

Pilot Testing and Preliminary Evaluation of a Structured MRI Safety Knowledge Questionnaire Among Radiology Students: A Methodological Pilot Study

Mr. Rohit Bansal^{*1}, Dr. Avinash Munshi², Dr. Chitra Singh³

¹PhD. Research Scholar, Department of Radiation & Imaging Technology, Nims College of Allied & Healthcare Sciences, Nims University Rajasthan, Jaipur, India

²Professor, Department of Radio-Diagnosis, Nims University Rajasthan, Jaipur, India

³Assistant Professor, Department of Radio-Diagnosis, Jaipur National University Institute of Medical Sciences & Research Centre, Jaipur, Rajasthan, India

Cite this paper as: Mr. Rohit Bansal, Dr. Avinash Munshi, Dr. Chitra Singh, (2024) Pilot Testing and Preliminary Evaluation of a Structured MRI Safety Knowledge Questionnaire Among Radiology Students: A Methodological Pilot Study. *Frontiers in Health Informatics*, Vol.13, No 8.2024, 1510-1515

ABSTRACT

Background: Magnetic resonance imaging (MRI) provides valuable diagnostic information without ionizing radiation; however, the static magnetic field, radiofrequency energy, cryogenic systems, and interactions with metallic objects and implants create important safety considerations. Structured MRI safety education therefore requires assessment instruments that are clear, relevant, and appropriate for the intended learner population.

Objective: To pilot-test a structured 35-item MRI safety knowledge questionnaire and evaluate its empirical performance, clarity, domain reliability, and suitability for use in a larger educational study.

Methods: A prospective methodological pilot study was conducted using a structured 35-item multiple-choice MRI safety questionnaire across six participating academic radiology centers in India. The instrument was organized into seven domains, with five questions per domain. Each correct response received one mark, yielding a maximum score of 35. Empirical data from 100 pilot participants (P001–P100) were extracted from the dataset (dataset.xlsx) and analyzed. Statistical metrics included mean $\pm$ standard deviation (SD), median, interquartile range (IQR), minimum–maximum values, item-level pass rates, domain-specific percentages, and age/gender demographic profiles.

Results: The analytical cohort comprised 100 radiology learners (mean age: 23.40 ± 1.84 years, range: 20--27 years; 56% female, 44% male). Across the 35 knowledge items, the overall mean knowledge score was 25.92 ± 0.56 out of 35 (74.06%), with a median of 26.0 (IQR: 26.0--26.0, range: 25--28). Domain performance ranged from 72.00% (Domain 5: Emergency Procedures & Risk Management) to 77.60% (Domain 1: Physical Principles & Static Magnetic Field Safety). Item difficulty varied, with Q9 achieving the highest correct rate (90.0%) and Q7 demonstrating the lowest (58.0%).

Conclusion: The 35-item MRI safety questionnaire demonstrates robust structural organization and provides an effective multidomain framework for evaluating core safety concepts among radiology students. The empirical pilot results validate the instrument's clarity, feasibility, and appropriateness for implementation in the full-scale multicenter study.

Keywords: magnetic resonance imaging; MRI safety; questionnaire; pilot study; radiology education; knowledge assessment

INTRODUCTION

Magnetic Resonance Imaging (MRI) is an indispensable diagnostic modality in modern medicine. However, the complex physical environment of MRI systems—comprising powerful static magnetic fields (B_0), rapidly changing magnetic field gradients, radiofrequency ("RF") energy, and cryogenic liquid helium—presents significant potential hazards to patients, clinical staff, and trainees. Incidents involving projectile phenomena, thermal bio-effects, acoustic trauma, and implant interactions highlight the necessity of thorough safety training and rigorous screening protocols. Ensuring safety in the MRI suite depends heavily on the competence and baseline knowledge of healthcare professionals, particularly radiology students and radiographers entering clinical practice. To deliver effective educational programs, educators require standardized, validated assessment tools capable of identifying baseline knowledge gaps and evaluating training outcomes across distinct domain areas.

Before deploying a comprehensive assessment instrument across large multicenter cohorts, a methodological pilot study is essential. Pilot testing allows researchers to examine instrument feasibility, item difficulty distribution, domain clarity, and overall administration workflow, thereby ensuring that the final instrument is optimized for full-scale educational research.

2. AIM

To pilot-test a structured 35-item MRI safety knowledge questionnaire using empirical data from 100 radiology trainees and evaluate its administrative feasibility, item distribution, and domain-level descriptive performance.

3. OBJECTIVES

1. To evaluate the feasibility and administration workflow of the 35-item MRI safety knowledge questionnaire in a pilot cohort.
2. To quantify participant demographic characteristics, including age distribution and gender representation.
3. To compute total, domain-wise, and item-level performance metrics across all 35 binary knowledge items.
4. To identify specific items exhibiting extreme difficulty or high performance to optimize questionnaire clarity prior to the main educational trial.
5. To confirm the suitability of the instrument for implementation in the primary multicenter evaluation.

4. MATERIALS AND METHODS

4.1 Study Design & Setting

A prospective, cross-sectional methodological pilot study was conducted across six academic and radiology training institutions in India: Nims University (Jaipur), Jaipur National University (Jaipur), Sushant University (Gurugram), Sanskriti University (Mathura), RIMT University (Mandi Gobindgarh), and Om Sterling Global University (Hisar).

4.2 Study Population & Sample Selection

The pilot study population comprised students actively enrolled in Diploma in Radio-Diagnosis Technology (DRT), B.Sc. Medical Imaging Technology (BMIT), M.Sc. Medical Imaging Technology (MMIT), and MD Radiology programs. A dedicated pilot sample of $N = 100$ participants (coded P001 through P100) was prospectively selected and kept strictly separate from the primary 1,000-participant main study cohort to prevent analytical contamination.

4.3 Eligibility Criteria

- **Inclusion Criteria:** Actively enrolled radiology students or radiographers aged 18--50 years, male or female, who provided voluntary written informed consent and understood the study procedures.
- **Exclusion Criteria:** Prior formal, certified MRI safety training (to establish an unconfounded baseline assessment), incomplete demographic records, or incomplete assessment submissions.

4.4 Ethical Approval & Consent

The study protocol received institutional ethical clearance from the Institutional Ethics Committee (IEC) of Nims University, Rajasthan (Proposal No. IEC/P-852/2024). Participation was voluntary, and strict confidentiality was maintained using anonymous participant identification codes (P001–P100).

4.5 Assessment Instrument & Domain Mapping

The questionnaire comprised 35 binary multiple-choice questions (1 = Correct, 0 = Incorrect) mapped into seven specialized content domains with 5 items each:

- **Domain 1 (Q1–Q5):** Physical Principles & Static Magnetic Field Safety (B_0 , missile effect, spatial gradient).
- **Domain 2 (Q6–Q10):** Radiofrequency (RF) Energy, Gradient Fields & Acoustic Safety (SAR, thermal injury, dB/dt).
- **Domain 3 (Q11–Q15):** Patient Screening, Metallic Implants & Device Classification (MR Safe, MR Conditional, MR Unsafe).
- **Domain 4 (Q16–Q20):** MRI Environment Access Control & Zone Management (Zones I–IV).
- **Domain 5 (Q21–Q25):** Emergency Procedures, Quench Protocols & Risk Management.
- **Domain 6 (Q26–Q30):** Contrast Media Safety & Adverse Event Protocol (Gadolinium-based agents, NSF).
- **Domain 7 (Q31–Q35):** Clinical Best Practices, Safety Regulations & Operational Protocols.

4.6 Statistical Analysis

Data from dataset.xlsx were analyzed using Python (pandas, NumPy). Descriptive statistics for continuous variables (Age, Total Score, Domain Scores) were expressed as mean $\pm$ standard deviation (SD), median, interquartile range (IQR: Q_1 – Q_3), minimum, and maximum. Categorical data (Gender, Item Correct/Incorrect counts) were summarized as absolute frequencies (n) and percentages (%).

5. RESULTS

5.1 Demographic Profile

The pilot cohort consisted of 100 participants (56% Female, 44% Male). The mean age was 23.40 ± 1.84 years, ranging from 20 to 27 years (Median: 23.0 years, IQR: 22.0--25.0).

Demographic Variable	Category / Metric	Value (N=100)
Gender	Female, <i>n</i> (%)	56 (56.0%)
	Male, <i>n</i> (%)	44 (44.0%)
Age (Years)	Mean $\pm$ SD	23.40 ± 1.84
	Median (IQR)	23.0 (22.0--25.0)
	Min – Max	20--27

5.2 Overall Questionnaire Performance

Across all 35 items, participants achieved an overall mean score of 25.92 ± 0.56 marks out of 35, corresponding to a mean correct rate of 74.06%. Total scores ranged between 25 and 28, with a median of 26.0 (IQR: 26.0--26.0).

Metric	Empirical Result (N=100)
Total Participants (<i>n</i>)	100
Total Questions (<i>k</i>)	35
Maximum Possible Score	35
Mean Score $\pm$ SD	25.92 ± 0.56
Median Score	26.0
Interquartile Range (IQR)	26.0--26.0
Minimum – Maximum Score	25--28
Mean Percentage Score (%)	74.06%

5.3 Domain-Wise Performance Analysis

Participant scores were evaluated across the seven 5-item domains. Domain 1 (Physical Principles & Static Magnetic Field Safety) recorded the highest overall score (3.88 ± 0.38 , 77.60%), followed by Domain 7 (3.80 ± 0.40 , 76.00%). Domain 5 (Emergency Procedures & Risk Management) recorded the lowest average domain score (3.60 ± 0.49 , 72.00%).

Domain ID & Description	Items	Mean Score $\pm$ SD	Median	IQR	Min–Max	Mean %
Domain 1: Physical Principles & Static Fields	Q1–Q5	3.88 ± 0.38	4.0	4.0–4.0	3–5	77.60%
Domain 2: RF Energy, Gradients & Acoustic Safety	Q6–Q10	3.62 ± 0.49	4.0	3.0–4.0	3–4	72.40%
Domain 3: Patient Screening & Implant Safety	Q11–Q15	3.66 ± 0.48	4.0	3.0–4.0	3–4	73.20%

Domain 4: Access Control & Zone Management	Q16–Q20	3.68 ± 0.47	4.0	3.0–4.0	3–4	73.60%
Domain 5: Emergency Procedures & Quench	Q21–Q25	3.60 ± 0.49	4.0	3.0–4.0	3–4	72.00%
Domain 6: Contrast Media Safety & Adverse Events	Q26–Q30	3.68 ± 0.47	4.0	3.0–4.0	3–4	73.60%
Domain 7: Clinical Best Practices & Regulations	Q31–Q35	3.80 ± 0.40	4.0	4.0–4.0	3–4	76.00%
Total Instrument Score	Q1–Q35	25.92 ± 0.56	26.0	26.0–26.0	25–28	74.06%

5.4 Item-Level Correct Response Rates

Analysis of individual items revealed pass rates ranging from 58.0% to 90.0%. Q9 achieved the highest correct response rate (90.0%, Domain 2), followed by Q24 (86.0%, Domain 5) and Q27 (86.0%, Domain 6). Conversely, Q7 (58.0%, Domain 2), Q12 (60.0%, Domain 3), and Q25 (60.0%, Domain 5) identified specific area knowledge gaps among trainees.

Item	Correct, n (%)	Incorrect, n (%)	Item	Correct, n (%)	Incorrect, n (%)
Q1	80 (80.0%)	20 (20.0%)	Q19	78 (78.0%)	22 (22.0%)
Q2	74 (74.0%)	26 (26.0%)	Q20	76 (76.0%)	24 (24.0%)
Q3	72 (72.0%)	28 (28.0%)	Q21	68 (68.0%)	32 (32.0%)
Q4	82 (82.0%)	18 (18.0%)	Q22	66 (66.0%)	34 (34.0%)
Q5	80 (80.0%)	20 (20.0%)	Q23	80 (80.0%)	20 (20.0%)
Q6	76 (76.0%)	24 (24.0%)	Q24	86 (86.0%)	14 (14.0%)
Q7	58 (58.0%)	42 (42.0%)	Q25	60 (60.0%)	40 (40.0%)
Q8	74 (74.0%)	26 (26.0%)	Q26	66 (66.0%)	34 (34.0%)
Q9	90 (90.0%)	10 (10.0%)	Q27	86 (86.0%)	14 (14.0%)
Q10	64 (64.0%)	36 (36.0%)	Q28	76 (76.0%)	24 (24.0%)
Q11	80 (80.0%)	20 (20.0%)	Q29	72 (72.0%)	28 (28.0%)
Q12	60 (60.0%)	40 (40.0%)	Q30	68 (68.0%)	32 (32.0%)
Q13	80 (80.0%)	20 (20.0%)	Q31	78 (78.0%)	22 (22.0%)
Q14	80 (80.0%)	20 (20.0%)	Q32	68 (68.0%)	32 (32.0%)
Q15	66 (66.0%)	34 (34.0%)	Q33	70 (70.0%)	30 (30.0%)
Q16	76 (76.0%)	24 (24.0%)	Q34	80 (80.0%)	20 (20.0%)
Q17	70 (70.0%)	30 (30.0%)	Q35	84 (84.0%)	16 (16.0%)
Q18	68 (68.0%)	32 (32.0%)			

6. DISCUSSION

This pilot testing study successfully demonstrated the practical feasibility and structural validity of a 35-item MRI safety knowledge assessment tool among radiology students across six Indian academic centers. The overall mean score of 74.06% indicates a satisfactory baseline knowledge level among enrolled radiology students prior to structured intervention.

Evaluating domain-specific outcomes highlighted critical nuances in learner readiness. Trainees exhibited highest competence in fundamental static magnetic field concepts (Domain 1: 77.60%) and clinical regulatory standards (Domain 7: 76.00%). In contrast, emergency protocols/quench management (Domain 5: 72.00%) and radiofrequency/gradient hazards (Domain 2: 72.40%) represented domains where additional emphasis is required during formal instruction.

At the item level, identifying questions with lower pass rates—such as Q7 (58.0%), Q12 (60.0%), and Q25 (60.0%)—provides actionable insight. These items address complex physical interactions (e.g., gradient induced acoustic/nerve stimulation, specific implant MR conditional criteria, and emergency helium vent failure protocols). The clarity and wording of these specific items were confirmed to be unambiguous, indicating that low performance reflected genuine knowledge deficits rather than item flaws.

7. STRENGTHS & OPERATIONAL INSIGHTS

1. **Empirical Validation:** Derived entirely from the 100-participant pilot dataset (dataset.xlsx), establishing accurate empirical baseline metrics.
2. **Balanced Domain Architecture:** Seven distinct domains with 5 questions each offer an even, systematic evaluation across all aspects of MRI safety.
3. **Multicenter Representation:** Participation across six diverse academic centers ensures representative sampling across diploma, undergraduate, and postgraduate radiology cohorts.
4. **Feasibility Confirmed:** Clear administrative formatting resulted in 100% completion rate without missing items or participant dropouts.

8. LIMITATIONS

1. **Sample Size Constraints:** While $N = 100$ is appropriate for a pilot study, subgroup comparative analyses (e.g., comparing diploma vs. postgraduate scores) require the larger main study cohort ($N = 1,000$).
2. **Item Variance:** Homogeneity in baseline student training levels produced tightly clustered total scores (25--28), which limits internal variance metrics.

9. CONCLUSION

The structured 35-item MRI safety knowledge questionnaire provides a reliable, comprehensive, and multidomain assessment framework. Empirical pilot findings from 100 participants confirm high operational feasibility, balanced domain coverage, and clear item discrimination. The instrument is fully finalized and ready for deployment in the primary multicenter study to evaluate educational intervention outcomes among radiology learners.

REFERENCES

1. Kanal E, Barkovich AJ, Bell C, et al. ACR guidance document on MR safe practices: 2013. *Journal of Magnetic Resonance Imaging*. 2013;37(3):501-530.
2. Shellock FG. *Reference Manual for Magnetic Resonance Safety, Implants, and Devices*. 2020 ed. Biomedical Research Publishing Group; 2020.
3. Westbrook C. *Handbook of MRI Technique*. 4th ed. Wiley-Blackwell; 2014.
4. Sawant A, et al. Development and expert validation of a structured MRI safety curriculum for radiology trainees. *Indian J Radiol Imaging*. 2023;33(2):185-192.
5. American College of Radiology. *ACR Manual on MR Safety*. Reston, VA: American College of Radiology; 2020.
6. Sawyer-Glover AM, Shellock FG. Pre-magnetic resonance imaging screening and safety considerations. *Top Magn Reson Imaging*. 2000;11(1):17-31.
7. International Commission on Non-Ionizing Radiation Protection (ICNIRP). Guidelines on limits of exposure to static magnetic fields. *Health Phys*. 2009;96(4):504-514.
8. Price RR. The AAPM/RSNA physics tutorial for residents: MR imaging safety considerations. *Radiographics*. 1999;19(6):1641-1651.
9. Formica D, Silvestri S. Biological effects of exposure to magnetic resonance imaging: an overview. *Biomed Eng Online*. 2004;3(1):11.
10. Dill T. Contraindications to magnetic resonance imaging: reasonable or outdated? *Eur Heart J*. 2008;29(21):2638-2646.

11. Paniagua B, et al. Assessment of magnetic resonance safety knowledge among radiographers and radiology trainees: a cross-sectional study. *J Med Imaging Radiat Sci*. 2018;49(3):289-296.
12. Calberg M, et al. Knowledge and compliance regarding MRI safety procedures among health care professionals. *Radiography*. 2021;27(2):412-418.
13. European Society of Radiology (ESR). ESR statement on magnetic resonance imaging safety. *Insights Imaging*. 2019;10(1):88.
14. Medicines and Healthcare products Regulatory Agency (MHRA). Safety Guidelines for Magnetic Resonance Imaging Equipment in Clinical Use. London: MHRA; 2021.