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Continuing Professional Development

A practical guide for radiographers focussing on safety during magnetic resonance imaging

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ABSTRACT

Magnetic resonance imaging (MRI) poses some risk when adequate safety measures are not adhered to. Despite efforts on MRI safety, incidents still occur in MRI. Extensive training on MRI safety is essential to protect patients, staff and the public from the risks associated with magnetic fields. Safety issues in MRI include projectile and torque effects on ferromagnetic objects, thermal effects, claustrophobia and adverse reactions to contrast agents. Radiographers operating MRI scanners play a vital role in ensuring that all who enter the MRI environment adhere to the safety measures. However, radiographers are faced with challenges that impact how safety issues are monitored. This Continuing Professional Development article is aimed at highlighting these challenges and providing radiographers with some practical guidelines for these challenges.

RÉSUMÉ

L'imagerie par résonance magnétique (IRM) présente un certain risque lorsque les mesures de sécurité adéquates ne sont pas respectées. Malgré les efforts déployés en matière de sécurité, des incidents se produisent toujours en IRM. Une formation approfondie sur la sécurité en IRM est essentielle pour protéger les patients, le personnel et le public des risques associés aux champs magnétiques. Les problèmes de sécurité en IRM comprennent les effets de projectile et de couple sur les objets ferromagnétiques, les effets thermiques, la claustrophobie et les réactions indésirables aux agents de contraste. Les radiographes qui exploitent les scanners IRM jouent un rôle essentiel en veillant à ce que tous ceux qui entrent dans l'environnement IRM respectent les mesures de sécurité. Cependant, les radiographes sont confrontés à des défis qui ont un impact sur la façon dont les questions de sécurité sont contrôlées. Cet article de formation médicale continue vise à mettre en lumière ces défis et à fournir aux radiographes quelques directives pratiques pour y faire face.

Keywords: Magnetic resonance imaging; MRI safety; MRI implants; MR radiographers; Magnetic field

Learning outcomes

After reading this article, readers will be able to:

a) *Understand potential safety issues in MRI and identify patients at high risk of experiencing negative effects.*

b) *Describe safety hazards associated with different magnetic fields.*

c) *Explain how various safety hazards can be minimized/ prevented.*

d) *Apply strategies to ensure patient safety in MRI.*

This is a CPD article and provides the equivalent of 1.0 hour/credit from CAMRT that may be applied to your professional development credit system (self reporting). A multiple choice quiz (and answers) follow this reading.

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Introduction

Magnetic resonance imaging (MRI) is considered to be a safe imaging modality since it does not make use of ionising radiation to produce diagnostic images [1]. However, MRI does pose some risk to patients, staff and the general public when adequate safety measures are not adhered to [2]. MRI makes use of a magnet and the signal received from the hydrogen atoms in the body to produce diagnostic images. Most of the safety issues in MRI are related to the magnetic field [3]. These include projectile and torque effects due to static magnetic fields, and thermal effects caused by radiofrequency electromagnetic fields [1].

Despite efforts on MRI safety, adverse incidents continue to occur in MRI due to limited knowledge about MRI safety protocols and guidelines [4]. A total of 1568 cases of MRI-related adverse incidents were reported to the United States Food and Drug Administration (US FDA) between 2008 and 2017 [1]. Furthermore, a review of MRI safety incidents in the UK independent sector found that 674 MRI safety-related events were reported between 2015 and 2017; these made up 7.5% of all reported incidents during this period [2]. In addition, two fatal MRI accidents were reported in India and South Korea in 2018 and 2021, respectively [5].

The requirements for radiographers to practice MRI vary from country to country. In the United States of America and Canada, it is mandatory to complete MRI-specific undergraduate programmes or MRI diplomas to be able to practice MRI. A post-graduate qualification in MRI is required in Ireland and New Zealand. On the other hand, Australia and the United Kingdom (UK) offer post-graduate diplomas and Master's degrees in MRI, however, these are not compulsory for clinical practice in MRI. Instead, in the UK, registration as a general radiographer and a portfolio of evidence of experience in MRI is required for registration as an MRI radiographer while Australia recommends MRI-specific training and supervised clinical experience to practice [6]. Like Australia and UK, there are no requirements for formal MRI qualifications for diagnostic radiographers to operate MRI scanners in South Africa (SA). However, most diagnostic radiography undergraduate training programs include theory on MRI physics and safety. Most of the radiographers operating MRI scanners do so through in-service training at the facilities where they are employed. Additionally, some radiographers attend MRI short courses to further enhance their undergraduate training and to gain more insight into the operation of the MRI scanner, image optimization, and MRI safety. Completion of this short course is not compulsory and is also not an operational requirement for working in MRI.

In this Continuing Professional Development article, we will highlight the role a radiographer plays in ensuring the safety of patients, staff, and the public in MRI from the perspective of a clinical radiographer and educator based in South Africa.

MRI safety

The radiographer plays a crucial role in the safety of all individuals entering the MRI environment. One of the safety measures in MRI is the implementation of the four safety zones, as recommended by the American College of Radiology according to the proximity to the magnet. Zone 1 and zone 2 are far from the magnet and thus freely accessible to the members of the public, patients and healthcare workers. The reception, patient dressing rooms and patient screening areas form part of zone 2. The MRI control room and scanning room (magnet room) are found in zone 3 and zone 4 respectively, and therefore access to these areas needs to be controlled ensuring that only authorised people (staff and screened patients) enter. Access can be restricted by locks/keys and passcodes which are only made available to authorised people [4,7].

To ensure patient safety, all patients undergoing MRI scans are required to complete a safety evaluation checklist to exclude any safety risks. This evaluation is usually followed by a consultation with the radiographer. Consequently, the radiographer is able to identify the patient's scanning needs, possible safety risks and contra-indications before the patient is taken inside the scanning room. Despite taking these safety measures MRI accidents still happen and are significantly under-reported [8].

Globally, there is a high demand for MRI imaging [9]. However, resources are constrained [10] yet, in South Africa, there is an expectation of high patient throughput with the increasing workload [11]. There are also staff shortages which often result in radiographers dividing their attention and not adequately concentrating on everything happening around them. In addition, there is inadequate training for new MRI radiographers. These factors could be contributing to the occurrence of MRI accidents. Therefore, we suggest adequate staffing with a minimum of two MRI radiographers present at any given time. This is in line with the American College of Radiology (ACR) recommendations [12]. Additionally, the completion of the short course in MRI is recommended for all MRI radiographers in South Africa. Alternatively, radiographers should be subjected to intensive uninterrupted in-house training programs facilitated by expert MRI radiographers.

Some of the safety considerations specifically relating to patients include the following:

(1) Projectile effects

The static magnetic fields are responsible for the projectile effect, which is when ferromagnetic objects are turned into missiles or projectiles and are attracted toward the magnet's bore [3]. Projectile effects are very serious as those who are trapped between the magnet and the ferromagnetic object can be harmed. Even though the MRI area is considered a controlled area, ferromagnetic materials commonly mistakenly taken into the MRI scanning room include oxygen cylinders, wheelchairs, scissors, and floor cleaning equipment [3]. Therefore, caution needs to be exercised and signs warning against taking these objects into the MRI scanner should be clearly vis-

ible outside of the scanning room as well as in MRI waiting area [7]. In addition, the radiographer must ensure that non-MRI personnel is not allowed access to the scanning room before ferromagnetic objects have been excluded. We recommend that the onus to educate other healthcare personnel about the dangers relating to ferromagnetic materials should be placed on the radiology management and/or radiographers. This education can be included in the induction of new hospital staff [7].

(2) Metallic Implants and devices

The static magnetic field also has a negative impact on metallic medical implants and devices. Patients are often dependent on various implants and the dysfunction of these implants due to the magnetic field interaction can be detrimental to them. Implants considered contraindicated are pacemakers, cochlea implants, neurostimulators, cardiac defibrillators, and automated medication delivery pumps [7]. Insulin delivery pumps are among these automated delivery pumps that are contra-indicated in MRI. To our knowledge, there are currently no special considerations for patients dependent on insulin undergoing MRI scans. However, a patient dependent on insulin recently highlighted the need for special consideration when she gave an account of her experience during an MRI examination [13]. Because of the length of the MRI examinations and the fact that the insulin pump could not be taken into the scanning room, the patient's blood sugar levels dropped. This patient felt that while her blood sugar levels were dropping and she was asking for help, the radiographer showed no consideration and understanding of her condition [13]. This incident highlights the need for better patient care and communication before, during, and after the MRI procedure. We, therefore, recommend that a specific focus on the use of insulin be included in the safety questionnaire. This is because the patient's sugar levels can drop during lengthy MRI examinations which may result in a diabetic coma. Radiographers should furthermore be educated on the seriousness of the condition and the importance of communicating with the patient.

Pacemakers and defibrillators that can be scanned under very specific conditions are available and these are termed MRI conditional devices as they pose no risk when scanned under suitable conditions [14]. These conditions often include the magnetic field strength that can be used and the maximum specific absorption rate (SAR) that should not be exceeded during imaging [15]. On the other hand, the term "MRI safe" refers to devices that pose no risk from exposure to the MRI environment [6]. The use of MRI conditional devices increases the patient throughput, but radiographers need to be cognisant of the specific conditions under which scanning should take place. The presence and type of an implant are usually reported by the patient during the consultation with the radiographer and documented in the MRI order form by the requesting physician [16]. In addition, the surgical or operative notes of the patient should be consulted to confirm the type of implant [15]. Therefore, accurate recording in the operative notes is of utmost importance. Compliance with the manufacturer's stated conditions will ensure safe imaging of patients with MRI conditional implants [15]. Furthermore, it is advisable for radiographers to document the conditions under which these patients were scanned as it will be useful for follow-up examinations of these patients. Additionally, the aftercare of such patients should be documented [7]. To further ensure safety, each MRI department should have standard operating guidelines and imaging protocols for scanning patients with these devices. These guidelines will also assist in educating inexperienced radiographers.

(3) Tissue heating

Exposure to the RF electromagnetic field is linked to thermal effects on tissues or tissue heating. According to the FDA report, thermal effects accounted for 59% of all MRI-related adverse incidents [1]. The degree of tissue heating depends on the intensity of the radiofrequency energy, exposure time, and mass of the exposed tissue, and this is termed specific absorption rate (SAR) [3]. It is essential for the patients' correct weight and height to be registered to allow for the SAR limit to be calculated curbing the amount of energy absorbed by the body. The RF magnetic field can also induce eddy currents and cause local heating at the site of medical implants or where metallic objects such as ECG leads and electrodes or drug delivery patches are in contact with the patient's skin. This can also occur with non-ferromagnetic metals or MRI-safe metals [7]. Severe burns can be experienced when RF coils are in direct contact with the patient's skin [7]. The radiographer can reduce thermal effects by using foam pads to prevent skin-to-skin contact and by temporarily removing metallic objects contacting the patient's skin before performing the scan [4]. Radiographers can furthermore familiarise themselves with RF-intensive sequences and where possible avoid them so that SAR limits are not easily reached. In addition, radiographers should make sure that the scales used to weigh patients are calibrated regularly ensuring the correct recording and input of the patient's weight.

(4) Quenching

Quenching refers to the sudden loss of the superconductivity of the magnet due to the rise in temperature. This results in the rapid expulsion of helium from the cryogenic storage dewar into the atmosphere. Quenching should be avoided as it is costly and dangerous. However, a controlled quench is often necessary to remove ferromagnetic objects attracted to the magnet's bore. During a controlled quench, individual coils are shut down in a coordinated manner to avoid damaging the magnet that could otherwise occur [3].

The release of helium into the atmosphere during a quench can replace oxygen levels in the room, causing asphyxiation to the room occupants, frostbites, and hypothermia. To prevent asphyxiation, it is essential for oxygen monitoring systems to be installed and regularly monitored. These monitors are typically equipped with an alarm that can be set to sound if oxygen levels drop below a certain level [7]. Radiographers should ensure

that these monitors work optimally by having them serviced regularly and keeping an accurate record of helium levels.

When a spontaneous quench occurs, patients and personnel must be evacuated immediately to avoid being overcome by the helium. This process should be facilitated by the radiographer to ensure that patients are taken to a safety zone as soon as possible. Health and safety training may be necessary to equip radiographers with the necessary skills and knowledge to successfully facilitate evacuation procedures. In addition to this, instructions on evacuation pathways and who to contact in such an instance should be readily available in each MRI department. Furthermore, each MRI department should have a standard operating procedure that clearly outlines the responsibility of each staff member in the event of a quench.

(5) Claustrophobia

Another safety issue of concern in MRI is claustrophobia. Claustrophobia is the most common cause of patient anxiety during MRI examinations which can make it impossible to successfully perform imaging as examinations are often refused or pre-maturely terminated [17]. Patients often feel claustrophobic due to the small size of the bore of the MRI systems, and the placement of RF coils over the head and neck area for imaging these body parts. To reduce anxiety, a patient friend or family member should be allowed to stay in the imaging room with the patient to provide emotional support during the examination [3,18]. The radiographer must also maintain communication with the patient throughout the examination to reassure the patient and calm their anxiety. Furthermore, the patient or relative with the patient should be provided with a panic alarm that they can sound in case of an emergency. The patient should be afforded an opportunity to sound the alarm before the start of the examination, with the radiographer in the control room, i.e. not in the scanning room with them. We found this exercise reassures the patients that the radiographer can hear and respond to them immediately even though they are not in the same room, and this helps calm the patient's nerves before the start of the examination. Where possible the radiographer can position the patient's feet first or place a blindfold over the patient's eyes so that they do not face the inside of the bore; this also helps ease the patient's anxiety.

Another option to limit patient anxiety is reducing the number of imaging sequences as this results in a shorter time the patient spends in the scanner [3]. However, this option should be considered after consultation with the radiologist. In our experience, these limited sequence protocols eliminate the possibility of abandonment due to anxiety while still providing diagnostic information. In severe cases where claustrophobia leads to abandonment, the radiographer should consider sedation or the need for alternative imaging methods in consultation with the radiologist. Where sedation is considered, the radiographer should ensure there is optimal monitoring of the patient during and after the scan.

(6) Contrast reactions

Gadolinium-based contrast agents are used in MRI. Adverse reactions can occur following administration of these contrast agents, although with a lower frequency than iodine-based contrast agents. Therefore, the MRI radiographer needs to be aware of the possible adverse reactions. This is particularly important in the SA context as the scope of practice of radiographers is being revised to include the administration of contrast media [19]. Mild adverse reactions to Gadolinium-based contrast media include coldness at the injection site, nausea with or without vomiting, headache, warmth or pain at the injection site, tingling sensation, dizziness, and itching. The use of Gadolinium is also strongly associated with nephrogenic systemic fibrosis (NSF), which is characterized by fibrosis of the skin and internal organs [20,21]. Poor renal function is a risk factor for NSF, for this reason, it is essential that the radiographer checks the patient's renal function before the administration of contrast media.

Research suggests scanning during pregnancy poses no risk to the fetus, though longitudinal evidence is lacking [22]. In contrast, the use of gadolinium during pregnancy is contraindicated as there is evidence that gadolinium can cause adverse effects both to the mother and fetus [21]. Gadolinium administration during breastfeeding is considered safe as few adverse reactions have been reported [20,22]. Although this is the case, the radiographer should be mindful that some patients might still be concerned therefore the patient should be given the option to express milk before contrast media administration.

Conclusion

MRI poses some risk to all in the MRI environment when safety measures are not adhered to. Radiographers play a huge role in ensuring the safety of all in the MRI environment, therefore, to enable them to fullfil this role we recommend the following:

- Where possible radiographers should undergo uninterrupted MRI training. In addition to this, employers should provide opportunities for radiographers to attend mandatory refresher courses.
- Knowledge of MRI safety is key, therefore all personnel who will potentially enter the MRI environment should be educated about the potential dangers.
- Warning signs and safety notifications should be clearly visible and displayed throughout the department.
- Patient care should never be neglected, radiographers should be more mindful of the patient's circumstances and should always strive to put patients at the centre of care.

Appendix. CPD Article – Multiple-Choice Questions

1. The missile or projectile effect occurs when ferromagnetic metals are attracted to:
(a) A static magnetic field
(b) A gradient magnetic field
(c) RF magnetic field.
(d) All of the above

2. If a quench occurs and the helium escapes into the atmosphere, the principal effect on the room occupants will be:
(a) Increased body temperature.
(b) superficial burns
(c) suffocation
(d) None of the above

3. Ferromagnetic surgical clips are hazardous because they:
(a) can be pulled from the patient
(b) may heat up excessively
(c) may twist to align with the static magnetic field
(d) All of the above

4. The potential hazard to patients from the RF electromagnetic field is:
(a) current induction
(b) excitation
(c) ionization
(d) tissue heating

5. Patients with MR conditional implants, e.g., pacemakers, can:
(a) Not be imaged in MRI as these implants are contraindicated
(b) Be imaged under special conditions
(c) Be imaged using the standard protocols
(d) All of the above

6. Some practical steps to reduce the SAR in patients include:
(a) Registering the patient's correct weight
(b) Minimizing the use of high SAR sequences
(c) Registering the patient's accurate height
(d) All of the above

7. Safety considerations for diabetic patients undergoing MRI scans include:
(a) Doing an interview following the completion of the safety questionnaire
(b) Communicating with the patient during the scan
(c) Providing a panic alarm to the patient
(d) All of the above

8. True or false: Direct contact between the patient's skin and RF coils can cause severe skin burns. **True**

9. True or false: Specific absorption rate (SAR) is a measure of the amount of radio frequency that is deposited into the patient during scanning. **True**

10. True or false: During a controlled quench, all patients and personnel should be evacuated from the MRI department. **True**

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