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Systematic Review

Radiographer training for screening of patients referred for Magnetic Resonance Imaging: A scoping review

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ABSTRACT

Introduction: Strict safety practices are essential to ensure the safety of patients and staff in Magnetic Resonance Imaging (MRI). Training regarding the fundamentals of MRI safety is well-established and commonly agreed upon. However, more complex aspect of screening patients, such as image review or screening of unconscious patients/patients with communication difficulties is less well discussed. The current UK and USA guidelines do not suggest the use of communication training for MRI staff nor indicate any training to encourage reviewing images in the screening process. This review aims to map the current guidance regarding safety and patient screening training for MRI diagnostic and therapeutic radiographers.

Methods: A systematic search of PubMed, Trip Medical database and Radiography journal was conducted. Studies were chosen based on the review objectives and pre-determined inclusion/exclusion criteria using the PRISMA-ScR framework.

Results: Twenty-four studies were included in the review, which identified some key concepts including MRI safety training and delivery methods, screening and communication, screening of unconscious or non-ambulatory patients and the use of imaging.

Conclusion: Training gaps lie within the more complex elements of screening such as the inclusiveness of question phrasing, particularly to the neurodivergent population, how we teach radiographers to screen unconscious/unresponsive patients and using imaging to detect implants.

Implications for practice: The consequences of incomplete or inaccurate pre-MRI safety screening could be the introduction of unexpected implants into the scanner or forgoing MRI for a less desirable modality. The development of enhanced training programs in implant recognition using imaging and communication could complement existing training.

Introduction

Magnetic Resonance Imaging (MRI) is a clinical imaging tool commonly used to diagnose and monitor many different pathologies and disorders.[1–3] MRI combines static magnetic fields, Time-Varying Magnetic Fields (TVMFs) and Radiofrequency (RF) fields to produce images,[4] all of which can pose safety issues to patients and staff without safe working practices. Since the inception of clinical MRI,[1] there have been many instances of documented injuries, and death, resulting from improper practices or insufficient screening.[5–7]

The static magnetic field is the most recognised hazard and can turn ferromagnetic objects into projectiles. The response to the tragic death of Michael Colombini in 2001[5] was the initiation and impetus to bring MRI safety to the forefront —however, incidents introducing MR Unsafe equipment to the magnetic field still occur.[8,9] Projectiles formed of objects such as keys, coins or scissors, left in the pockets of staff or patients, also have the potential to cause injury. Internally implanted devices or Foreign Bodies (FBs) containing ferromagnetic material,[10,11] can experience movement or twisting, which can cause harm[6] or damage to the device itself, reducing or stopping its functionality.

The views expressed in this publication are those of the author(s) and not necessarily those of the NHS, the National Institute for Health and Care Research or the Department of Health and Social Care.

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The other MRI hazards are only present during image acquisition, namely the TVMF and RF fields. Screening methods cannot mitigate the effects of TVMFs. However, RF fields, used to produce the MRI signal,[12] can cause burns through thermal heating, the most commonly reported adverse event in MRI.[3,13] Burns can be caused by skin-to-skin contact,[14] contact with the machine bore[15] or contact with an object.[9,13] Recent reports have also shown that previously unremarkable items such as some clothing materials[16–18] dermal medicine patches[10,19,20] and even some tattoos[21,22] can also be affected by heating.

To minimise risk, in-depth knowledge of MRI safety is essential to all personnel working in MRI. However, the Medicines and Healthcare products Regulatory Agency (MHRA)[10] and American College of Radiology (ACR)[23] currently provide little guidance for the screening of patients who present with communication difficulties, such as learning disabilities or neurological disorders. Next of Kin (NOK) or medical records to complete a safety questionnaire assumes the presence and accuracy of both, which cannot be guaranteed, especially in an emergency or tertiary referral centre. Furthermore, neither guidance recommends communication training as part of core MRI safety training. As such, there is a risk that patients are admitted to MRI scanners with unexpected implants present.[8]

Unconscious or non-ambulatory patients with no available medical records or NOK provide further challenges. The MHRA[10] and ACR[23] suggest performing plain film radiographs to identify MRI contraindications. However, there is no guidance on the interpretation of these images. In the UK, radiographers are responsible for patient screening in the first instance but may require radiologist or medical physics input for complex cases. In an emergency or out-of-hours, there may not be radiologists or physics support easily accessible. Additionally, with the emergence of early-career specialisation, assistant practitioner roles and MRI-based radiotherapy treatments, it cannot be presumed that all staff have the same level of experience regarding diagnostic radiographic images.

This review aims to map the current literature regarding safety and patient screening training for MRI staff (radiographers, radiologists, MRI medical physics and support staff), both diagnostic and therapeutic. A scoping review is a tool used to provide an overview of existing literature on a specific topic. It has been utilised to determine the conceptual boundaries of the topic and identify any existing knowledge gaps.[25,26]

The research questions are:

'How are radiographers taught to undertake a screening assessment, especially for patients unable to answer a written or verbal questionnaire?'

'What are MRI staff being taught regarding the safety screening of patients undergoing MRI scans?'

These will be answered by the following objectives:

- To identify the key topic areas covered in MRI safety training;
- To understand what guidance is available for patient screening;
- To discover if communication training exists to aid the acquisition of accurate information;
- To ascertain if training exists to allow MRI staff to screen patients who are unable to answer a safety questionnaire either verbally or written, e.g., unconscious patients or those with learning disabilities.

Methodology

This study utilised a three-step search strategy, as described by the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement for scoping reviews,[27] recommended by the Joanna Biggs Institute.[28]

A search strategy was developed with the help of a librarian. The pilot search was conducted using PubMed and Trip Medical databases, selected because they included a range of material relevant to this review including peer-reviewed published studies, grey literature, book chapters and international guidance. Search engines, such as Google, were not utilised due to the extensive number of returned results and the difficulty and time-consuming nature of screening these results by the reviewers. The search helped to refine the search terms and to identify keywords and synonyms.

The refined search terms and keywords (Table 1), were inputted into the same databases, PubMed and Trip Medical Database. Due to the subject area, Radiography Journal was hand searched. All results were screened by title and abstract against the inclusion criteria (Table 2). Where a title and abstract met the inclusion criteria, the researchers (HB + SR) assessed and screened the full-text articles. Citation lists from the included studies were screened for additional sources.

Primary and review studies were included with no limit on date because, despite the increasing number of implantable devices, the fundamentals of MRI safety and safety screening have remained consistent.

A quality review was not conducted due to the nature of a scoping review. Instead, each item was assessed against the research questions and objectives utilising the Population Concept Context (PCC) principle (Table 3). Any disagreements between the reviewers were resolved by consensus.

Despite the literature recognising the need for staff training in MRI safety, and the need to screen patients for MRI contraindication, most studies gave no further details on how to achieve this within the main body of the article. Discussions in the included studies were subsequently reviewed for relevant content (Table 3).

Results

Of the original 68 studies screened, 24 were included in this review (Fig. 1). Of the 24 included studies, four were national guidance documents from the USA (ACR), UK (MHRA), Australia and New Zealand (ANZ) (Royal Australia and New Zealand College of Radiologists, RANZCR) and Canada (Canadian Association of Radiologists, CAR). Most of the studies originated from the USA (n = 10) with four originating from the UK, three from ANZ, one from Ghana and one from Sweden. The publication dates range from 1994 to 2023. Most studies focused on the general diagnostic workforce. Two studies were aimed at radiologists[34,45] and three studies were aimed at MRI radiotherapy teams[29,30,31] one of which was specifically aimed at radiotherapy medical physics.[29] Data extracted from each included study comprised of study characteristics, information regarding MRI training topics/patient screening and key findings (Table 4). A review of the data allowed a range of key concepts to be identified which are presented in a narrative. A meta-analysis was not possible.

MRI safety training

The four national guidance documents (Table 5) and seven published studies discuss MRI safety training. All radiotherapy-based studies discuss MRI safety training topics, likely due to MRI being a new role extension for radiotherapy staff[29,30,31].

The national guidelines agree that the level of training an individual receives should be adequate and appropriate to their role. Training requirements recommended in the UK and ANZ guidance documents were reflected in six studies[29,30,31,34,35,36]. Six of the

Table 1
Search phrases and search combinations used in the literature search.

Keywords	Synonyms
Magnetic Resonance Imaging	MRI, MR
Radiographer	Technologist
Training, education	Teaching, knowledge
Safety screening	Screening, questionnaire
CT scout	CT localiser, Computed Tomography
Plain film radiograph	X-ray
Intensive Care unit	ICU, ITU, Intensive Therapy Unit
#	Search phrases
P1	MRI radiographer OR Magnetic Resonance Imaging radiographer
P2	MRI technologist OR Magnetic Resonance Imaging technologist
P3	MRI safety screening OR MRI screening OR MRI questionnaire
P4	MRI safety OR Magnetic Resonance Imaging safety OR MR safety
P5	Education OR training OR teaching OR knowledge
P6	Patient-centred care OR person-centred care
P7	Unconscious patients OR Learning difficulties OR Incapacitated patients OR Communication difficulties
P8	Cognitive difficulties OR dementia
P9	Guidelines
P10	ITU patient OR ICU patient OR Intensive care unit patient OR Intensive therapy unit
P11	Therapeutic radiographer OR MRI radiotherapist OR therapeutic technologist OR radiation therapist technologist
P12	Emergency OR traumatic brain injury
P13	X-ray OR plain film radiographs OR CT OR computed tomography OR CT scouts OR CT localisers
#	Search combinations employed
S1	P1 AND P4
S2	P2 AND P4
S3	P1 AND P2 AND P3
S4	P3 AND P10
S5	P1 AND P2 AND P5
S6	P4 AND P5
S7	P4 And P6
S8	P3 AND P6
S9	P3 AND P7
S10	P3 AND P12
S11	P3 AND P4 AND P8
S12	P3 AND P4 AND P9
S13	P11 AND P3 AND P5
S14	P4 AND P13

seven studies, despite containing no analysis of safety training requirements, stated that it should occur annually, in line with the guidance (Table 5)[29,30,31,34,36,37]. Additionally, the MHRA[10] and RANZCR[32] suggest the establishment of MRI safety committees to share knowledge, learning and to enhance training. Two studies mention the formation of MRI safety committees,[29,38] with Rogg[38] describing how sharing information between five hospitals positively impacted their ability to identify potential safety issues, discuss solutions and share safety updates, creating best practice within the network.

Methods of training

Training methods can be categorised into two groups, theoretical safety training (principles of MRI safety) and practical training sessions, for example, emergency drills.

Of the six studies that discuss theoretical MRI safety training, training delivery methods were not described in half,[32,37] and no study reported in-person training. eLearning sessions were utilised in the remaining three[31,34,36] with options for in-person educational sessions.[34,36] One study showed the move from MRI safety presentations to interactive eLearning sessions increased

Table 2
Inclusion and exclusion criteria.

Inclusion Criteria	Exclusion Criteria
All research (primary/review and grey literature)	Full text not available in the English language
All sources that mention the training of MRI staff/provide suggestions for MRI staff to effectively screen a patient	Any studies where the full text could not be obtained
Include sources aimed at all staff who are responsible for safety/conducting screening (Radiographic assistants (RDAs), radiographers, radiologists, medical physics)	Literature that refers to the paediatric population
No limit on date as even though the number and types of implantable devices on the market are increasing, the fundamentals of MRI safety and safety screening have largely stayed the same.	Any literature that doesn't mention specifically the screening of patients or training related to MRI safety
Sources that document/measure/focus on MRI safety training	Screening that involves Artificial Intelligence (AI)/mechanical input (metal detectors)
Sources that document/measure/focus on screening of underserved population groups	Training for non-radiology personnel (e.g., anaesthetic staff)
Sources that document/measure/focus on communication with patients	Literature that focused on the safety of implants/devices
Sources that document/measure/focus on screening patients with communication difficulties	Literature that states MRI personnel need to be trained/patients need to be screened without any information on what the training should include/advice on screening methods

Table 3
Initial data charting table to help determine the included and excluded full-text records based on the PCC principle (Population-radiology personnel, Concept- MRI safety training and screening, Context-specialised population groups with communication difficulties).

Author(s)	Title	Year	Does the study focus on radiology staff? (Y/N)	Does the study mention what should be included in MR safety training for radiology staff? (Y/N)	Does the study talk about how to screen patients? Elements of screening (Y/N)	Does the study discuss methods of communication with patients for effective safety screening? (Y/N)	Does the study discuss the use of imaging for screening patients? (Y/N)	Does the study talk about specialised patient groups (unconscious/ communication difficulties etc)? (Y/N)	Comments	Should the study be included in the review? (Y/N)

engagement and trackability. This allowed the knowledge of staff to be monitored and common misunderstandings explained, resulting in more tailored and effective training.[31]

The MHRA[10] and ACR[23] promote the use of emergency drills to simulate emergency procedures. The RANZCR[32] states that procedures should be in place to deal with emergencies, such as cardiac arrest or entrapment, cryogen leak or fire. Several studies discuss emergency procedures.[30,35–37,39] However, only two studies discuss performing emergency drills.[32,43] In a national survey of Ghana,[40] many departments were not proactive in the delivery of emergency drill training, evidenced by a lack of documentation and procedures. Therefore, MRI staff were less able to ensure the safety of themselves, the patients and other professional groups required in a response.[40]

Screening and communication

The national guidelines screening requirements are summarised in Table 5. The recommended two-step questionnaire followed by verbal review has been reported since 1994,[41] where it's argued that written questionnaires alone are imperfect and that a verbal review is required to determine the reliability of answers. Ten studies state this should be the minimum standard.[33,35,36,38–44] However, where questionnaires serve to prompt a person's memory[46] the quality of the answers depends on the types and phrasing of the questions used.[41,43] Additionally, the effectiveness of the screening process is only as good as the methods used and the consistency with which these methods are performed.[41] A survey of 206 institutions in 1994 found that 7% did not use written questionnaires and 5% of radiographers did not acquire any patient history.[41] Missing safety questionnaires and formal documentation were also observed when reviewing near-miss cases in 2015–2016, highlighting that compliance with formal procedures still varies.[36] Two studies promote diagrammatic questions, aimed at people with language or literacy issues.[45,47]

Patients may not understand the risks associated with MRI. When discussing patients' recollections of Intra-Ocular Foreign Body (IOFB) exposure, solely relying on patients' memory can cause issues.[48] For example, a patient may not remember sustaining an eye injury, may choose not to disclose an injury for fear of a cancelled appointment or may be unable to answer the questions.[33,48] Evidence indicates that a lack of recall/withholding information and communication barriers results in ineffective safety screening.[36] As such, good communication skills are seen as essential in MRI to ensure safe conditions.[36] Three studies discussed how to question patients effectively and how communication can affect the screening process. One study described using repetitive questioning throughout their screening process, increasing patient awareness and implant disclosure.[44] One study emphasised that using closed questions or asking negative or suggestible questions may not elicit accurate responses.[36] It is recommended that flexible questioning is employed when verbally screening patients, adjusting communication style to the individual, as patients cannot be assumed to have similar levels of knowledge.[32,36] One study[50] did provide their staff with training on screening patients. However, they focused on the content of the questionnaire and why it is important to complete, rather than how to supplement the information it contained.

Only one study mentioned the communication difficulties and needs within a neurodivergent population,[49] with another acknowledging that MRI staff may need more specialised training and experience with this patient group.[35] Despite not focusing on the screening process, having suitable private spaces and time to conduct the safety screening could improve overall satisfaction.[49] This study also noted that a lack of communication between

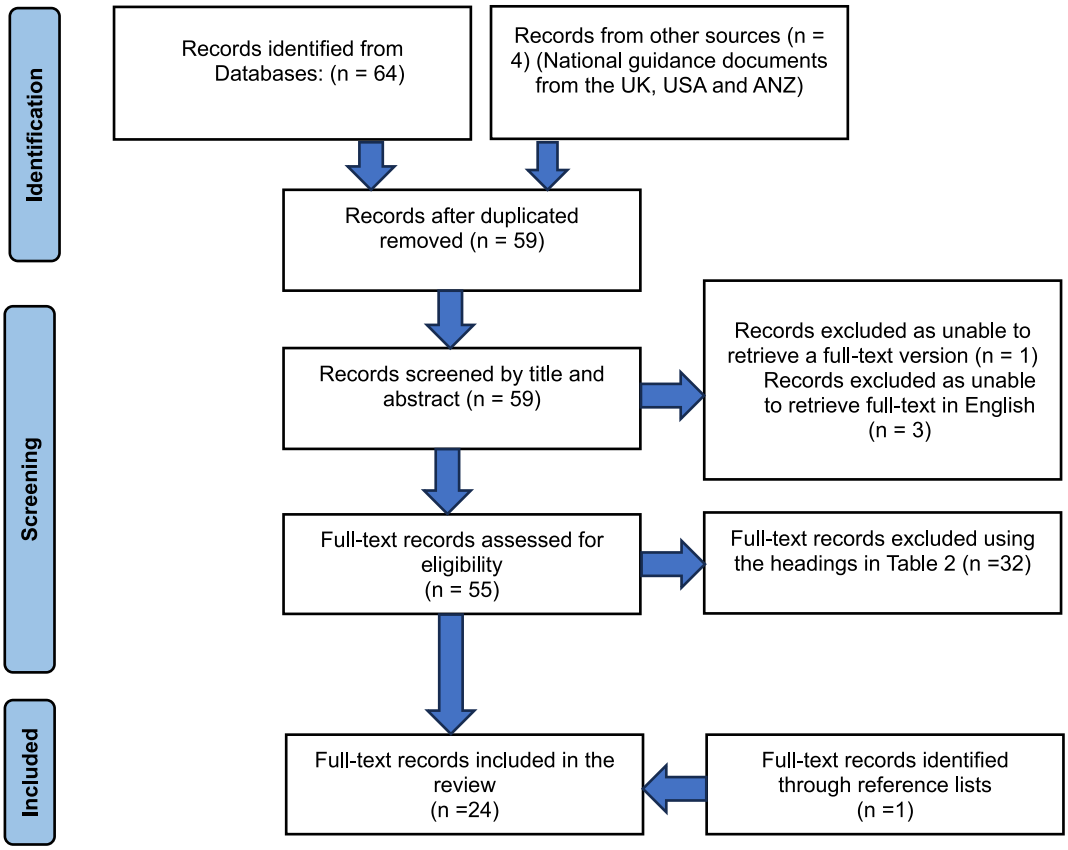

Figure 1. Flow diagram of the included studies, adapted from the PRISMA-ScR flowchart for scoping reviews.

referrers and the MRI team caused difficulties because adjustments in advance of the patient's appointment could not be facilitated.[49] However, these issues also arise in other areas of the pre-MRI process, such as referrers not highlighting any medical implants in advance of an appointment.[36,50]

No studies discussed specific training for safety screening patients or advised any form of communication training to ensure all the relevant information is obtained.

Screening of unconscious or non-ambulatory patients and the use of imaging

Five studies mention screening for unconscious or unresponsive patients.[34,37–39,42] Three studies mention contacting NOK or family members for medical information.[37,39,42] Two studies discuss utilising medical records to investigate an individual's medical and surgical history.[34,42] One study suggested the screening form should be completed by the referring doctor, or a member of the referring team, utilising existing medical records.[34] Five studies mention using existing imaging if available.[34,37–39,42] Kimbrell[42] promotes the use of plain film radiographs and CT examinations but does not specify body region. Two studies recommend reviewing existing CT or plain film studies.[34,37] If there are none available, they suggest acquiring plain radiographs of the head, chest, abdomen and pelvis, an approach also echoed by Franco.[39] Rogg[38] recommended plain film radiographs as directed by the ACR[23] (Table 5) and also supported the use of whole-body CT scout images to ensure rapid access to MRI for suspected acute stroke patients. Three studies suggest physical examinations[38,39,42]

The ACR[23] states that screening can be bypassed if there is a serious risk to life or limb. This can be done by consensus agreement of the referring doctor and senior MRI doctor. This is only mentioned by one study.[37]

Imaging may be used to identify FBs present within a person, the most common being IOFBs.

Recommendations from the national guidelines vary. From no imaging recommendations (CAR[33]), a plain film radiograph for IOBF only (MHRA[10]), to plain film radiographs for implanted devices and FBs in any anatomical location, or CT if deemed appropriate (RANCR,[32] ACR[23]). Reviewing past MRIs for susceptibility artefacts is also mentioned (ACR[23]). In practice, there is no agreed standard protocol for IOFB identification,[36,48] often meaning policies vary across institutions.[41] Only one study suggested solely plain film radiographs for IOFB imaging,[39] while another mentions plain film radiographs and CT.[45] The different imaging modalities often utilised for IOFB screening have been investigated and not only is there no standardised modality to detect IOFBs, but the range of screening protocols and projections also varies greatly.[48] Additionally, it was observed that where plain radiographs can underestimate IOFBs, CT can be more sensitive, but with a much higher dose.[48] Therefore, it is recommend limiting CT to patients who have experienced orbital trauma, rather than for those with a history of working with metal.[48] The use of ultrasound was explored but there are difficulties in determining whether a FB is intra or extraocular.[48]

Only one study mentioned FBs in locations outside the eye and recommended plain film radiographs to localise. This was also the only study to state that FB radiographs need to be cleared by a radiologist before proceeding,[39] despite evidence that when radiographer image interpretation of IOFB was carried out, after a short course of formal training, high accuracy levels were recorded post-training.[43]

Table 4
Data extraction table.

Authors(s) and year	Country	Title	Target audience	Type of Evidence	Themes/Key Findings
American College of Radiology, 2020[23]	USA	ACR manual on MR safety	All personnel within an MR facility	National guidance document	• Discusses the screening of patients, including unconscious/ nonresponsive patients • Discusses the use of imaging (plain film and CT) for screening • Clear statements on best practice for all patient groups including unconscious/nonresponsive patients
Bailey et al., 2007[48]	UK	Screening for intra-orbital metallic foreign bodies prior to MRI: Review of the evidence	Radiographers	Review article	• There is no standardised way to screen for IOFBs • Discusses the different modalities that can be utilised and their pros and cons • Talks about the issues surrounding patient recall and the reasons someone may not give accurate information
Boutin et al., 1994[41]	USA	Injuries associated with MR imaging: Survey of Safety records and methods used to screen patients for metallic foreign bodies before imaging.	Radiologists, radiographers	Primary (Quantitative)	• The modalities and projections used for IOFB detection greatly vary across the USA • Written questionnaires alone can be ineffective • Verbal review with the patient allows the reliability of the answers to be judged and further clarification of written responses • All persons entering the magnet room should be screened the same way a patient would be •The most common types of injuries (from burns and projectiles) are easily preventable • Focussed on IOFB, but has good insights. Includes potential issues and risks with those not able to communicate well.
Calamante et al., 2015[35]	International	MR system operator: Recommended minimum requirements for performing MRI in human subjects in a research setting	MR system operators	Review article	• Provides guidelines on the minimum levels of knowledge required to safely perform MRI scans for research • Lists the topics that should be included in any safety or educational program • Lists what is required to be discussed while screening a patient or visitor that might enter the magnet room • Lists the types of emergency situation that could cause issues in MRI, necessitating proper local policies to be established
Chakraborty et al., 2011[33]	Canada	CAR Standard for Magnetic Resonance Imaging	All personnel within an MR facility	National guidance document	• Canadian guidance, limited information but does discuss need for screening • Statements on best practice and minimum requirements/ responsibilities of each professional group
Cook et al., 2023[29]	ANZ	ACPSEM position paper: the safety of magnetic resonance imaging linear accelerators	MRI radiotherapy medical physicists	Position paper	• Lists the topics that should be included in any safety or educational program and the type of training that is required for different staff groups within a facility •Briefly mentions the requirements for safety screening a patient and what it should include
Doda Khera et al., 2022[37]	USA	ED MRI: Safety, Consent, and Regulatory Considerations	All personnel within an MR facility	Review article	• Lists what should be asked when screening a patient, including what to do if a patient has an unidentified implant • Discusses the use of plain film radiographs or CT scouts to visualise any MR contraindications • Talks about the screening and scanning of unconscious/

Table 4 (*continued*)

Authors(s) and year	Country	Title	Target audience	Type of Evidence	Themes/Key Findings
					nonresponsive patients, including what to do in a medical emergency
Franco, 2020[39]	USA	Magnetic resonance imaging safety	Radiographers	Educational article	• Discusses the procedures of a medical emergency • Discusses the screening process, methods for doing it and what to ask for • Does talk about unconscious/ nonresponsive patients and the process for screening them • Discusses the importance of a written questionnaire complemented by a verbal review • Limited discussion regarding FBs
Goolsarran et al., 2019[50]	USA	Using near-miss events to improve MRI safety in a large academic centre	Radiographers	Quality improvement report	• Good descriptions of risks and issues associated with unidentified implants and the importance of good quality screening • Mentions training staff and the importance of screening and the contents of the questionnaire
Hansson et al., 2022[44]	Sweden	MR-safety in clinical practice at 7 T: Evaluation of a multistep screening process in 1819 subjects	Radiographers	Quality improvement report	• Emphasises the issues with screening and the importance of a multi-step screening process • Highlights that a repetitive approach to asking questions is more likely to raise awareness and prompt people's memories
Hogan et al., 2023[30]	ANZ	Old dogs, new tricks: MR-Linac training and credentialing of radiation oncologists, radiation therapists and medical physicists	MR radiotherapy teams	Commentary	• Recognises the limited knowledge MR radiotherapy teams possess regarding MR safety so gives a detailed list of what should be included in safety training and specific to different staff groups
Hudson et al., 2019[36]	UK	A 3-year review of MRI safety incidents within a UK independent sector provider of diagnostic services	Radiographers	Quality improvement report	• Details what needs to be included with screening and ways that the process can be adapted but only for the conscious, ambulant patient • Discusses the human factors that affect accurate screening • Promotes a flexible style of screening and open questions • Includes discussion of teaching and training.
Kimbrell, 2020[42]	USA	Elements of Effective Patient Screening to Improve Safety in MRI	Radiographers	Educational article	• Discusses screening methods, including the use of other imaging. • Does discuss screening for unconscious/nonresponsive patients
Lockwood et al., 2016[43]	UK	Intraorbital foreign body detection and localisation by radiographers: A preliminary JAFROC observer performance study	Radiographers	Primary (Quantitative)	• Specifically investigates IOFB but discusses training, why it is helpful, and how it should be undertaken • Positive results from radiographer training regarding image review
McDaid et al., 2021[31]	ANZ	Developing electronic learning to deliver MR safety training in a radiotherapy department	MR radiotherapy teams	Primary (Quantitative)	• Discusses the use of an eLearning training program to deliver MRI safety training in a radiotherapy department with the associated pros and cons • mentions the dangers of over cautiousness and if patients are denied admission to MR radiotherapy treatments
MHRA, 2021[10]	UK	Safety Guidelines for Magnetic Resonance Equipment in Clinical Use	All personnel within an MR facility	National guidance document	• Discusses the screening of patients, including unconscious/ nonresponsive patients • Discusses the use of imaging (plain film) for screening • Clear statements on best practice for all patient groups including unconscious/nonresponsive patients • Clearly states what should be included in MRI safety training

(*continued on next page*)

Table 4 (*continued*)

Authors(s) and year	Country	Title	Target audience	Type of Evidence	Themes/Key Findings
Piersson et al., 2017[40]	Ghana	A national survey of MRI safety practices in Ghana	Radiographers	Primary (Quantitative)	• Good summary of one country's practice related to a known standard (ACR), details of the importance of screening • Talks about the use of emergency drills.
Price, 1999[45]	USA	The AAPM/RSNA physics tutorial for residents	Radiologists	Educational article	• Lists subjects required in MRI safety training/education • Communication issues are lightly addressed • Mentions the use of imaging for IOFB detection • States what questions are needed on the questionnaire but does not elaborate on verbal review
RANZCR, 2021[32]	ANZ	MRI Safety Guidelines	All personnel within an MR facility	National guidance document	• Discusses the screening of patients, including unconscious/ nonresponsive patients • Discusses the use of imaging (plain film + CT) for screening • Clear statements on best practice for all patient groups including unconscious/nonresponsive patients • Clearly states what should be included in MRI safety training
Rogg, 2020[38]	USA	Key Elements of Clinical Magnetic Resonance Imaging Safety: It Takes a Village	All personnel within an MR facility	Review article	• Discusses the importance of the questionnaire and verbal review • Good detail of a screening process and how to work through unknown situations with radiographs • Promotes the use of previous imaging to exclude MRI contraindications • Talks about using CT scouts to identify implants • Mentions training a number of times but doesn't specify what is included
Tsai et al., 2015[34]	USA	A practical guide to MR imaging safety: what radiologists need to know	Radiologists	Educational article	• Discuss issues surrounding unconscious patients, and the need for effective screening • Plain film radiographs can be taken if no existing imaging otherwise previous plain film/CT can be reviewed • Details what should be included in the training for different staff groups • Mentions evacuation procedures
Sawyer-Glover et al., 2000[46]	USA	Pre-MRI procedure screening: Recommendations and safety considerations for biomedical implants and devices	Radiographers	Review article	• Good overview of what needs to happen in a variety of scenarios when screening a patient. • Discusses methods of screening and how to ensure the correct information is obtained • Mentions using medical records
Stogiannos et al., 2023[49]	UK	Toward Autism-Friendly Magnetic Resonance Imaging: Exploring Autistic Individuals' Experiences of Magnetic Resonance Imaging Scans in the United Kingdom, a Cross-Sectional Survey	Radiographers	Primary (Quantitative)	• Discusses the communication difficulties experienced by autistic people and ways these could be mitigated • Mentions the training of healthcare staff to adapt the ways in which communication occurs • Doesn't focus on pre-MRI screening but can extrapolate relevant scenarios
Weidman et al., 1015[47]	USA	MRI safety: A report of current practice and advancements in patient preparation and screening	Radiographers	Review article	• Emphasises the completion of the safety questionnaire for every attendance • Reinforces repetitive questioning through the preparatory stages to assist the memory of the patients

Table 5
Summary of the results from the national guidance documents.

Identified Key Concepts	Medicines and Healthcare products Regulatory Agency (MHRA),[10] UK	American College of Radiology (ACR)[23]	Royal Australia and New Zealand College of Radiologists (RANZCR)[32]	Canadian Association of Radiologists (CAR)[33]
MRI safety training				
MRI safety training and its contents are the responsibility of the Magnetic Resonance Medical Director (MRMD) in charge of individual facilities		X		X
Safety training should include the following subjects:				
The safety aspects of the magnetic fields and their effects	X		X	
Fringe fields	X		X	
Cryogens	X		X	
Knowledge of local regulations, including zoning and access	X		X	
Emergency procedures including simulation training	X		X	
Full instruction on the use of the equipment	X		X	
Consequences of quenching the magnet and rules relating to the exposure of MRI	X		X	
Bio-effects of the magnetic fields and the use of hearing protection	X		X	
Safety training should be attended annually	X	X	X	X
Establishment of MRI safety committees	X		X	
Screening and communication				
Safety screening should be conducted with a written questionnaire followed by verbal review	X	X	X	
Screening of unconscious/non-ambulatory patients and the use of imaging				
Discusses methods of screening unconscious/unresponsive patients	X	X	X	
Advises contacting the NOK to seek relevant medical history.		X	X	
Recommends the use of imaging to rule out any MRI contraindication.	X	X	X	
Recommends viewing existing plain film radiographs	X	X	X[a,b]	
Recommends viewing existing CTs		X	X[a,b]	
Recommends viewing existing MRIs		X		
If there is no available imaging:				
Recommends performing plain film radiographs	X	X[a,b,c,d]	X[a,b]	
Recommends performing CT			X[a,b]	
Recommends the use of physical examinations	X	X	X	

X denotes responses present within a national guidance document.
Stated anatomical regions:
[a] Head.
[b] Chest.
[c] Abdomen/pelvis.
[d] Extremities.

Discussion

MRI safety training is essential to prevent harm to staff and patients from the risks associated with MRI. Despite many references to MRI safety throughout the literature, there is no universally agreed way to undertake the training of MRI staff. This has led to inconsistencies in the levels of proficiency globally and ongoing concerns over safe working practices.[51,52]

MRI safety training

In the UK, there is currently no nationally agreed consensus on how to effectively deliver MRI safety training[31] and none of the national guidance documents provide advice on this. The ACR's 2002 white paper was the earliest to call for consistent and systematic policies for safety training and screening in MRI.[38,53] Despite the hazards of MRI being widely detailed for over two decades and the acknowledgement that MRI safety awareness directly influences the safety of all,[51] very little is documented about the contents and delivery of MRI safety education, the most common statement being 'it is required'. General MRI safety training is available online. However, this often has access limits, for example, a paywall,[54] or restricted access to certain groups.[55] As such, individual organisations tend to create their own MRI safety-based training programs, exacerbating the issue of non-standardised learning. Furthermore, existing national training[55] focuses on the fundamentals of MRI safety only, with no inclusion of enhanced patient screening or implant recognition. Compliance with mandated training schedules and measured competence of staff in this area is even less well discussed.[56]

Formal education, as opposed to on-the-job training, has similarly been debated over the years[52] as a lack of safety knowledge can aid non-compliance.[40] Some countries require MRI staff to have completed undergraduate training or a diploma.[24,33,52,57,58] These programs cover the breadth of MRI learning, from MRI principles and techniques to anatomy and safety. Other countries have post-graduate programs with similar content but are not mandated[59] and safety training is not mandated in others at all.[60] In the UK, MRI is taught as part of undergraduate programs, but there is no evidence that core skills, such as MRI safety and patient screening, can be sufficiently attained due to the lack of hands-on experience and competing requirements within the curriculum.[33,40] Westbrook[52] argues that on-the-job learning can be inadequate because it lacks a standardised curriculum or formal assessments. Additionally, a general lack of understanding surrounding the interaction of devices within MRI, or policies governing them, can lead to

adverse events, such as misinterpretation of generic implant safety policies.[36] Even though formal MRI education programs cover a broad range of topics, it could be concluded that without a working knowledge of MRI and image acquisition, an individual's ability to assess risk related to implanted devices or FBs may be hindered. This has been demonstrated in radiographers in ANZ, showing that those without formal MRI education have lower confidence, knowledge and poorer clinical decision-making skills than their peers.[51]

Methods of training

The positive aspects of online training are echoed in the literature, suggesting that it allows for greater flexibility and convenience,[61] ideal for workplaces where shift working occurs. However, the performance between traditional and online learning is undecided with a paucity of formal evaluation of eLearning programs.[62] Yet, some studies report better performances following online learning.[61] Therefore, purpose-built, interactive and nationally available online MRI safety training could be effective in ensuring the MRI workforce maintains their training requirements while allowing for assessments of knowledge and record documentation. In addition, trends in feedback from users can highlight knowledge gaps, supporting the development of further online training programs and training can be tailored to different groups based on their experience and role within an organisation.[62]

Emergency response drills (simulation training) allow staff to rehearse emergency procedures and build staff confidence.[40] Practical learning is shown to be more effective in-person[63] and these are increasingly being incorporated into medical-based training across all disciplines. Despite being a requirement in some national guidance,[10,23] this type of training in MRI is not well documented.[64] Simulation-based training has been shown to reduce medical errors by improving performance and communication between team members in emergencies, especially important in MRI. Therefore, it is apparent that practical safety training needs to be undertaken face-to-face and with the same importance as theory-based safety education.

Screening and communication

Pre-MRI safety screening is critical to ensure there are no MRI contraindication.[10,23,32] Although the guidance documents state that the MRI safety screening process starts with the referrer, this does not always happen in practice.[24,36] The responsibilities of referrers is outside the scope of this review but has been identified as an issue,[24,50] hence MRI staff are required to effectively and efficiently screen patients at their appointment.

Taking a medical history is seen as an essential part of medical and nursing training, and taught at the undergraduate level.[65,66] Clinicians are taught to undertake history taking in a systematic way, ensuring the symptoms of the current complaint and an overview of the patient's health status are captured.[67] However, the systematic approach often refers to gaining comprehensive insights into a person's health, such as medications, medical, family and social history, rather than the presence of implants. Additionally, as the main aim is to acquire information about the current condition to make a diagnosis, a situation the patient is most familiar with, it is assumed a patient can communicate this information accurately and with little prompt. However, to establish safety, a complete surgical history is essential, even if not related to the current complaint and little guidance is available regarding achieving a complete and accurate history. One approach is to develop a systematic method to ensure all the relevant questions are asked without repeating verbatim the questions on the MRI safety questionnaire. Alternatively, a combination of open and closed questions has been suggested,[66] starting with open questions, to provide an overview of medical information. However, this approach may not ensure all relevant information is gathered and information may be mistakenly omitted without structure. Additionally, in MRI, asking open questions could invite an excess of irrelevant information not relating to surgical history, adding time and potentially increasing the anxiety of the patient.[68] Following up with closed questions can clarify or add additional detail. Although, it has been reported that asking closed questions and technical descriptions can prevent people from disclosing relevant information.[36]

Radiographers do not traditionally take medical histories, unlike nurses who often have more face-to-face time with patients, and in more informal settings, enabling them to build a rapport and trust to acquire information.[69] The lack of rapport can be compounded by other components, such as poor communication practices, potentially leading to patients not disclosing relevant clinical information. Additionally, a lack of trust, or privacy concerns, may also hinder the disclosure of relevant medical history.[70] The fear of judgement, embarrassment, not wanting to take up time or being thought of as a difficult patient have also been highlighted as reasons for non-disclosure of information.[71] This can be further compounded in certain groups who could feel discriminated against in the healthcare setting.[70] Although, withholding medical information may not be intentional. A growing reason for poor recollection includes age-related memory issues.[72] An ageing population relies more heavily on healthcare services to treat longer-term conditions.[73] Memory fades faster in the elderly, as they experience more difficulty structuring information, especially in a healthcare setting where information is often relayed in an unstructured fashion, e.g., different test results and treatment plans being discussed at different times.[72] Coupled with anxiety or stress can also affect the recall of information.[72] The perceived importance of the information by the patient, an issue in MRI if previous surgical interventions are not related to the condition being imaged, and the methods with which information is communicated, are also thought to affect the recollection of medical information.[72]

Despite the importance of accurate safety screening being universally accepted, little emphasis is directed at ensuring MRI staff have the communication skills necessary.[42] There is a lack of literature describing a standard approach to questioning and acquiring communication skills, particularly for new staff members.[68] Even with publicly available MRI safety questionnaire templates,[74,75] many institutions develop their own safety questionnaires, specific to their specialities.[50]

Communication training for healthcare workers to allow reasonable adjustments for the autistic community has been identified[76] and was recently introduced to the NHS in England.[77] Mandated for all health and social care workers, it educates on how to communicate with people with learning difficulties and disabilities. Insufficient time for questions and answers negatively affects this group,[49] which is echoed in the literature towards the wider population, suggesting that insufficient time can result in an incomplete history and that feeling rushed can inhibit the disclosure of potentially relevant information.[66] Additionally, for patients with multiple morbidities or in an acute/time-sensitive situation, history taking can be time-consuming and can be potentially unreliable.[78] Effective two-way communication within all population groups is essential to ensure that any questions are understood and that the replies are being listened to36. A combination of verbal and non-verbal cues builds up an intuition as to the reliability of the answers being given. However, autistic people, for example, may not communicate in traditional ways and both verbal and non-verbal communication may be different to what you might expect.[79] As such, these cues may be less obvious and cause misunderstandings.[80] Conversely, an autistic staff member may be

unable to pick up on verbal and non-verbal cues in the same way, necessitating alternate methods to effectively screen their patients.

Screening of unconscious or non-ambulatory patients and the use of imaging

The necessity of scanning acutely unwell patients in MRI is increasing.[37,81,82] It has been suggested that safety screening can be bypassed in extenuating circumstances, but there is no justification for this, comments on the consequences or how often this might occur.[23,37] The potential impact of not picking up a medical implant or FB could have severe consequences for the patient, especially if they are unable to communicate any heating or unusual sensations within their person. However, these issues can also arise if incomplete screening occurs. The RANZCR[32] focuses on imaging the head and chest when a medical history is incomplete or potentially inaccurate, leaving the possibility for abdominally placed implants[83] or FBs to be missed if solely relying on image review for the screening process.

Two studies suggested the faster, lower dose and more easily acquired CT scout as a method of safety screening, which could provide critical information in an emergency setting.[37,38] To date, only one study has investigated CT scouts for MRI safety screening as they have the same anatomical view as plain film radiographs.[82] While acknowledging that some small endovascular stents are not visible on plain film radiographs or CT scouts, they recorded a sensitivity of 85% and a specificity of 95%, indicating that whole-body CT scouts could be an alternative method of MRI safety screening in time-sensitive situations, especially if a CT is already being performed.[38]

The ACR,[23] RANZCR[32] and MHRA[10] suggest physical examinations to identify any scars from previous surgery. However, with the evolution of technology, active devices are becoming harder to externally locate. For example, traditional pacemakers utilise a subcutaneous generator box, which would have a scar associated with it in the pectoral region of the chest.[84] However, pacemakers can now be leadless and implanted endovascularly, meaning no scar would be seen.[85] Additionally, some spinal cord stimulators are wireless with small subcutaneous components, rather than the larger generator boxes.[86] If the external component has been removed before arrival, it could be missed, which limits the effectiveness of physical examinations in some scenarios.

The UK has had formal post-graduate training programs for radiographers reporting plain film studies since the 1990s, an established advanced practice role.[87] A large portion of radiographer reporting has been concerned with plain film imaging with reported high levels of sensitivity and specificity.[88] Only one study in this review looked at radiographers' abilities to identify IOFBs on plain film radiographs.[43] Despite the positive results post-training, the ability of radiographers to identify FBs, or internally implanted medical devices, anywhere else in the body has not been evaluated. This is pertinent as certain categories of emergencies are more likely to occur out-of-hours,[78] which is likely to see fewer senior staff, fewer support staff, such as medical physics, and reduced access to radiologists. Therefore, radiographers must have the confidence to accurately screen prospective MRI patients, even if they are unconscious or unresponsive. No study within this review highlighted any training available to any category of MRI staff in the finding and naming of medical implants using imaging.

Limitations

Due to the omission of using databases, such as Google, not all relevant material may have been captured within this review. This could include material from professional organisations, educational institutions or healthcare providers.

Conclusion

This review has been conducted to determine what we teach MRI staff to safely screen patients in MRI. Despite training regarding the inherent hazards of MRI being commonplace and universally agreed upon, training regarding the screening of patients and emergency drills is not as well established. A written questionnaire followed by verbal review is the most common form of safety screening, but there is no training for radiographers regarding communication skills and advanced screening methods. This includes image review if a patient is unconscious or unresponsive.

Although the importance of MRI safety training and screening is well-established there is a need for consensus on best practice. Gaps lie with the more complex elements of screening such as how questions are asked to all patients including the neurodivergent population. Communication training specific to radiographers could improve the quality of routine safety screening, which could include recognising verbal and non-verbal cues from both neurodivergent and neurotypical patients. There is also no recognised training for radiographers to identify implants on imaging. Therefore, future work could include training MRI staff to find and identify implants using imaging, which could enhance this form of safety screening.

Conflict of interest statement

None.

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