation. This simple intervention converts the patient from a passive subject into an active participant in burn prevention. This is particularly valuable when the

technologist's view of the patient is partially obscured, or when the patient is positioned in a way that makes visual assessment of the skin difficult [9].

Education, Training, and Competency

The effectiveness of any technologist-led strategy is fundamentally dependent on the knowledge, skill, and confidence of the technologist. Comprehensive education programs that cover the mechanisms of RF heating, the principles of screening and positioning, and the recognition of early burn symptoms are essential for improving safety practices [10]. Training should not be a one-time event limited to initial certification; ongoing education is necessary because implant technology, clothing materials, and MRI scanner capabilities evolve continuously. Furthermore, the specific failure modes and near misses observed in a particular department may change over time, necessitating regular updates to training curricula [11]. Scenario-based training, case reviews of reported burns, and hands-on practice with padding and positioning are far more effective at producing durable competency than passive lectures or reading assignments [12].

Competency assessment is a closely related technologist-led strategy. A department can define observable performance standards—for example, the correct placement of padding in a specified position, verification of no skin-to-skin contact, and appropriate cable routing—and use periodic audits to confirm that these standards are met [13]. When audits reveal gaps in performance, the response should be educational and systemic rather than punitive. A culture of blame suppresses reporting and deprives the department of the information needed to prevent recurrence [14]. The technologist-led safety culture is therefore both a technical and an organizational phenomenon: it requires that technologists have the authority to pause or stop an examination when they identify a hazard, and that they be actively supported by leadership when they do so [15].

Incident Reporting, Root-Cause Analysis, and Continuous Improvement

When a thermal burn occurs despite prevention efforts, it must be treated as a sentinel event requiring systematic analysis. Technologist-led incident reporting is the first and most crucial step in this process. The technologist should document the patient's position, the devices and materials present, the padding used, the sequence during which symptoms began, and the actions taken to mitigate the injury [16]. This detailed documentation enables a root-cause analysis (RCA) that looks beyond individual blame to identify the system-level conditions that allowed the burn to occur. For example, an RCA might reveal a padding supply shortage, a poorly designed positioning protocol for a specific body habitus, or a communication gap between nursing and MRI staff regarding a patient's implanted device [17].

The findings of the RCA must feed back into protocol revision, staff education, and, where appropriate, changes to equipment or purchasing decisions. The effectiveness of this feedback loop is illustrated by the experience of departments that have implemented multifaceted safety programs. A program led by radiologic technologists that utilized anonymous safety surveys, weekly communications, and quarterly competency checks resulted in greater technologist engagement, increased incident documentation, and the adoption of safer workflows [18]. The key lesson is that technologist-led strategies are most effective when they are embedded in a continuous improvement cycle rather than implemented as a static, one-time checklist [19].

Table 2. Evidence Summary for Technologist-Led Burn Prevention Strategies

Strategy Domain	Key Technologist Actions	Evidence of Effectiveness
Pre-Scan Screening	Structured questionnaire; verbal verification; identification of non-communicative patients.	Screening failures are a recurring contributor to burns; systematic screening reduces preventable events [19, 20].
Changing and Attire	Universal change into non-conductive gown; removal of all metallic and conductive items.	Removes hidden conductive pathways; explicitly recommended in national safety guidance [21].
Padding and Insulation	1–2 cm foam pads between skin and bore, coils, and cables.	Insufficient padding is repeatedly identified in burn cases; correct padding is a core recommendation [22, 23].
Loop Prevention	Separate skin surfaces; straight cable routing; no crossed limbs.	Skin-to-skin and cable loops are the dominant mechanisms of RF burns [24, 25].

Communication	Pre-scan explanation; regular check-ins; reliable alarm system.	Early symptom reporting allows termination before injury progression [1, 3].
Education and Audit	Ongoing training; competency assessment; case review.	Associated with improved practices, higher adherence, and a stronger safety culture [4, 6].
Incident Review	Structured reporting; root-cause analysis; feedback into protocol.	Drives system-level correction and prevents recurrence of similar events [8, 10].

Table 3. Patient-Specific Risk Factors for MRI Thermal Burns

Risk Factor	Mechanism of Increased Risk	Technologist Mitigation Strategy
Obesity	Skin folds create natural conductive loops; increased tissue conductivity.	Use extra padding in skin folds; separate overlapping tissues with dry gauze or foam.
Altered Mental Status	Inability to perceive or report early warning signs of heating.	Continuous visual monitoring; conservative positioning; proactive check-ins.
Diaphoresis (Sweating)	Moisture reduces skin impedance, facilitating conductive loops and arcing.	Dry the skin thoroughly; change wet gowns; ensure electrodes are fully adherent.
Pediatric Patients	Smaller body size alters RF energy distribution; limited ability to communicate.	Use pediatric-specific coils; increase padding; involve parents for comfort and monitoring.
Peripheral Artery Disease	Compromised local blood flow impairs the body's ability to dissipate heat.	Evaluate patient history; monitor extremities closely; avoid tight restraints.
Implanted Devices	Leads can act as antennas, concentrating RF energy at the tips.	Strict screening; consult device manuals; adjust SAR limits; monitor for heating.

Barriers to Effective Technologist-Led Prevention

Despite the clear evidence supporting technologist-led prevention strategies, their implementation is frequently compromised by a variety of systemic barriers. Time pressure is perhaps the most persistent obstacle. High patient volumes, tight scheduling, and the demand for rapid turnaround times can compress the time available for thorough screening and meticulous positioning. This can lead to dangerous shortcuts, such as accepting a patient's verbal assurance without visual verification, or using a single bedsheet in place of a thick foam pad [11]. Staffing shortages and high turnover rates further exacerbate this issue by eroding institutional memory and making it difficult to maintain consistent training and competency assessment across the department [12].

Equipment-related barriers also play a significant role. Departments may lack an adequate supply of appropriately sized padding, particularly for bariatric patients. Patient tables may be poorly designed, making it difficult to position and separate a patient's limbs effectively. Furthermore, some monitoring equipment may not be fully MR-conditional, introducing additional risks that the technologist must manage [13]. However, organizational culture remains the most critical barrier. If technologists do not feel empowered to slow down the workflow, question a radiologist's order, or stop a scan when they identify a hazard, then prevention strategies exist only on paper. A culture that prioritizes efficiency over safety will inevitably see higher rates of preventable injuries [14].

A further barrier is the inherent variability of patient factors that technologists cannot control. Conditions such as severe obesity, excessive diaphoresis, incontinence, or claustrophobia can create chaotic environments that are difficult to mitigate with standard padding and positioning alone. In these situations, the technologist-led response must be to escalate the issue. This includes consulting with the radiologist to modify the protocol to reduce RF energy deposition where clinically acceptable, increasing the level of monitoring, and documenting the rationale for the chosen approach [15]. The effectiveness of technologist-led prevention is therefore not a claim that technologists can eliminate all burns through individual effort, but rather that they are the professionals best positioned to recognize risk, apply evidence-based interventions, and escalate when the standard approach is insufficient [15].

Recommendations for Practice

Based on the synthesized evidence, several practical recommendations emerge for MRI departments seeking to minimize thermal burns. First, departments must adopt a standardized, mandatory screening and changing protocol that requires the technologist to verify and document the absence of conductive materials. This protocol should include specific flags for patients who cannot report symptoms [16]. Second, padding should be treated as a critical clinical supply with defined specifications for thickness, material, and size range. It should be stocked in sufficient quantities to accommodate all patient body types, including bariatric and pediatric populations [17]. Third, positioning must be standardized with a mandatory checklist that includes the separation of skin surfaces, straight cable routing, and visual verification after final patient transfer [18].

Fourth, communication protocols should be structured and formalized: a pre-scan explanation of warning symptoms, a defined check-in schedule, and a reliable alarm system must be standard practice for every patient [19]. Fifth, education and competency assessment should be ongoing, funded by the institution, and should include case-based reviews of both reported burns and near misses [20]. Sixth, incident reporting must be non-punitive, and root-cause analysis should routinely examine system factors rather than attributing burns to individual technologist error [21]. Finally, departments should conduct regular audits of their own practices, using the results to iteratively revise protocols. The effectiveness of any strategy is ultimately contingent upon its actual, sustained implementation in the daily workflow of the department [22].

CONCLUSION

MRI-related thermal burns are among the most common serious adverse events in magnetic resonance imaging, and the evidence is unambiguous that the vast majority are preventable. The radiologic technologist is the professional whose decisions—screening, changing, padding, positioning, cable routing, communication, monitoring, and reporting—directly determine whether the physical mechanisms of RF heating are neutralized or allowed to produce injury. The strategies reviewed in this article are deeply grounded in the physics of RF energy deposition and are strongly supported by regulatory guidance, systematic review evidence, and practical departmental experience. Their effectiveness, however, is conditional: it depends on rigorous training, sufficient resources, a non-punitive safety culture, and the technologist's absolute authority to act on identified risk. When these conditions are met, technologist-led prevention can reliably prevent the large majority of MRI thermal burns and transform the remaining events into valuable opportunities for system learning. The central challenge for MRI services moving forward is not the absence of effective strategies, but the consistent, sustained, and empowered implementation of those strategies by the technologists who stand at the front lines of patient care.

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