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A national survey of MRI safety practices in Ghana

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Abstract

Objective: The aim of the present study was to assess current MRI safety practices among MRI facilities in Ghana, and their compliance with the 2013 American College of Radiology (ACR) guidance document on MR safe practices.
Material and methods: A questionnaire developed from the 2013 ACR Guidance Document was used to collect information on magnetic field strengths, MR safety policy and compliance, patient screening, emergency preparedness, infection control, MRI safety accessories, equipment safety, signage and barriers, report of adverse incidents, and access and communication.
Results: Out of the 13 MRI facilities identified, response rate of 92% was obtained. Six (50%) facilities indicated they have MRI safety policy and have it present and readily available to facility staff. Five (42%) facilities indicated they have handheld magnets, and 1(8%) has ferromagnetic detection system. Only one (8%) had crash carts. Seven (58%) facilities have zone 4 clearly marked with a red light and lighted sign stating "The Magnet is On". One (8%) recorded projectile incident and fire outbreak. Eight (67%) facilities have direct visual observation of access corridors to zone IV.
Conclusion: There was compliance in some areas of MRI safety practice, however there were some shortfalls which need to be addressed. We therefore recommend improvement in the following areas: (1) establishment, implementation, and maintenance of current MRI safety policy, (2) patient screening, (3) provision of training and routine drills on emergency response protocols with documentations,

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(4) emergency preparedness, and (5) provision of colour codes for equipment used within MRI environment.

Keywords: Health profession, Health sciences, Medical imaging

1. Introduction

Magnetic resonance imaging (MRI) is considered a safe imaging modality because it does not alter the structure, composition, and properties of atoms, as ionizing radiation-based modalities attempt to do [1]. However, the MRI environment presents potential risks due to three magnetic fields – the strong static magnetic fields, the gradient magnetic fields, and the pulsed radio-frequency (RF) fields employed to produce the three dimensional images. The hazards associated with static magnetic fields are interactions with human tissue and interactions with equipment (i.e. projectiles, implant malfunction, implant movement, monitoring device malfunction and monitoring device movement) [2]. The RF associated risks include specific absorption rate (SAR) issues, tissue heating, burns, implant heating and implant interference effects [2, 3, 4]. The main concerns with time-varying gradients are peripheral nerve stimulation and acoustic noise, including potential implant or monitoring device interference [2, 3, 4]. Most MR incidents can be attributed to the presence of ferromagnetic devices and equipment, including implants, in the MR environment. Reports of MRI adverse incidents have been published extensively in the medical literature and media [5]. Indeed in Ghana, the MRI suite of the Korle-bu Teaching Hospital have recorded incidents of fire outbreak in 2007, a projectile incident in 2010 (Fig. 1), and wrong switching off of the MR safety button [6]. These incidents similar to others globally clearly demonstrate the risks associated with the MRI environment. To reduce these risks, in 2013 the American College of Radiology (ACR) [5] guidance document on MR safe practices was published as a reviewed, modified, and updated versions of the 2002, 2004, and 2007 document. The rationale for providing this document is in view of the potential risks associated with the MRI environment and reports of adverse incidents involving patients, personnel, and equipment.

Since the release of this document [5], only one study has been conducted to investigate safety standards of MRI at the Korle-bu Teaching Hospital in Ghana [6]. The objectives of the study included identification of safety policies regarding the operations of the MRI unit and their conformance to international, adherence and compliance of the policy guidelines, evaluation of the design features of the MRI suite for its safety compatibility as well as to determine the safety training needs of radiographers who operate the MRI [6]. Key findings of the study included a low general knowledge in MRI, and a huge knowledge gap on the safety issues of MRI among respondents [6]. It is most likely that the few radiographers who had some knowledge about MRI acquired it through personal effort and on the

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Fig. 1. Photograph shows a wheelchair pulled into the bore by the strong magnetic force of the MRI Scanner at the Korle Bu Teaching Hospital in Ghana, From "Assessment of Safety Standards of Magnetic Resonance Imaging at the Korle Bu Teaching Hospital (KBTH) in Accra, Ghana," by Samuel Opoku, William Antwi and Stephanie Ruby Sarblah, 2013, in Faycal Kharfi (Ed.), Imaging and Radioanalytical Techniques in Interdisciplinary Research – Fundamentals and Cutting Edge Applications, InTech, CC BY 3.0 [6].

job observations [6]. Even though some might have also acquired their knowledge on MRI from application specialists who provide training on MRI after the installation of the MRI scanners, it is most likely that such trainings often lack depth and breadth, and do not include training on MRI safety. It is also difficult to ascertain whether such application specialists have the required formal MRI qualification to provide such trainings. Furthermore, undergraduate training in radiography only include basic theoretical concept on MRI with little to no hands-on practical. This training is woefully inadequate to provide radiographers the requisite skills and knowledge on the operation of MRI and the safety issues associated with it. In addition, there is no formal education provided on MRI in Ghana, as compared to Europe and America. To the best of our knowledge, only two radiographers (one of which is the first author) have postgraduate qualification in MRI, which they obtained abroad.

Though an initial study which provided information on safety standards in the MRI suite of a hospital in Ghana, the study [6] findings have limited generalizability as it was a single site study. Also, the study did not provide an extensive coverage of safety guidelines presented in the ACR guidance document. To surmount these

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limitations, our study was a nationwide survey which employed the current version of the ACR document [5] to reflect current MRI safety practices. Therefore, the aim of this national survey was to assess current MRI safety practices among MRI facilities in Ghana, and their compliance with the 2013 American College of Radiology (ACR) guidance document on MR safe practices.

1.1. Material and methods

A total number of 13 facilities with MRI suites were identified nationwide based on information from professional associations and people in the MR imaging field. These included tertiary hospitals, private hospitals, and private diagnostic centres. From each identified MRI suite, a contact person received a two-page survey questionnaire developed from the 2013 ACR Guidance Document on MR Safe Practices [5]. The questionnaire was distributed via email to inquire about MR equipment, and MR Safety Policies and Procedures (i.e. MR safety policy and compliance, patient screening, emergency preparedness, infection control, MRI safety accessories, equipment safety, signage and barriers, report of adverse incidents, and access and communication) (20 yes-or-no questions). Contact persons were employees of the radiology department who were actively involved in the work practice of the MRI suite in particular [7]. The questionnaire was sent out via email in August 2016 and received in November 2016. Confidentiality, anonymity, and consent options were provided for the respondents. The results were presented using descriptive statistics in the form of graphs and frequency tables.

2. Results

Out of the 13 MRI facilities identified, 12 responded to the survey questionnaire giving a response rate of 92%. The response rate was high due to the relatively few number of MRI scans nationwide, and easy accessibility to the respondents.

3. Discussion

This survey presents the results of current MRI safety practices in Ghana. It provides historical developments in MRI and numerical and graphical illustrations of current safety practices. The ACR guidance document on MR safe practices [5] was adopted as a template. The increase in MRI scanners (Table 1) over the years suggests an increase in potential risks in the MR environment not only for patients, but also for accompanying family members, staff, and others who find themselves occasionally or rarely in the MR environment. This necessitates the need to put in safety standards to ensure responsible practices in clinical MR environments.

The finding that half of the respondents indicated they have MRI safety policy document, and only 4(33%) review and update it (Fig. 2) on regular basis is

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Table 1. Summary of MR facilities: type of facility, magnetic field strength, and number of MRI scanners in Ghana.

MRF	TYPE OF FACILITY	FIELD STRENGTH (TESLA)	NUMBER OF MRI SCANNERS	YEAR OF OPERATION
1	Public Hospital	1.5	2	2006
2	Public Hospital	1.5	1	2009
3	Diagnostic Centre	≤0.5	1	2010
4	Private Hospital	1.5	1	2012
5	Diagnostic Centre	≤0.5	1	2012
6	Public Hospital	1.5	1	2013
7	Private Hospital	≤0.5	1	2013
8	Public Hospital	1.5	1	2013
9	Public Hospital	1.5	1	2015
10	Public Hospital	1.5	1	2015
11	Diagnostic Centre	≤0.5	1	2015
12	Private Hospital	≤0.5	1	2015

disconcerting and it is unclear whether this is associated with facilities' lack of MRI safety awareness, and knowledge gap on the safety issues of MRI. Indeed Opoku et al. [6] in their single site study of MRI safety practice noted that there was lack of an effective and efficient policy and guidelines in the hospital in general and the radiography department in particular. The authors [6] further revealed that the huge training gap in the use of MRI equipment by radiographers may be attributable to the lack of policies and guidelines. In addition, the authors [6] reiterate the fact that the absence of a framework for operational safety of the

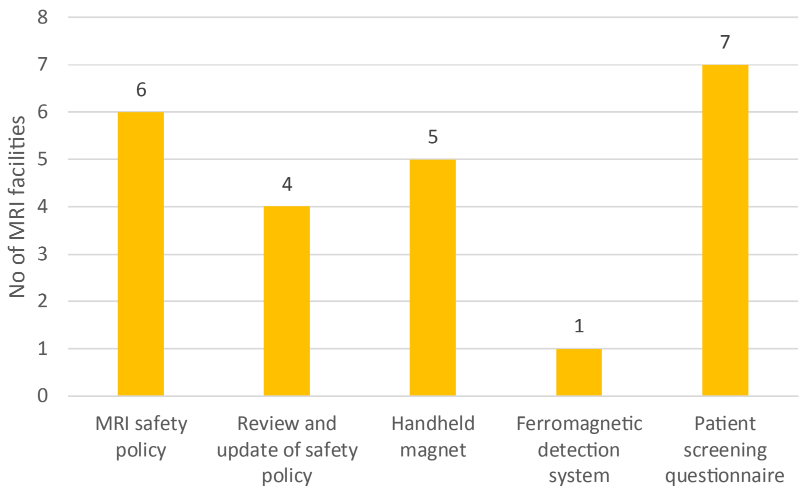

Fig. 2. Summary of respondents' indication to availability of MRI safety policy, review and update of safety policy, and patient screening tools.

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MRI could be a major issue that mitigates against the effective practice of safety at the MRI unit in the radiology department of the hospital. The cornerstone of *safety* practice at the workplace is a *safety policy*. Therefore healthcare organizations responsible for clinical care are expected to have a formal written policy that includes guidelines on safety practices, and which should be backed up with action. This is important in order for employees to become aware of safety aims, objectives, organizations, arrangements, and targets for all safety issues [8]. Such policy documents should be regularly reviewed and updated to reflect best practices. This is supported by the ACR in their 2013 Guidance Document on MR Safe Practices [5] which recommends that all MR sites should establish, implement, and maintain current MR Safety policies and procedures, and should be reviewed concurrently with the introduction of any significant changes in safety parameters of the MR environment of the site. In addition, in the review process, it is required that national and international standards and recommendations are factored into the establishment of local guidelines, policies, and procedures [5].

In our study, the use of patient screening questionnaire (Fig. 2) is most common, although not so encouraging. This result revealed that patients and non-MRI staff are likely to enter the MRI scanner room without undergoing any safety screening, thus putting them at the risk of the magnetic fields of the scanner. This was also observed by Opoku et al. [6] in their study that accompanying family members, and other clinical staff (i.e. nurses, anaesthetists, medical doctors) were not subjected to mandatory screening apart from taking out their metallic possessions on their own volition before entering the scanner room. In the same study, the authors [6] reported that apart from patients completing the MRI screening form, metal detector screening coupled with visual observation was the only form of screening that was done at the unit. It is also noted that the inappropriate design feature of an MRI suite can be a hindrance to effective safety screening practices [6]. It is well established that most MRI-related incidents have been due to deficiencies in screening methods and/or a lack of properly controlled access to the MRI suite [9]. The importance of employing standardized screening form, visual observation, and the use of ferromagnetic detection system are critical for the identification of materials that may be potentially harmful to patients and other individuals that may be within the environment of the static magnetic fields [10]. Even though handheld magnets are currently in use as an adjunct screening tool, their use is dissuaded in current practice as they are limited in differentiating between ferrous and non-ferrous materials, and their inability to detect very small ferromagnetic materials that may cause injury [2]. Currently, ferromagnetic detection systems are recommended as they are simple to operate, and capable of detecting small ferromagnetic objects external to the patient [5, 11]. In a review of the FDA's MAUDE (Manufacturer and User Facility Device Experience) database,

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the ECRI noted several ferromagnetic-related incidents that may have been prevented if a ferromagnetic detection system had been used [11].

With regards to the availability of accessories for emergency preparedness, most respondents indicated they have fire tender, and other source of power in case of outage (Fig. 3). However the low availability of MRI-compatible crash carts and emergency resuscitation equipment within the MRI suites is appalling. Occasionally, patients with unstable health conditions undergo MRI, and emergency situations may occur within the MRI environment, which often includes reactions to MRI contrast agents, sedation, and anaesthesia. This situations warrants the need for resuscitation equipment with emergency medications within the vicinity of the MRI environment, particularly in either Zone II or Zone III as emergency events are difficult to access and respond to when patients are within the magnet bore [3, 5].

We noted that majority of the respondents indicated they lacked drills on emergency response protocols which is supported by their lack of documents to show for it (Fig. 3). Indeed, in a survey of MRI sites conducted by the Veteran Administration's Office of Healthcare Inspections in the United States of America to determine whether facilities ensured safety in MRI in accordance with Veterans Health Administration, it was reported that out of 50 MRI suites in 43 facilities, only 24(48%) conducted emergency response drills, 22(44%) conducted medical or

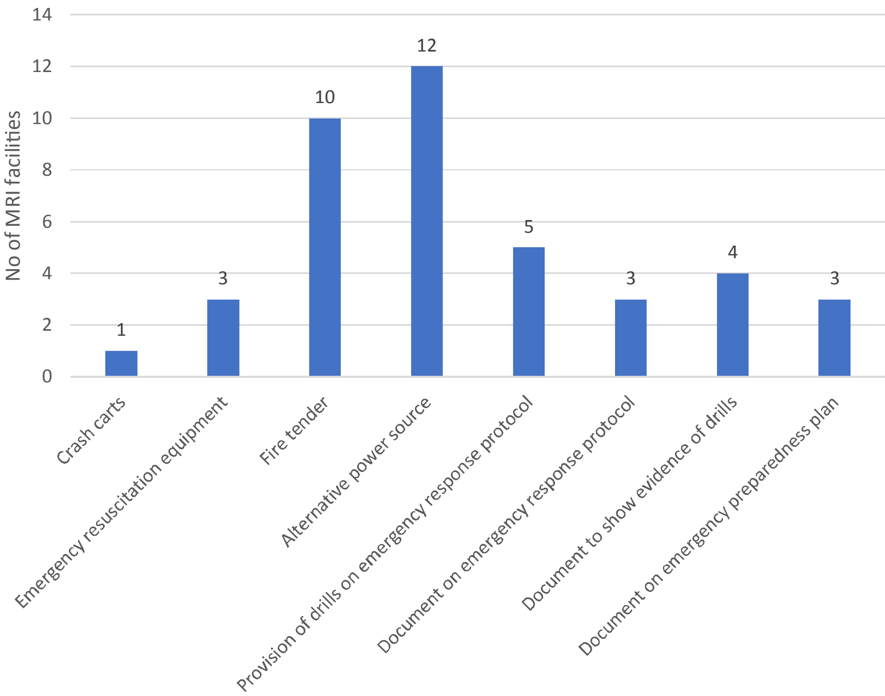

Fig. 3. Summary of respondents' indication of availability of accessories for emergency preparedness, and documentation on drills.

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mental health emergency drills, but 32(64%) conducted fire drills [12]. This study [12] though of a larger sample size which share similar areas of concern with regards to MRI safety with the current study clearly demonstrated the lapses on the provision of training on drills necessary to build the capacity of staff working in the MRI suite. Studies have shown that many health professionals are unprepared for a disasters or sometimes even common medical emergencies [13, 14]. The clinical environment is not immune to emergencies as events such as accident, medical event, or trauma; a natural disaster; or an act of violence can occur [15]. For this reason, emergency preparedness plans must be part of organizational safety culture and should include information necessary for restoring clinical services, including contacts for MRI system vendor, RF shield vendor, cryogen contractor, MR suite architect and construction contractor, local and state officials, and affiliated hospital and professional organizations [5]. Furthermore, health professionals are to be equipped with practical skills and knowledge on emergency situations, i.e. how to recognize several life-threatening emergencies [16], how to minimize the risks and potentially prevent adverse outcomes [15]. Providing appropriate training to staff who are involved in emergency response is fundamental to an organisation's ability to handle any type of emergency, and will ensure that staff feel confident and competent in any emergency situation that may confront them in their clinical practice [15, 16, 17]. In the event that a person within the MRI suite should require emergency medical or mental health attention, it is imperative that those responding to a call for assistance are aware of and comply with MRI safety protocols [12]. It is therefore recommended that healthcare practices should consider having all staff obtain certification on CPR (cardiopulmonary) [15], first aid, fire safety and perform regular drills to rehearse and refine emergency response protocols to protect patients, MR staff and emergency responders [5]. In fact it is recommended that MRI facilities conduct regular emergency response drills to simulate a patient who has an allergic reaction to contrast media while in the magnet, a cardiac arrest in the magnet, a patient who is trapped in the magnet by a ferromagnetic object, and a fire in the magnet room and contrast reaction drills in MRI areas [12, 18, 19]. Furthermore, emergency drills should verify knowledge of emergency techniques, protocols, and usage of emergency response equipment and supplies [15]. Additionally, healthcare providers should be certified and trained to safely operate all equipment, and administer appropriate emergency medication when the need arises [15].

The availability of hand washing sink and hand sanitizers in most facilities (Fig. 4) as indicated by the respondents is laudable. To demonstrate the importance of hand washing, the ACR [5] recommended that infection control policy be instituted in the clinical practice of MRI with consideration for hand washing stations. This is to prevent cross-infection among staff who come into direct contact with patients.

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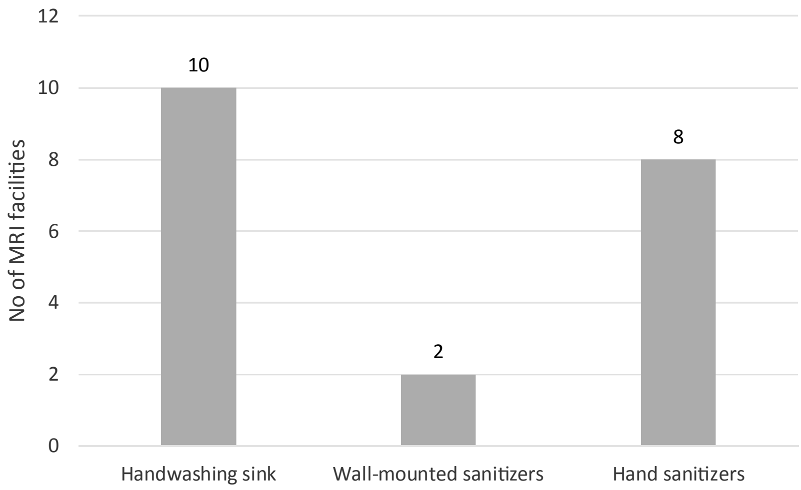

Fig. 4. Summary of Infection control practices.

It is important that MRI suites readily have MRI compatible accessories to ensure any untoward situation within the MRI environment. Our study revealed that most facilities have earplugs, and compatible wheelchairs; however most lacked MRI compatible trolleys, and a half indicated they lacked headphones (Fig. 5). The non-availability of MRI compatible trolleys in more than half of the facilities of respondents may pose some challenges when there is the need to transport non-ambulatory patients from ferromagnetic trolleys and wheelchairs to the MRI couch. Patients that are wheelchair bound due to their condition may be helpless when they need to be transported to the scanner room. In such situations, patients have had to be supported by staff to the changing room and the scanner room, a situation which may result in more harm to the patient. The use of hearing protection materials i.e. disposable ear plugs and close fitting headphones is

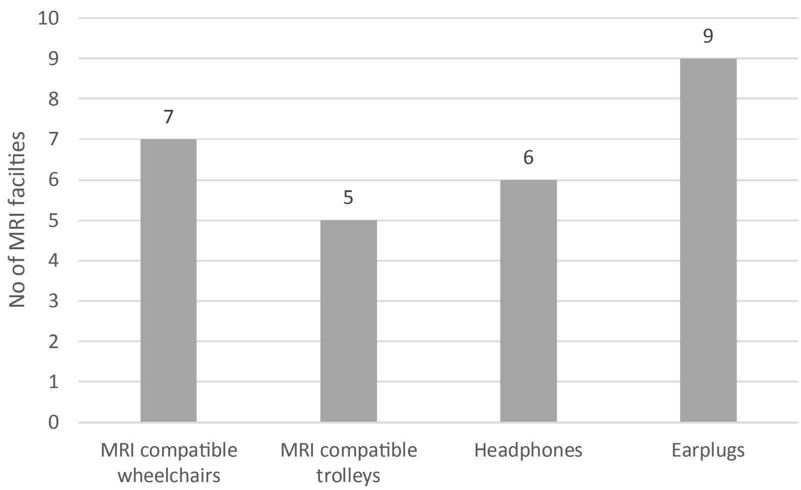

Fig. 5. Summary of MRI safety accessories.

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Table 2. Summary response to equipment safety and signage and barriers.

Questions	Responses to Equipment Safety		
	Yes	No	Total
Do you check equipment brought into the MRI suite?	12(100%)	0(0%)	12(100%)
Do you have emergency exit door?	8(67%)	4(33%)	12(100%)
Are equipment used in the MRI suite colour coded.	0(0%)	12(100%)	12(100%)
	Responses to Signage and Barriers		
	Yes	No	Total
Is zone 4 clearly marked with a red light and lighted sign stating "The Magnet is On"?	7(58%)	5(42%)	12(100%)
Is zone 3 demarcated and clearly marked as being potentially dangerous?	6(50%)	6(50%)	12(100%)
Are all entrances marked to indicate the presence of a magnetic field hazard?	11(92%)	1(8%)	12(100%)
Are there physical barriers to prevent unauthorized or accidental access to zones 3 and 4?	8(67%)	4(33%)	12(100%)

mandatory for all patients and others who may be in the MRI scan room during scanning. This is to reduce the acoustic noise generated by the gradient coils.

Impressively, all respondents indicated that they check all equipment brought into the MRI suite (Table 2). This is an improvement compared to the study conducted by Opoku et al. [6] in which they reported that 75% respondents indicated they check equipment used in the MRI environment. The study also revealed that most respondents (8[67%]) indicated they have emergency exit door. However none of the respondents indicated the equipment used in the MRI suite are colour coded. The American Society of Testing and Materials (ASTM) International standard specified new terminology and symbols for identifying medical devices (see Fig. 6) for use in the MR environment to reduce MRI-associated incidents [20]. Field conditions that define the specified MR environment include field strength, spatial gradient, dB/dt (time rate of change of the magnetic field), radio frequency (RF) fields, and specific absorption rate (SAR). "MR Safe" devices poses no known hazards in all MRI environments, and they are identified with a green square. They

Fig. 6. Symbols for device labeling terms (MR safe, conditional, and unsafe).

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include nonconducting, nonmetallic, and nonmagnetic items. “MR conditional” —An item that has been demonstrated to pose no known hazards in a specified MRI environment with specified conditions of use. It is identified with triangular yellow label. “MR unsafe”—An MR unsafe item is one that is known to pose hazards in all MRI environments. It is identified with circular red label.

The provision of markings on all entrances to indicate the presence of a magnetic field hazard was on the whole a positive one as Table 2 demonstrates. We noted a high compliance with the ACR document [5] with regards to the provision of markings on zones 3 and 4 to indicate “being potentially dangerous” and “The Magnet is On” respectively, including the availability of physical barriers to prevent unauthorized or accidental access to these zones. This is in agreement with previous study [12].

In finding out reports of MRI-related incidents in this study, contrast reaction occurred more frequently. Other reports were projectile incident and fire outbreak (Fig. 7). Gadolinium-based contrast agents are routinely used in many MRI studies used to improve tissue contrast in MRI. Although initially thought to be extremely safe compared with alternative contrast agents, several studies have raised concerns regarding their safety. Administration of gadolinium contrast agents to patients may cause nausea, headache, and severe allergic reactions [18]. Nephrogenic systemic fibrosis, a rare multisystemic fibrosing disorder which has been widely reported in the medical literature has also been found to be linked with the use of GBCAs in patients with renal impairment, noted to be most frequently associated with gadodiamide, a high risk GBCA. Coincidentally, in a recent Ghanaian study on the use of GBCAs, the authors reported that gadodiamide accounted for more than half of first line agents thus it has the largest market shares in Ghana [21]. GBCAs can also cause acute kidney injury, especially at high doses

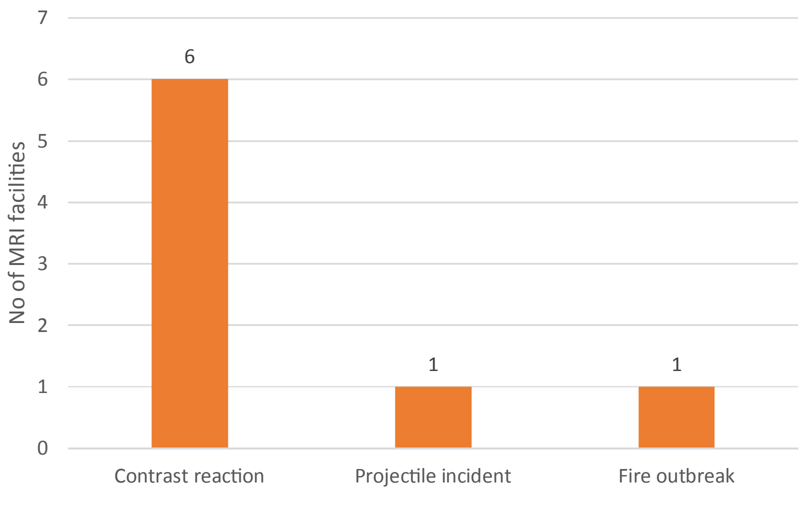

Fig. 7. Summary of Report of adverse incidents.

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required for angiography [22]. Evidence also shows that several laboratory artifacts are associated with gadolinium administration, with pseudohypocalcemia being the most important [22]. According to the ACR Manual on Contrast Media [23] adverse events after administration of gadolinium seem to be more prevalent in patients who had previous reactions to an MR contrast. Patients with asthma, allergic respiratory histories, prior iodinated or gadolinium-based contrast reactions are also susceptible to contrast reaction. Even though there are no well-defined policies for patients who are considered to be at increased risk for having adverse reaction to MR contrast agents, it is recommended that such patients should be closely monitored as they are at a demonstrably higher risk of adverse contrast reaction, those who have previously reacted to one MR contrast agent can be injected with another agent if they are restudied, and at-risk patients can be premedicated with corticosteroids and, occasionally, antihistamines [5, 23]. For the recommendations of the ACR Committee on GBCA, the reader should check the most recent publication in the 2016 ACR Manual on Contrast Media [23], Version 10.2 from the American College of Radiology website at http://www.acr.org/Quality-Safety/Resources/Contrast-Manual

With regards to report of adverse effects, only one projectile incident and fire outbreak were reported. It is acknowledged that the most significant known danger working around a strong magnet is the risk associated with the attraction of ferromagnetic devices and equipment to the magnet causing them to become projectiles [3]. Projectiles can lead to injury or even death, high cost equipment damage, and loss of imaging time [24].

Finally, our study revealed that for access and communication, most respondents indicated they have direct visual observation of access corridors to zone 4 from their working positions in the MRI scanner room (Table 3). The ACR [5] recommended that by means of line of sight or video monitors, MR radiographer should have direct visual observation and control of entrances or access corridors to Zone IV from their from their sitting positions in the scan control room. Continuous monitoring of patients during the scan process is an important practice, which can be ensured by having an optimal view of the scanner room. This can

Table 3. Summary of response to Access and communication.

Questions	Responses to Access and Communication		
	Yes	No	Total
Do employees have direct visual observation of access corridors to zone 4 from their working positions in the MRI scanner room?	8(67%)	4(33%)	12(100%)
Has the facility ever invited police/fire representatives to MRI safety presentations or facility tours?	0(0%)	12(100%)	12(100%)

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allow the radiographer to provide immediate attention to the patient in case of distress. It is laudable to know that employees have direct visual observation of access corridors to zone 4 from their working positions in the MRI scanner room. However, surprisingly, none of the facilities has ever invited police or fire representatives to MR safety presentations or facility tours (Table 3). The need to invite the police and fire personnel cannot be overemphasized as it is well captured in the ACR document [5]. This recommendation need to be adopted as there is the likelihood occurrence of emergencies that may require fire and/or police response [5].

The results of this survey can be generalized as a high response rate was obtained from key personnel working as MRI professionals in the facilities who were able to provide the response to this study. In addition it is a nationwide survey which has a higher generalizability as compared to the single site study carried out by Opoku et al. [6]. Nevertheless the study findings have limitations. Our survey was not able to ensure that every member of the MRI staff was consulted, and so we could not ascertain if respondents have the adequate skills and knowledge of MRI safety issues. However, it is possible that their knowledge gap in MRI safety issues might have resulted in non-compliance in many areas of MRI safety, and underreports of MRI-related incidents. We also did not conduct physical inspections of the MRI facilities to ensure that the information provided by the respondents were accurate.

4. Conclusion

This survey reflects current MRI safety practices in Ghana. Even though many respondents demonstrated compliance in some areas of MRI safety practice, there are as well several shortfalls which did not meet the ACR guidance document on MR safe practices. To ensure high compliance with the ACR MRI safety requirements and guidelines, we therefore recommend improvement in the following areas: (1) establishment, implementation, and maintenance of current MRI safety policy, (2) patient screening, (3) provision of training and routine drills on emergency response protocols with documentations, (4) emergency preparedness, (5) provision of colour codes for equipment used within MRI environment, and (5) invitation of police or fire representatives to MR safety presentations or facility tours. Generally, MRI safety training should be routinely undertaken to create and increase awareness of the potential risks associated the MRI environment.

Declarations

Author contribution statement

Albert Dayor Piersson: Conceived and designed the experiments; Performed the experiments; Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data; Wrote the paper.

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Philip Gorleku: Performed the experiments; Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data; Wrote the paper.

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Competing interest statement

The authors declare no conflict of interest.

Additional information

No additional information is available for this paper.

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