HAZARDS IN MRI SETTINGS: A CROSS-SECTIONAL STUDY OF ADVERSE INCIDENTS AND RISK FACTORS IN DIAGNOSTIC CENTERS ACROSS PUNJAB

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ABSTRACT

Background: Magnetic Resonance Imaging (MRI) is considered a safe diagnostic tool when appropriate safety protocols are followed. However, significant hazards can occur due to lapses in screening, poor infrastructure, and inadequate staff training. In India, particularly in Punjab, limited data exist on the prevalence and causes of MRI-related safety incidents.

Objective: To investigate the types, frequency, and causes of MRI-related hazards across public and private diagnostic centers in Punjab and to identify risk factors and institutional preparedness in managing such incidents.

Methods: A cross-sectional study was conducted across 30 MRI facilities in Punjab, involving 120 MRI personnel, including technologists, radiologists, and support staff. Data were collected using a structured questionnaire and an observation checklist. Quantitative data were analyzed using descriptive and inferential statistics, including chi-square tests, while open-ended responses were subjected to thematic analysis.

Results: Projectile incidents (40.8%) were the most frequently reported hazard, followed by patient burns (31.7%), contrast media reactions (22.5%), and acoustic damage (20.0%). Inadequate screening (55.0%) and poor staff training (48.3%) were the most cited causes. Chi-square analysis showed significant associations between facility type and projectile events ($p = 0.012$), and between facility location and safety infrastructure such as zoning ($p = 0.020$) and ferromagnetic screening ($p = 0.005$). Thematic analysis revealed three major issues: lack of regular training, administrative neglect, and inconsistent protocol enforcement.

Conclusion: The study underscores the urgent need for stronger institutional safety practices, especially in public and rural facilities. Policy reforms should focus on mandatory training, protocol standardization, investment in safety infrastructure, and the creation of a national incident-reporting registry to improve MRI safety across India.

KEYWORDS: MRI safety, projectile incidents, Punjab, healthcare risk, institutional compliance, patient screening, radiology safety

INTRODUCTION

Magnetic Resonance Imaging (MRI) has become an essential diagnostic tool in modern medicine due to its ability to produce high-resolution images without ionizing radiation. However, its operation involves significant safety risks stemming from strong magnetic fields, radiofrequency pulses, and rapidly switching gradient fields. These risks can result in a range of adverse incidents such as projectile accidents, patient burns, hearing damage, and allergic reactions to contrast agents [1,2]. Reports from various countries have shown that safety breaches continue to occur despite the availability of international guidelines and protocols [3].

MRI safety hazards often stem from inadequate screening procedures, poor protocol implementation, lack of staff training, or negligence. In particular, incidents involving ferromagnetic objects turning into projectiles due to strong magnetic attraction remain a serious threat to both patients and staff [4]. Thermal injuries caused by radiofrequency energy deposition, especially when conductive materials are present, are also increasingly reported [5]. Moreover, excessive acoustic noise during scans has been associated with hearing impairment if proper ear protection is not used [6].

India lacks a robust, centralized reporting system for MRI-related safety incidents, making it difficult to assess the true burden of these hazards [7]. Regional studies have highlighted inconsistencies in safety practices and limited compliance with recommended guidelines such as those from the American College of Radiology (ACR) or the Atomic Energy Regulatory Board (AERB) of India [8]. In the state of Punjab, the growing number of MRI installations across both public and private sectors, coupled with varying infrastructure and training standards, raises concerns about safety oversight.

This study seeks to fill a critical gap by exploring MRI-related hazards across a representative sample of diagnostic centers in Punjab. It investigates the types and frequency of adverse incidents, examines contributing factors such as staff errors or system failures, and identifies populations most at risk. The findings are expected to provide evidence for policy development, training enhancements, and improved institutional protocols.

METHODOLOGY

Study Design

This study utilized a cross-sectional descriptive design to gather data on the prevalence and nature of MRI-related hazards across healthcare institutions in Punjab. This design was appropriate for providing a snapshot of safety incidents and associated risk factors at a single point in time [9].

Study Setting and Population

The research was conducted in diagnostic centers and hospitals offering MRI services across both urban and rural districts in Punjab. These included government hospitals, private multispecialty facilities, and standalone imaging centers. The study population consisted of healthcare professionals actively involved in MRI operations, such as radiologists, MRI technologists, radiographers, nurses, and facility safety officers.

Sampling Strategy and Sample Size

A multistage sampling method was employed. First, districts were stratified by urbanicity and economic profile. From each stratum, MRI facilities were randomly selected. Within each facility, purposive sampling was used to select respondents who were directly involved in MRI procedures or safety management. A total of 30 facilities participated in the study. From these, 120 professionals were recruited based on informed consent and availability.

Data Collection Instruments

Data were gathered using a structured questionnaire and an observation checklist. The questionnaire captured information on:

- Incidents of MRI-related hazards witnessed or experienced
- Staff awareness of MRI safety protocols
- Perceived causes of safety breaches
- Availability and adequacy of safety training
- Institutional preparedness for MRI emergencies

The observation checklist evaluated:

- Presence of zoning systems (Zone I–IV)
- Warning signage and access control
- Screening procedures for patients and accompanying persons
- Ear protection availability
- Contrast media use protocols
- Emergency preparedness measures

Both tools were pretested in two facilities outside the study sample. Based on feedback, revisions were made to improve clarity and contextual relevance.

Data Collection Procedure

Data collection took place over a six-week period. Trained research assistants visited each facility to administer the questionnaire and conduct direct observations using the checklist. Interviews were conducted privately, and confidentiality was assured. Observational data were collected discreetly without disrupting workflow. Informed consent was obtained from all participants, and participation was entirely voluntary.

Data Analysis

Quantitative data were entered into SPSS version 25. Descriptive statistics such as frequencies and percentages were computed to summarize types of incidents and facility compliance. Inferential analysis using chi-square tests was performed to identify associations between facility characteristics (e.g., public vs private, urban vs rural) and incident rates. Open-ended responses were analyzed thematically to identify common patterns in perceived risk factors and safety gaps.

Ethical Considerations

Ethical approval for the study was obtained from the Institutional Ethics Committee of Desh Bhagat University. Participants provided written informed consent. No personally identifiable data was collected, and strict confidentiality was maintained throughout. Data was anonymized during analysis and reporting.

Demographic Variable	Frequency	Percentage (%)
Gender		
Male		
Female	45	37.5
Professional Role		
MRI Technologist	58	48.3
Radiologist	31	25.8
Nurse	18	15.0
Admin/Safety Staff	13	10.9
Years of MRI Experience		
Less than 3 years	22	18.3
3-5 years	24	20.0
More than 5 years	74	61.7

Table 1: Participant Demographics (n = 120)

A total of **120 healthcare professionals** participated in the study across **30 MRI facilities** in Punjab. Participants included MRI technologists (48.3%), radiologists (25.8%), nurses (15%), and administrative/safety personnel (10.9%). The majority were male (62.5%), with 61.7% of participants having more than five years of MRI-related experience.

The participant pool was experienced and professionally diverse, with a notable majority of technologists and radiologists. Over 60% had extensive experience in MRI practice, suggesting familiarity with operational procedures.

Hazard Type	Frequency	Percentage (%)
Projectile incidents	49	40.8
Patient burns (thermal/contact)	38	31.7
Contrast media reactions	27	22.5
Acoustic damage	24	20.0
Claustrophobia/anxiety attacks	18	15.0
Equipment malfunction	15	12.5
Emergency evacuation delays	10	8.3

Table 2: Types of MRI-Related Hazards Reported (n = 120)

Participants identified multiple types of safety hazards observed or experienced in their workplaces. Projectile incidents were the most commonly reported, followed by burns and contrast reactions.

Projectile events were the most prevalent, indicating weaknesses in screening and ferromagnetic control. Burns and contrast reactions also represented significant risks, suggesting procedural lapses during patient preparation. Acoustic trauma was less frequent but pointed to a lack of adequate hearing protection in some facilities.

Contributing Factor	Frequency	Percentage (%)
Inadequate patient/visitor screening	66	55.0
Poor staff training or safety awareness	58	48.3
Absence of zoning/access control	44	36.7
Use of non-MRI-compatible equipment	33	27.5
Emergency unpreparedness	29	24.2
Absence of clear safety signage	26	21.7

Table 3: Reported Contributing Factors to MRI Hazards (n = 120)

Respondents were asked to identify factors they believed contributed to MRI-related hazards. Inadequate screening and limited staff training emerged as the leading causes.

Inadequate screening emerged as the single most significant contributor to hazards. Training deficits and poor infrastructure-such as missing zoning and signage-were commonly cited, suggesting a need for policy-level interventions and administrative accountability.

Population Group	Frequency	Percentage (%)
Patients with implants/devices	73	60.8
Pediatric patients	46	38.3
Geriatric patients	39	32.5
Unconscious/uncooperative patients	28	23.3
Pregnant women	21	17.5

Table 4: At-Risk Populations for MRI Hazards (n = 120)

Certain populations were perceived to be more vulnerable to MRI-related incidents. Patients with implants and pediatric patients were the most frequently cited.

Patients with implants were widely acknowledged as the most vulnerable, particularly when screening was inadequate. Pediatric and elderly patients also faced challenges, often requiring additional supervision or sedation, increasing their exposure to risk.

Safety Practice	Facilities	Percentage (%)
Zoning system (Zones I-IV)	19	63.3
Ferromagnetic screening systems	14	46.7
Annual staff safety training programs	11	36.7
Posted warning signage at entrances	17	56.7
Emergency evacuation protocols	13	43.3
Routine use of ear protection for patients	21	70.0

Table 5: Institutional Safety Measures Observed (n = 30 Facilities)

On-site observations assessed the presence of structural and procedural safety measures. Implementation was uneven across facilities.Although some facilities had foundational safety structures in place, many lacked comprehensive preparedness. Fewer than half used ferromagnetic detectors or held regular training. Emergency procedures were poorly established in a significant number of sites.

Variable	χ^2 value	df	p-value	Significance
Facility Type × Projectile Events	6.27	1	0.012	Significant
Facility Type × Contrast Reactions	2.91	1	0.088	Not Significant
Facility Type × Contrast Reactions	1.77	1	0.184	Not Significant

Table 6: Chi-Square Association Between Facility Type and Hazard Reporting

A chi-square analysis was conducted to examine associations between facility type (public vs. private) and the occurrence of MRI-related hazards, as well as between facility location (urban vs. rural) and presence of safety measures.

There was a statistically significant association between facility type and projectile incidents, with public facilities reporting more such events than private ones ($p = 0.012$). This may suggest weaker enforcement of screening protocols or outdated equipment in public hospitals. However, other types of incidents (burns and contrast reactions) did not show significant associations with facility type.

Safety Measure	χ^2 value	df	p-value	Significance
Location × Zoning Implementation	5.43	1	0.020	Significant
Location × Staff Safety Training	3.82	1	0.051	Not Significant
Location × Ferromagnetic	7.91	1	0.005	Not Significant

Table 7: Chi-Square Association Between Facility Location and Safety Preparedness

Facilities in urban areas were significantly more likely to implement zoning systems ($p = 0.020$) and to have ferromagnetic screening systems in place ($p = 0.005$). There was also a marginally significant association with staff safety training ($p = 0.051$), suggesting better training access in urban settings. These findings highlight disparities in safety infrastructure and training across geographic locations.

Qualitative Findings: Thematic Analysis of Open Responses

Open-ended responses from MRI professionals across the 30 facilities were analyzed thematically to extract deeper insights into the systemic and operational challenges contributing to MRI-related hazards. Thematic coding yielded three major themes, each supported by illustrative perspectives from participants.

Theme 1: Gaps in Training and Knowledge Dissemination

A consistent concern expressed by respondents was the lack of standardized, recurrent training for staff involved in MRI operations. Many facilities relied on informal learning or on-the-job experience rather than structured education programs. Several staff members indicated that training was typically a one-time event during onboarding and seldom updated.

"We never had a refresher course since I joined two years ago. New safety guidelines are hardly discussed." - MRI Technologist, Public Facility, Ludhiana

This lack of continued professional development was perceived to contribute to errors in patient screening, emergency response, and equipment handling. The absence of designated MR Safety Officers (MRSOs) or formal safety leadership in most institutions further weakened knowledge dissemination.

This theme reflects a systemic weakness in professional capacity-building, pointing to a broader need for institutionalized safety certification and continuing education programs for all MRI staff, including support personnel.

Theme 2: Administrative Apathy and Resource Neglect

Many participants voiced frustration about the lack of administrative priority given to MRI safety. Budgetary limitations were often cited as reasons for delays in acquiring ferromagnetic detectors, replacing outdated MRI-compatible equipment, or conducting emergency drills.

"We requested a new screening device months ago, but management said it wasn't urgent." - Radiographer, Private Facility, Amritsar

Furthermore, respondents noted that safety concerns were often brushed aside unless a serious incident occurred. Some institutions lacked even basic signage, restricted access controls, or protocols for dealing with medical emergencies.

This theme highlights the role of institutional leadership and budgetary decision-making in compromising MRI safety. Safety culture in these settings appears reactive rather than preventive, indicating the need for policy-mandated audits and administrative accountability mechanisms.

Theme 3: Inconsistent Protocol Implementation

Several respondents acknowledged the existence of written safety protocols, yet admitted that these were inconsistently followed or poorly enforced. Staff often made judgment calls based on individual discretion rather than standardized procedures. In some centers, different shifts followed different informal routines.

"Even though we have a checklist, no one uses it strictly. Sometimes we skip screening questions if there's a queue." - MRI Nurse, Private Diagnostic Center, Patiala

Respondents also indicated a lack of coordination among departments, with radiology teams sometimes unaware of critical patient information shared earlier with clinicians or nurses.

This theme points to the breakdown of procedural discipline, even in the presence of formal guidelines. The variability in practice suggests a need for stronger internal audits, role-based accountability, and the embedding of protocol compliance into performance evaluations.

Synthesis of Themes

Together, these themes reveal that MRI safety breaches in Punjab are not solely due to technical failures but are largely a consequence of institutional neglect, human factors, and organizational disconnection. A comprehensive approach that combines administrative reform, workforce development, and procedural enforcement is essential for improving safety outcomes.

DISCUSSION

This study provides critical insights into the prevalence, nature, and causes of MRI-related hazards in diagnostic facilities across Punjab, India. The findings demonstrate that preventable incidents, particularly projectile events, burns, and contrast-related reactions, remain prevalent and are significantly influenced by facility type, location, and institutional preparedness.

The high frequency of projectile-related accidents (40.8%) aligns with international literature emphasizing that these events often result from poor screening and failure to enforce ferromagnetic restrictions [10,11]. Such events pose serious threats to both patients and staff and have, in some cases, resulted in fatalities [12]. The present study reveals that these incidents are more likely to occur in public facilities, possibly due to outdated infrastructure, high patient volume, or limited training resources.

Patient burns, often caused by conductive materials or improper positioning, were reported in nearly one-third of the participating facilities. Similar findings were noted in studies conducted in South Asia and the Middle East, where radiofrequency-induced thermal injuries are underreported but common [13,14]. The underutilization of non-metallic patient accessories and failure to ensure skin-to-skin separation during scanning are contributing factors that must be addressed through strict adherence to safety protocols.

Contrast reactions were reported by 22.5% of respondents, consistent with previous reports indicating the risks of gadolinium-based agents, especially when pre-scan evaluation is inadequate [15]. Although severe reactions are rare, failure to monitor for renal function or prior allergies significantly increases the risk. Our findings highlight the need for consistent use of contrast administration checklists and emergency readiness in case of anaphylaxis.

Acoustic damage, though less frequently reported (20%), reflects an area often neglected in Indian settings. MRI scanners typically produce noise levels exceeding 100 decibels, which can lead to transient or permanent hearing loss if adequate ear protection is not provided [16]. Despite this, nearly 30% of the facilities in this study failed to routinely provide earplugs or earmuffs to patients, suggesting the need for regulatory enforcement.

Chi-square analyses revealed significant differences in hazard occurrence and safety preparedness based on facility type and location. Public institutions and rural facilities were less likely to implement zoning, ferromagnetic detection, and structured training programs. These disparities mirror those reported in broader healthcare infrastructure studies in India, where urban centers are more likely to receive technological upgrades and specialized personnel [17,18].

The thematic analysis of open responses pointed to deeper systemic issues. Staff commonly cited a lack of regular training, particularly for new employees, and highlighted weak administrative engagement in enforcing safety protocols. These findings support similar studies in low- and middle-income countries where MRI safety is viewed as secondary to operational efficiency [19]

A crucial implication of these findings is the urgent need for policy reforms that extend beyond mere guidelines. First, mandatory certification and recertification of MRI personnel, including non-clinical staff, should be instituted. This would align with international models such as the ACR MR Safety Officer training [20]. Second, public institutions require targeted investments to install ferromagnetic detectors, upgrade outdated MRI systems, and provide regular emergency drills. Third, safety audits should be mandated by regulatory bodies like the Atomic Energy Regulatory Board (AERB), and facilities should be penalized for repeated breaches, similar to accreditation penalties used in other imaging quality frameworks [21].

At a broader level, the absence of a national incident-reporting registry for MRI-related adverse events in India is a critical gap. Establishing such a system, ideally managed by a centralized body, would not only improve data transparency but also help identify trends and intervene early. Patient education, especially in rural settings, should also be prioritized. Many respondents noted that patients and their families often failed to disclose metal implants or medical histories due to fear, stigma, or low awareness. This calls for a communication strategy that empowers patients to participate in their own safety.

While this study provides valuable insights, certain limitations must be acknowledged. First, self-reporting may have introduced bias, as staff could underreport incidents to protect institutional reputation. Second, the observational component was cross-sectional and limited to a single visit per site, which may not capture episodic lapses. Third, qualitative insights were drawn from open-ended survey responses and not from in-depth interviews, which may limit contextual richness. Lastly, the sample, while diverse across facility types and locations, may not be fully representative of all MRI centers in India.

CONCLUSION

This study has highlighted critical safety lapses in MRI practices across healthcare facilities in Punjab. The high frequency of preventable incidents—particularly projectile accidents, patient burns, contrast reactions, and acoustic damage—demonstrates that MRI environments remain vulnerable to risks when essential safety protocols are inadequately enforced. Public facilities and those located in rural areas were significantly more likely to report safety incidents, pointing to disparities in training, infrastructure, and policy compliance.

Inadequate patient screening, limited staff training, and insufficient institutional investment in safety systems were found to be major contributors to these hazards. Moreover, the absence of standardized emergency protocols and inconsistent use of zoning and signage further increased vulnerability. These issues persist despite the availability of national and international safety guidelines.

Addressing MRI-related hazards requires a systemic and policy-driven approach. Regular and mandatory staff training, institutional accreditation linked to safety compliance, infrastructure upgrades in public and rural facilities, and the establishment of a centralized incident reporting system are urgently needed. Administrators and regulatory bodies must move beyond passive guidelines and ensure active monitoring, enforcement, and accountability to reduce preventable harm.

As MRI technology continues to expand across India, strengthening safety frameworks is essential not only to protect patients and staff but also to uphold public trust in diagnostic imaging services.

REFERENCES

1. Shellock FG, Kanal E. MRI: Bioeffects, safety, and patient management. 2nd ed. Philadelphia: Lippincott Williams & Wilkins; 2000.
2. Kanal E, Tweedle MF, Shellock FG. Safety of magnetic resonance imaging contrast agents. J Magn Reson Imaging. 2013;37(2):247-53. doi:10.1002/jmri.24049.
3. Dillman JR, Ellis JH, Cohan RH, Davenport MS. Frequency and severity of acute reactions to gadolinium-based contrast media in children and adults. AJR Am J Roentgenol. 2015;204(4):827-32. doi:10.2214/AJR.14.13156.
4. Foster J, Moore MM, Rollins N. Ferromagnetic projectile accidents in MRI: Causes, consequences, and corrective strategies. J Magn Reson Imaging. 2020;52(4):1181-90. doi:10.1002/jmri.27101.
5. Falahati F, Abbasi HR, Hojjat A. MRI-related thermal injuries: Clinical experiences and safety guidelines. Eur J Radiol Open.

2021;8:100337. doi:10.1016/j.ejro.2021.100337.

6. Moore MM, Foster J, Kirschen MP. Sound levels during 1.5-T and 3-T MRI scanning: Comparison and risk assessment. AJNR Am J Neuroradiol. 2008;29(1):142-7.doi:10.3174/ajnr.A0783.
7. Bhosale R, Pandey S, Kapoor A. Medical imaging safety in India: A review of regulatory practices and challenges. Indian J Med Ethics. 2020;5(2):94-9. doi:10.20529/IJME.2020.023.
8. Kumar P, Yadav S, Gupta M. MRI safety practices and compliance with AERB guidelines in India: A cross-sectional review. Indian J Radiol Saf. 2022;8(1):12-9.
9. Creswell JW, Creswell JD. Research design: Qualitative, quantitative, and mixed methods approaches. 5th ed. Thousand Oaks (CA): SAGE Publications; 2018.
10. Shellock FG, Spinazzi A. MRI safety update 2008: Part 2, screening patients for MRI. AJR Am J Roentgenol. 2008;191(4):1140-9. doi:10.2214/AJR.07.4036.
11. Kanal E, Barkovich AJ, Bell C, Borgstede JP, Bradley WG, Froelich JW, et al. ACR guidance document for safe MR practices: 2007. AJR Am J Roentgenol. 2007;188(6):1447-74. doi:10.2214/AJR.06.1616.
12. Baig M, Wani S, Ahmad S. Safety issues and adverse events in MRI settings: An observational study in Indian diagnostic centers. Indian J Radiol Imaging. 2021;31(2):158-63. doi:10.4103/ijri.IJRI_274_20.
13. Al-Busaidi AS, Al-Rasbi S, Al-Hinai M, Al-Sukaiti R. MRI-related burns: A case series, risk assessment, and prevention strategies. Radiol Case Rep. 2018;13(5):1065-70. doi:10.1016/j.radcr.2018.03.002.
14. Prince MR, Zhang H, Zou Z, Staron RB, Brill PW. Incidence of immediate gadolinium contrast media reactions. AJR Am J Roentgenol. 2011;196(2):W138-43. doi:10.2214/AJR.10.4685.
15. Jeong JH, Kim JH. Assessment of noise-induced hearing loss during MRI: A clinical study and preventive recommendations. Noise Health. 2020;22(104):1-6. doi:10.4103/nah.NAH_3_19.
16. Reddy MS, Chander S. Inequity in health resource allocation: A case study of medical imaging in India. Health Econ Rev. 2018;8(1):14. doi:10.1186/s13561-018-0193-4.
17. Kumar A, Kaur R. Disparities in diagnostic imaging services between rural and urban healthcare centers in India. J Public Health Policy Plan. 2021;5(3):101-9.
18. Ghazwin MY, Paydar S. Safety practices in MRI units: A survey of awareness and training among healthcare workers in low-resource settings. Radiography (Lond). 2021;27(1):34-40. doi:10.1016/j.radi.2020.04.011.
19. American College of Radiology. ACR Manual on MR Safety. Reston (VA): ACR; 2020. Available from: https:// www.acr.org/Clinical-Resources/Radiology-Safety/ MR-Safety.
20. Patel S, Thomas R. Linking accreditation with MRI safety compliance: A review of best practices in imaging centers. Int J Qual Health Care. 2019;31(5):405-10.doi:10.1093/intqhc/mzz049.