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Chapter 3

Assessment of Safety Standards of Magnetic Resonance Imaging at the Korle Bu Teaching Hospital (KBTH) in Accra, Ghana

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Additional information is available at the end of the chapter

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1. Introduction

The various equipment and chemicals used in the radiology departments can be a source of hazards and hence result in an adverse effect to affected individuals (Johnston and Killion, 2005). Interdisciplinary approach to monitor the activities at radiology departments to ensure compliance in safety standards may help avoid or reduce hazards in the working environment (Byrns*et al.,* 2000). Magnetic Resonance Imaging (MRI) unit in a radiology department is one particular place where safety precautions should be directed due to the ferromagnetic nature of the equipment and the strong magnetic field used in its operations (Joseph, 2006).

MRI is a painless, non-invasive and one of the most advanced imaging modalities currently available in radiology departments (Kusumasuganda, 2010). Research and awareness of safety issues concerning MRI has received much attention (Ordridge*et al.,* 2000). According to Westbrook *et al* (2009), recent occurrences in the operation of MRI have led to questions being raised on the safety of the modality. Phin (2001) has suggested that adequate policies and procedures should be developed and adhered to in order to ensure safe, efficient and operating conditions of MRI. Several potential problems and hazards are associated with the performance of patient monitoring and support in the MRI environment (Kanal and Shellock, 1992). According to Henner and Servomaa (2010), the main factors that affect safety practice in the MRI unit is management style and attitude of staff. Various reports found in the literature have indicated that MRI accidents are mostly caused by human errors rather than scanner malfunction. These have led to several calls for regu-

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lations and policies to guide the operations of MRI (New York Times, 2010; Healthcare Purchasing News, 2010). This has become necessary because the risk in the MRI environment does not only affect the patient, but also affects the health professionals and those who find themselves in the magnetic field (Kanal *et al.*, 2007). There is therefore the need for maximum safety to be ensured in the MRI unit. Moreover Chaljub (2003) and Joseph (2006) have both emphasized the need to keep training health personnel on safety issues relating to MRI. In particular, Joseph reiterated that the MRI's magnet which is over 100,000 times the earth's natural magnetic pull is always on mode; hence those who approach it should have training due to the special safety risk it poses. In addition to the risks to people, it is also important to put in precautionary measures to protect the equipment from damage and breakdowns. The need to assess the staff of the radiology department and hospital's management on their attitude and adherence towards maintaining safety at the MRI can therefore not be overemphased.

In recent times, Magnetic Resonance Imaging (MRI) unit of the Korle - Bu Teaching Hospital (KBTH) in Accra, Ghana has witnessed various degrees of accidents. In particular, there was a fire outbreak in 2007 which brought the operation of the MRI facility down for a whole year. Again in 2010, a wheelchair was pulled into the gantry of the MRI scanner by the missile effect when a patient was lifted off the wheelchair onto the MRI table as shown in appendix I on page 28. This incident resulted in three weeks down time of the facility. A second incident in the same year occurred where a Radiographer Intern at the MRI unit wrongly switched off the safety button, resulting in three weeks shut-down of the entire unit. These incidences have been documented in the Incidence Reporting Book at the MRI Unit and are reproduced here with the permission from the Radiology Department of the hospital. These incidences at MRI Unit at the Korle Bu Teaching Hospital are very worrying, suggesting that the safety aspects might have been compromised. Thus it is imperative that the existence of policy guidelines and manuals regarding the operational safety of the MRI in the hospital and their compliance and adherence by staff needed to be evaluated. Similar incidences occurring in other hospitals around the world are documented in the literature and some of which are reproduced in Appendix II on page 29.

2. Materials and methodology

This study was undertaken at the MRI Unit at Korle Bu Teaching Hospital in Accra, Ghana. The specific objectives of study were to identify safety policies regarding the operations of the MRI unit and whether they conform to international standards. Additionally, it sought to ascertain adherence and compliance of the policy guidelines and to evaluate 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.

The study focused on the safe use of MRI as an imaging modality and involved radiographers of the Radiology Department. A member of the Hospital Management Team also participated in the study since the management members are responsible for the safety policies formulation and ensuring their implementation at the MRI unit.

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3. Literature review

In order to have a broad perspective of MRI safety issues, an extensive literature review were done which centred on the concept of safety screening; principle and framework of safety in MRI; operational principles, safety policies and guidelines of MRI.

3.1. The concept of safety screening

It has been suggested that in dealing with safety issues the emphasis should be placed on prevention of accidents (Harding, 2010). This means measures need to be implemented to prevent accidents from occurring. Harding argued that even though total prevention of accidents is not achievable, every effort should be made to reduce their occurrences to the barest minimum. The concept of safety has a wider significance as safety is seen as a systemic approach with thresholds that define the standard of safety (Elagin, 1996). In order to ensure an accident free, Elagin has suggested that an ordered procedure, which shows the level of safety in a particular environment should be followed. In recent times, concerns have been raised about the safety of the MRI facility due to the increasing number of MRI incidents by an alarming 185% over the last few years (Gould, 2008). Gould further suggested that there is need for a comprehensive safety programme for any health institution with a zero tolerance for MRI errors. Several studies have shown that compromising patient safety have resulted in fatal consequences (Launders, 2005; Emergency Care Research Institute (ECRI), 2004). In 2005, Launders conducted an independent analysis of the Food and Drug Administration (FDA)'s Manufacturer and User Facility Device Experience Database (MAUDE) and gave a report on a database over a 10-year time span. This revealed 389 reports of MRI-related events, including nine deaths with three events related to pacemaker failure, two due to insulin pump failure and the remaining four related to implant disturbance, a projectile, and asphyxiation from a cryogenic mishap during installation of an MR imaging system. Various claims have been made in several publications which indicate that MRI accidents are largely due to failure to follow safety guidelines, use of inappropriate or outdated information related to the safety aspects of biomedical implants and devices and human errors (Shellock and Crues, 2004; New York Times, 2010; Healthcare Purchasing News, 2010). A panel under the auspices of the American College of Radiology (ACR) was constituted to address these critical issues. Kanal et al (2004) who were part of this panel pointed out that there was a continuous change in the use of the MRI as a technology with a drastic increase in the number of examinations done. They maintained that though there were safety guidelines, the increased number of MR practitioners and the increased use of the technology for critically ill patients, contributed to the increasing incidence of mishaps occurring in MRI surroundings. According to McRobbie et al (2007), the overall objective of a safety procedure is to provide an appropriate standard of protection of patients and staff in the MRI unit, without unduly limiting the beneficial practices and also prevent the occurrences of tragic events in the MRI suite. MRI suites in clinical and hospital surrounding should establish safety protocols with an MRI safety officer designated to ensure that policies are implemented and adhered to (Kanal, 2004).

3.2. MRI suite design and zones

An MRI suite should be designed to restrict access and limit exposure to static magnetic fields. Various publications have provided different designs to the MRI suite to ensure maximum safety and they all showed that an MRI suite should be built to restrict access by zones (Gould 2008; Kanal *et al.,* 2007; Junk and Gilk, 2005; Shellock and Crues, 2004). The zones suggested by the various articles are as follows;

Zone I: - Opens to the general public and presents the least exposure to the patients, staff and visitors. Usually it is the reception and waiting room for the MRI suite purposed to channel patients and medical staff to the pre-screening area (zone II) and limit entry to the MRI suite.

Zone II: - This is the first interaction site for patients, visitors and staff in the MRI suite. The purpose of this zone is to restrict further public access to the suite and provide direct supervision of patients and visitors by the MRI staff. Pre-screening of all patients, staff and visitors also takes place here. If ambulatory, the patient is screened through a ferrous metal detector installed into the zone II. Non ambulatory patients in walkers, wheelchairs or patient support need the transport equipment to be verified as MRI- safe or exchanged for MRI- safe equipment. The zone II generally has a metal detector and a 1000 gauss magnet to help screen medical equipment for ambulatory patients. MRI staff including the MRI technologist is directly responsible for enforcing strict adherence to the MRI safety protocols for the MRI suite and patient safety.

Zone III: - This is the entry zone to the MRI machine room which is zone IV. Entrance to this zone is restricted physically and by protocol. Being the last barrier against an incident or injury due to an interaction of a static or active magnetic field and any unscreened personnel, patient or equipment, only MRI technologist, certified staff and pre-screening attending physician accompany the patient into the MRI machine room. The portal or entrance to the MRI machine room must be monitored by a second ferromagnetic- sensitive detector and door must be locked. Sounding of detector will require verification of either an MRI- safe or compatible event or the discovery of an MRI–unsafe condition in the patient, transporting or medical equipment or the attending medical staff. The standard access method is a card access system which should allow access to only certified MRI staff between zone III and zone IV. All medical staff must be pre-screened prior to entry into zone III to make sure no unscreened individuals will be allowed access to zone IV. Ideally, the personnel in zone III must be uniformed in MRI compatible scrubs which will avoid the use of identification badges in the suite, MRI-safe shoes and undergarments. Personnel must avoid all jewellery, watches metallic writing instruments, and wire-framed glass which may raise a false alarm from the detector (Shellock and Crues, 2004).

Finally in zone IV, the MRI room should have a clear demarcation of the five gauss line taped or painted on the MRI suite floor to indicate the area beyond which requires MRI- safe or MRI – conditional equipment or instrumentation. This should be in line with the distance and tesla rating of the MRI. Zone IV should be clearly marked with a red light and lighted sign stating, “The Magnet is on.” In situations where an alarm goes off for a code red, there

is the need to use MRI- safe equipments to address the situation with restrictions of public first responders from zone IV of the MRI environment until safe conditions are established or responders are verified to be safe (Junk and Gilk, 2005). Access to zone IV should be enabled by a programmed key and the key kept in a restricted access box in the MRI control room.

Architectural and design engineering for a MRI suite have been established in standards published by the Joint Commission on the Accreditation of Health Organisations (JCAHO), the American College of Radiology guidelines, the International Building Code (IBC) and Occupational Safety and Health Administration (OSHA).

3.3. Pre- screening and screening forms

Shellock and Crues (2004) emphasized that the establishment of thorough and effective screening procedures for patients and other individuals is one of the most critical components of a programme to guard the safety of all those preparing to undergo MR procedures or to enter the MR environment. All preliminary patient history, MRI safety screening and documentation must be completed and signed by the patient, guardian or clinician before procedures are undertaken on patients (Shellock and Crues, 2004; Ferris *et al.*, 2007). Various screening forms are used for different categories of people who come to the MRI suite. In general, screening forms are developed with patients in mind (Sawyer-Glover and Shellock, 2002).

3.4. Colour and symbol coding

Various means have been adopted to help with ensuring safety in an MRI unit. This is usually meant to provide on the spot recognition of MR- safe equipment and surroundings, likewise unsafe and MRI-conditional equipments and locations. At the University of California San Francisco (2011), yellow is used to signify caution and is painted around the entrance of the door. Gas tanks that have been painted green signifies ferrous cylinder and hence make it easy for identification as MRI unsafe equipment. For safe MRI tanks, the cylinders are coloured silver. Symbols have also been used as a new classification system for implants and ancillary clinical devices.

An MRI safe symbol signifies that the device or implant is completely non-magnetic, non-electrically conductive, and non-RF reactive, eliminating all of the primary potential threats during an MRI procedure. An MRI Conditional sign is used to identify a device or implant that may contain magnetic, electrically conductive or RF-reactive components that is safe for operations in proximity to the MRI, provided the conditions for safe operation are defined and observed (such as 'tested safe to 1.5 teslas' or 'safe in magnetic fields below 500 gauss in strength). Finally, an MRI unsafe symbol is reserved for objects that are significantly ferromagnetic and pose a clear and direct threat to persons and equipment within the magnet room. An appropriate coding system is thus necessary to be adopted by every MRI unit to facilitate easy identification of safe items.

3.5. Operational principles of MRI

As opposed to conventional x-rays and computed tomography (CT) scans, there is no ionizing radiation used in MRI. However, MRI uses an extremely powerful static magnetic field, rapidly changing gradient magnetic fields and radiofrequency electromagnetic impulses to obtain detailed anatomic or functional images of any part of the body (Faulker, 2002; Berger, 2002). Currently, there is no evidence of a short or long term adverse effect due to exposure to field strengths of MRI and durations that is clinically used (Schenck, 2000).

Despite the relative safety of MRI, there are potential hazards associated with its operations. Some of these are related to the physical properties of the MRI equipment and also to the challenges of maintaining physiologic stability of the individual undergoing the examination. In a reported incident in 2001,a small boy undergoing an MRI following surgery to remove a benign tumour was struck and killed by an oxygen tank inadvertently taken into the MRI suite (Emergency Care Research Institute, 2001). In most situations the MR systems cause the disaster due to it interactions with other properties around it.

3.6. Magnetic fields and the missile effect

The static magnetic field generated by a powerful magnet is tens of thousands times stronger than the earth's magnetic field which can attract objects containing ferrous materials, transforming them into dangerous airborne projectiles (Dempsey *et al.,* 2002). There are two features of the magnetic field that are the source of most MRI incidents; the projectile or missile effect which is the ability of the magnet to attract ferromagnetic objects and draw them rapidly into the bore with considerable force (Centre for Devices and Radiological Health, 1997). Ferromagnetic objects include metallic objects containing iron such as scissors, laryngoscopes, nail clippers, pocket knives and steel buckets. Larger items like wheelchairs, gurneys, intravenous poles have also become MR-system- induced missiles (Centre for Devices and Radiological Health, 1997). The other source of most MRI incidents is the translational attraction which occurs when one point of an object in a magnetic field is attracted to a great extent than the object's furthest point from the attracting source (Gould, 2008).

3.7. Magnetic field interactions

The static magnetic field of an MR system is always on. No sound, sight, smells alerts personnel to the presence or the extent of the invisible field surrounding the magnet in all directions. The magnetic pull is strongest at the centre of the MR system and weakens with increased distance from the magnet, creating a spatial magnetic field gradient (Price, 1999). The distribution of the magnetic field outside the main magnet called fringe field is impossible to see, but it is critical to safety in the MR environment because it can determine whether a ferromagnetic object could become a projectile. MR systems with large fringe field generally create the greatest hazards (Price, 1999). If the fringe strength decreases more gradually with distance from the magnet, the object's attraction to the magnet progressively strengthens as it becomes closer to the magnet. Personnel within the MR room may notice an in-

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creasingly stronger pull on objects they are wearing or carrying as they walk closer to the MR system, permitting them to retreat from the MR system before an accident occurs (Kanal *et al.*, 2002).

3.8. Hazards in the MRI suite

Various forms of hazards occur in the MRI suite which can be categorized into translational force- missile effect, torque forces, induced magnetic fields, thermal heating and quenching (Colletti, 2004). In the translational force, the effect is manifested on the ferromagnetic materials and the static field generated by the MR system usually in the form of the missile effect involving non-compatible objects and miscellaneous patient and visitor objects.A hair or paper clip within the 5-10 gauss line range could reach a velocity of 40 mph (about 70 kph) and will be attracted to the centre of the lines of force of equal (Lahr and Rowan, 2004).

Just like the translational forces, the torque force is also associated with ferromagnetic materials and the static field generated by the MR machine. Ferromagnetic objects that are attracted by the magnetic field react by aligning parallel to the magnetic lines of the force being created by the MRI machine. The centre of the MRI- generated fields has the highest torque force, creating a serious exposure for all contraindicated items and MRI- conditional items in the MRI suite, depending on the tesla rating of the MRI (Gould, 2008). When any metallic object is introduced into a high flux field, current will be induced if that object is perpendicular and moving to the lines of the force. The new current will create a secondary magnet field that will oppose the original field. This can cause patient discomfort and anxiety due to the reactive forces on the MRI safe medical implants and a life threatening condition may be created under the five- gauss line (Kangarlau and Robitaille, 2000).

Magnetic Field type	Hazard	Potential Adverse Effects
Static magnetic field	Translational force: power. Attraction of ferromagnetic objects to intense magnetic field. Rotational force/ torque: rotation of object to align with the magnetic field	Missile effect: acceleration of objects into the bore of the magnet. Tearing of tissues, pain, and dislodgement of some implants.
Radiofrequency electromagnetic fields	Heating due to absorbed RF energy Electromagnetic interference	Overheating, burns (thermal, electrical) Device malfunction; imaging artefact
Gradient magnetic field	Induced currents in conductive tissues Induced current in electrical devices	Nerve and muscle stimulation Device malfunction/failure

Adapted with permission from Centre for Device and Radiological Health of USA

Table 1. Hazardous Magnetic Field Interactions

The most common source of thermal exposure tends to be looped or un-looped medical equipment leads, MRI accessories and sensors. The most serious exposure is located in the bore of the MRI machine and in the axis points, as they possess the highest potential torque forces. Extremity coils could increase the risk but this can be avoided by the use of MRI safe polymeric foam padding (Gilk, 2006). MRI machines are cooled by a super cooling fluid (liquid helium). The release of the super cooling fluid into the atmosphere is called quenching. Most clinical machines have about 700 to 1000 litre volume of this cryogenic. In the event that there is venting, it may cause the oxygen in the MRI room to condense around the vent pipe and accumulate in the MRI machine causing a red fire hazard. Another risk is a quench vent pipe breech which could flood the room with cryogenic fluids creating an asphyxiation hazard for the patient and the staff (Clark, 2007).

3.9. Radiofrequency electromagnetic fields effects

The MRI system has electromagnetic coils in a transmitter within it that delivers the radio-frequency (RF) pulses during imaging. When tissues absorb the RF energy, tissue heating can occur, mostly in patients with poor thermoregulatory control (Dempsey *et al.,* 2002). The rate at which RF energy is deposited in tissue is known as the specific absorption rate (SAR), measured in units of watts per kilogram (w/kg) (Centre for Devices and Radiological Health, 1997). The maximum allowed SAR is 3W/kg which is averaged over ten minutes for head imaging and 4W/kg for whole body imaging, averaged over fifteen minutes (Centre for Devices and Radiological Health, 2003).

Radiofrequency fields can cause skin burns if monitor cables or wires are permitted to form conductive loops with themselves or with other body parts (Kanal *et al.,* 2002). Temporary metallic intra cardiac pacing wires will behave like antennae and conduct electromagnetic waves, also resulting in thermal tissue injury (Dempsey *et al.,* 2002). Radiofrequency signals emitted during the MR examination can affect non- MR-compatible programmed infusion pumps, resulting in erratic performance. Affected pumps could deliver higher or lower than desired volumes of pressor agent, analgesics, sedative or dextrose and electrolytic solutions, all of which cause serious physiological consequences particularly, infants (Cornette*et al.,* 2002).

3.10. Gradient magnetic field effects

When an infant is subjected to sudden, rapidly changing gradient magnetic fields during imaging, the magnetic field can induce circulating currents in conductive tissues of the body (Schaefer *et al.,* 2000). These currents have been found to be large enough to produce changes in nerves and muscles function theoretically.Where safety standard limits are practiced, it limits the maximum rate of change of magnetic field strength that can be used thus reducing the likelihood of its observation during a clinical MRI (Center for Devices and Radiological Health, 2003).

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3.11. Safety policies and guidelines of MRI

The American College of Radiology (ACR) Guidance Document for Safe MRI Practices-2007 recommends that all MRI sites should maintain MR safety policies (Kanal *et al.,* 2007). These policies, it claims should be reviewed concurrently with the introduction of any significant changes in the safety parameters of the MR environment and updated as needed. It also stated that Site Administration is responsible to ensure that the policies and procedures are implemented and adhered to by all site personnel. Any adverse events, MR safety incidents or near incidents are to be reported and used in continuous quality improvement efforts. To augment the recommendations made by the ACR, the 2008 Joint Commission Sentinel Alert issued by the Medical College of Wisconsin's (2009) accreditation organisation suggested that actions consistent with the ACR recommendations should be used to prevent accidents and injuries in the MRI suite. In other works, the Device Bulletin (2007) produced a document to serve as guidelines covering important aspects of MRI equipment in clinical use with specific reference to safety. They were intended to bring to the attention of those involved with the clinical use of such equipment, important matters requiring careful consideration before purchase and after installation of the equipment. It was also to be used as an orientation for those who are not familiar with the type of equipment and act as a reminder for those who are familiar with the equipment (Buxton and Lui, 2007). It was further intended to act as a reminder of the legislation and published guidance relating to MRI, draw the attention of the users to the guidance published by the National Radiological Protection Board (NRPB), its successor the Health Protection Agency (HPA), the International Electrochemical Commission (IEC) and the International Commission on Non –Ionizing Radiation Protection (ICNIRP)

4. Materials and method

The study employed both qualitative and quantitative design using a structured interview and descriptive survey. A structured interview involves guiding the interview in a particular pattern such that the information received falls in line with the objective of the study without it being altered by the interviewer (Brink and Wood, 1994; Pontin, 2000). A descriptive survey provides a better means of investigating and assessing the attitude and practices of people when they are involved in a particular situation (Carter, 2000; Gray, 2004).

The study was carried out MRI Suite of the Radiology Department of the Korle Bu Teaching Hospital. (KBTH), Accra. Ghana. KBTH is the leading referral hospital in Ghana, with the radiology department being one of the busiest departments in the hospital. Currently, the hospital has a bed capacity of about 2000, with an average 1,500 outpatient attendances daily, an admission rate of 250 per day and 65% of the daily attendance visiting the radiology department (www.korlebuhospital.org).

The Radiology Department of the hospital has a staff population of forty-six. These include thirty-one radiographers, nine radiology residents and six consultant radiologists. Of the

thirty one radiographers, twelve are degree holders, fifteen are diploma holders and the rest are certificate holders.

The entire population of radiographers was used for the study. This gave a population size that was easy to handle and ensure an effective statistical analysis to be done (Burns and Grove, 2001). Using a small data set makes it possible to overcome the inconveniences created by lack of time, ensures homogeneity, improves the accuracy and quality of the data (Atkinson, 2000; Ader*et al.*, 2008). In Korle Bu Teaching Hospital, there are no specialized or permanent MRI radiographers and all of them rotate periodically to the MRI unit; hence the reason for using the entire population of radiographers for the study.

Polgar and Thomas (2000) emphasized that in any scientific research the primary consideration is the protection of the rights and welfare of participants. Thus, ethical approval was sought from the Ethical Review Committee of the School of Allied Health Sciences, College of Health Sciences, University of Ghana. Permission was also sought from the Dr. Frank G. Shellock (2002) to reproduce content in his work and from the Institute for Magnetic Resonance Safety, Education and Research as well as the Radiology Department of the Korle Bu Teaching Hospital for the use of facility for the study. Informed consent was sought from participants in the form of written consent forms after the objectives of the study had been explained to them. They were assured of their anonymity, confidentiality of identity and information provided.

A self- administered open and closed ended survey questionnaire was used to obtain data from the participants. Before the main study, a pilot study involving three radiographers was conducted to assess the validity and reliability of the questionnaires. A modified checklist designed by Gillies (2002) was attached to the pilot phase for respondents to make suggestions that helped to modify the questionnaire as required. Ambiguity was thus removed; clarity of the format and design adopted was also ensured (Bailey, 1997).

A structured interview also was conducted with a member of the hospital management. This was to obtain additional data, validate and verify results obtained from the survey (Polgar and Thomas, 2000). Policy formulation and supervision of implementation is the responsibility of management of the hospital and the department (Beddoe *et al.*, 2004). Thus interviewing members of the management was considered the best way to obtain detailed and comprehensive information about safety management.

Questions on the framework of operational safety of the MRI unit, training programmes and practical safety problems faced by the MRI unit were among other things asked during the interview. The interview was electronically recorded, transcribed and data grouped into themes and analyzed.

The data obtained from the questionnaires was rearranged in an ordered manner to enhance its processing by the Statistical Package for Social Sciences (SPSS) version 16.0. Nominal and ordinal levels of measurement were used because the study design was a descriptive survey (Burns and Grove, 2001). Results were presented using descriptive statistics in the form of charts, frequency tables and percentages.

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5. Results

This study investigated the availability of safety policies and guidelines and adherence to them by staff at the MRI suite of the Korle-Bu Teaching Hospital. It also investigated the design features of the MRI suite as to whether it meets the acceptable safety standards. A total of thirty-one closed ended questionnaires (31) were distributed to all the practicing radiographers twenty eight (28) questionnaires were completed and returned completed giving a response rate of 90.3% (n=28/31).

	Professional qualification held			Total
Gender of Respondents	**Certificate**	**Diploma**	**Bachelor's degree**	
Male	2	10	9	21
	7.1%	35.7%	32.1%	75.0%
Female	2	2	3	7
	7.1%	7.1%	10.7%	25.0%
Total	4	12	12	28
	14.3%	42.9%	42.9%	100.0%

Table 2. Demographic Data of the Respondents

The profile above shows that the ratio of male to female respondents was 3:1. Nearly half of the respondents (42.9%) were both diploma and degree holders respectively

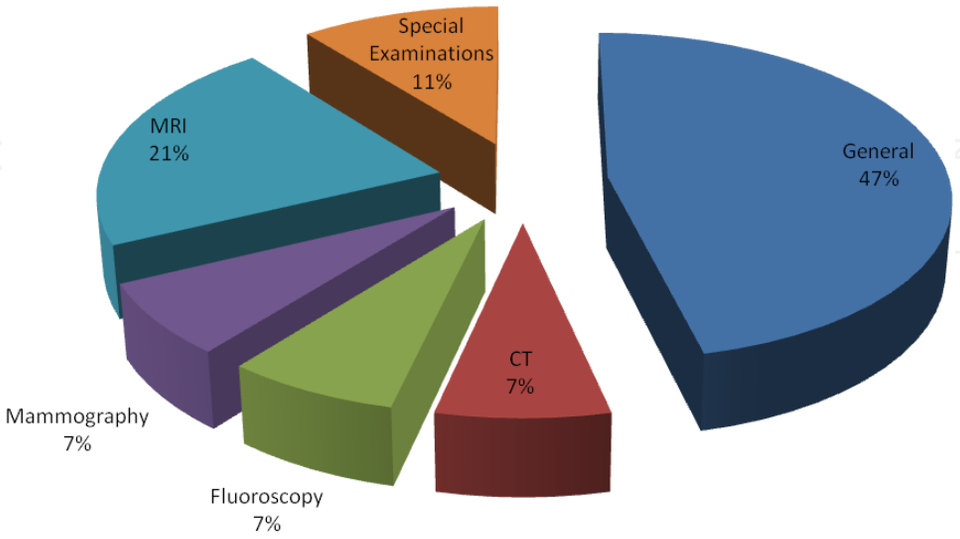


Figure 1. Area of work of Respondents. As shown, majority (47%) of Radiographers were engaged in general radiography.

Question Code	QUESTIONS	Responses to MRI Safety issues		Total
		Yes	No	
Q1	Is there a restricted access to everyone who comes to the MRI Suite	26 (92.9%)	2 (7.1 %)	28 (100.0%)
Q2	Do you undertake screening of patients who enter the MRI Suite?	21 (75.0%)	7 (25.0%)	28 (100.0%)
Q3	Do you undertake screening of staff who enters the MRI Suite?	10 (35.7 %)	18 (64.3 %)	28 (100.0%)
Q5	Are there lockers to store personal belongings that may be ferrous in nature or has a magnetic stripes in the MRI Unit	16 (57.1%)	12 (42.9%)	28 (100.0%)
Q6	Is the equipment used in the MRI environment checked by any authority, deemed MRI safe and labelled as such prior to implementation?	21 (75.0 %)	7 (25.0%)	28 (100.0%)
Q7	Does the equipment used in the MRI unit have colour codes to identify ferrous material and MRI safety material?	5 (17.9%)	23 (82.1)	28 (100.0%)
Q9	Do patients complete any MRI history and assessmentform that addresses possible contraindications prior to any MRI procedure?	26 (92.9%)	2 (7.1%)	28 (100.0%)
Q11	Are there proximity access doors and emergency exits to MRI suite?	15 (53.6%)	13 (46.4%)	28 (100.0%)
Q12	Do you face any problems in your bid to ensure the safety of patients and staff in the MRI unit?	14 (50.0%)	14 (50.0 %)	28 (100.0%)
Q14	Is there an assigned anaesthetist to the MRI unit to undertake procedures that need patients to be anesthetized?	7 (25.0%)	21 (75.0%)	28 (100.0%)

Table 3. Responses to MRI Safety Issues

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In Table 3, majority of 92.9 % (n=26/28) of the respondents stressed the need to restrict access to the MRI suite. Additionally, 75.0 % (n= 21/28) of the respondents were of the view that patients should be screened before allowed to enter MRI suites. However, only ten out of twenty eight (n= 10/28= 35.7%) suggested screening for radiographers' (workers), before they enter the MRI suite.

Table 3 also shows that 57.1% (16/28) of the respondents mentioned the presence of lockers in the MRI suite to store personal belongings that may be ferrous in nature or has magnetic stripes. Furthermore, 75% (n=21/28) reported that equipment used in the MRI environment undergo regular quality check. However, 82.0% (23/28) of the respondents disclosed that the equipment in the MRI unit did not have colour codes to identify ferrous material and MRI safety material.

Majority of the respondents (92.9%) reported that prior to procedure or examination, patients are asked to complete questionnaires to determine any contraindications they may have. A significant majority (53.6%) reported the presence of emergency exits to the MRI suite. Finally 75.0% of the respondents were unaware of availability of anaesthesia services at MRI unit for patients who would require anaesthesia as part of the procedure.

Question Code	QUESTIONS	Responses to Safety MRI training and unit design features		Total
		Yes	No	
Q15	Have you had any training programme(s) on MRI safety issues?	6 (21.4%)	22 (78.6%)	28 (100.0%)
Q16	Have you attended any of such training programmes, if yes to question 18?	4 (14.3%)	24 (85.7%)	28 (100.0%)
Q17	Do you know the MRI zones?	8 (28.6%)	20 (71.4 %)	28 (100.0%)

Table 4. Responses to Safety MRI Training and Unit Design Features

Training gap was identified in the use of MRI equipment and safety as demonstrated in Table 4 71.4% of the respondents were not aware of the existence of any MRI zones in the suite.

Table 5 shows that in general, the majority of the responded were unaware of the basic knowledge about the operations of MRI.

5.1. Analysis of the open ended part of the survey questionnaire

With regard to procedures undertaken for patients and staff entering the MRI unit, the majority of respondents (67.86%) had very little knowledge about what were being done. The remaining 32.14% had a fair idea but could not provide detailed description of the exact steps that were undertaken. When it came to the colours used to identify ferrous and MRI

safe material, there was a poor appreciation, evident by the fact all the 28 respondents did not know the existence of the colour identification of ferrous and MRI safe material.

QUESTIONS	Responses to MRI General Knowledge					
	Strongly disagree	Disagree	Undecided	Agree	Strongly agree	Total
Q21.The magnet is only on during the working day	14 (50.0%)	2 (7.1%)	3 (10.7%	4 (14.3%)	5 (17.9%)	28 (100.0%)
Q22.A strong magnetic field produces X-ray used for imaging	13 (46.4%)	2 (7.1 %)	1 (3.6%)	4 (14.3%)	8 (28.6%)	28 (100.0%)
Q23.A static magnetic field strength may be up to 100,000 times the magnetic field strength of the earth	1 (3.6%)	6 (21.4%)	13 (46.4%)	4 (14.3%)	4 (14.3%)	28 (100.0%)
Q24.5 Gauss line is the parameter around the MRI system where field strength is over 5 Gauss	0 (0.0%)	2 (7.1 %)	22 (78.6 %)	4 (14.3%)	0 (0.0 %)	28 (100.0 %)
Q25.At 5Gausspacemakers may be affected, ferrous items become potential flying projectiles and magnetic stripes are erased	1 (3.6 %)	1 (3.6 %)	19 (67.9%)	4 (14.3 %)	3 (10.7 %)	28 (100.0 %)
Q26.Below 5 Gaus is considered to be a safe level of magnetic field exposure to the public	0 (0.0%)	2 (7.1 %)	20 (71.4 %)	2 (7.1 %)	4 (14.3 %)	28 (100.0%)
Q27.Magnetic field strength is measured in Tesla (T) or Gauss (G)	2 (7.1 %)	2 (7.1 %)	3 (10.7 %)	8 (28.6 %)	13 (46.4 %)	28 (100.0 %)

Table 5. Responses to general knowledge about MRI

There was, however, high knowledge level in relation to how patients with implants and ferrous materials around the MRI suite were managed evident by the that fact 64.29% respondents could describe the correct steps that should be taken for such patients.

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All the respondents cited the following as challenges in ensuring safety of patients and staff at the MRI unit;

- A communication gap between patients and health professionals
- Unwillingness of co-workers to comply with protocol used at the unit
- Small waiting area which is shared by the CT-scanning unit and the MRI unit
- The lack of knowledge on continuity of procedure that has been performed for patients by referring clinicians.

On the issue of zoning in an MRI suite, 14.29% were aware of the different zones that are needed in a standard MRI unit as against 96.4% of the respondents which were not aware of the colour used to indicate the different zones. According to 21. 43% of the respondents, zoning was completely absent at the MRI unit of the Korle Bu Teaching Hospital. The general overview of the results suggests a huge knowledge gap on the safety issues of MRI by majority of the respondents.

5.2. The interview data

Thematic analysis was used to analyse the qualitative interview data. The predominant themes that emerged were the context for framework for operational safety at MRI unit, availability of departmental policy manual and training programmes for MRI. The areas identified included a maintenance programme for the MRI unit, structures in place for accidents and breakdown of the MRI unit and practical problems faced in ensuring safety at the MRI unit.

The context for framework for operational safety at MRI unit in this study represents a combination of organisational and operational methods that from the radiographers perspective, significantly affect the achievement of operational safety at MRI unit. It was noted that MRI was a relatively new modality in the country with the suite at the Korle Bu Teaching Hospital which was in 2006 being the first in the country. It was further observed that there was no documented formal framework by either the hospital or the department and that preparations were underway to produce one in accordance with best international standards. This observation was consistent with the findings from the survey questionnaire indicating the absence of a policy manual at the radiology department.

On the issue of continuous education and training of radiographers on MRI, it was noted that this was non-existent. As stated earlier, there was no MRI specialized radiographer in the department and any qualified radiographers who has basic knowledge in MRI could be assigned to the unit. The need to provide a platform to training and educate the practicing radiographers on MRI was identified.

On maintenance programme for the MRI unit, it was mentioned that the supplier of the equipment has a maintenance contract with the hospital to undertake routine maintenance of the MRI.

On measures that were being taken to prevent further accidents, it was indicated that the staff were required to report any incident or missed-incident to the appropriate authority. The absence of zoning in the suite and the adjoining CT scan suite made it difficult to undertake any effective screening because both MRI and CT scan patients have to enter through the same entrance. The absence of access codes for entrance into the MRI unit was also identified as a challenge to restricting access and this was attributed to defect in MRI – suite.

Other challenges identified include the attitude of some hospital personnel who were not willing to comply with safety and security measures in place. The need to undertake some structural adjustment to the unit was being considered to detach the CT suit from the MRI. Ensuring total commitment from both the management and staff of the hospital to safety and security issues was identified as one of the main means to prevent accidents at the MRI unit.

6. Discussion

This research sought to investigate the availability of safety policies and guidelines and adherence to them by staff at the MRI suite of the Korle-Bu Teaching Hospital. It also investigated the design features of the MRI suite to ascertain whether it meets the acceptable international safety standards as these inevitably, affect patient care during MRI procedures. In this chapter, the findings are discussed and key issues which require immediate attention are identified.

6.1. Response rate

Out of the 31 questionnaires administered, 28 were returned providing an appreciable response rate of 90.3% (n=28/31). The high response rate received could be due to the small population of radiographers in the department and their easy accessibility. It could also be due to the time and period that the data was collected; just after close of work. A response rate above 50% is an important part of a survey because it enables findings to be generalized (Burns and Grove, 2003). The survey undertaken can thus be generalized to the population that was studied.

6.2. Demographic profile of respondent: gender, professional qualification and working area

The demographic profile in table 2 on page 13 shows that the ratio of male to female respondents was 3:1 (75% - 25%). This observation may be associated to the general perception individuals have of radiation. As espoused by Maiorova et al (2008) most females prefer to work in other professions than to be in the radiography profession which is consistent with the Ghanaian situation where high numbers of females are found in other professions, particularly, nursing. As a result of the misconception people have about radiation in Ghana, some nurses even refuse to stay in the duty room at the radiography department to assist patients that they have accompanied. However, in other parts of the world, especially Australia, the radiography profession is dominated by the female population (Merchant *et al.*, 2011).

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Table 2 on page 13 also shows that equal numbers of the respondents were either diploma or degree holders (42.9% each) with the certificate holders being the least (14.3%). This is due to the fact that the certificate programme had been phased out long time ago and recently the diploma programme has also been stopped. The only radiography educational programme currently being offered in Ghana is the bachelor's programme. It was however observed that there was no respondent with a postgraduate degree hence the highest educational qualification in the study setting was first degree holders. As a result the absence of post-graduate education in the country, only few radiographers have managed to acquire post graduation abroad and they are mostly in the academia.

Figure 1 on page 13 shows that a good number of the respondents (47%) were into general radiography. The increased requests for general radiography examinations and the increased number of duty rooms may be responsible for this trend. Facilities for specialised imaging modalities are very limited and as has been stated earlier, there is only one MRI, a CT-scan and one mammogram in the department, hence the majority of the respondents in general radiography.

6.3. MRI safety issues

In this study, majority of the respondent were of the view that access to the MRI suite should be restricted to everybody who enters the unit. Whilst majority of the respondents claimed that patients were screened before entry, the same could not be said about the staff members as only ten respondents reported to be screening staff members. However, this assertion could not be entirely true because close observation during the study revealed that not a single staff was made to undergo mandatory screening apart from taking out their metallic possessions on their own volition. This also goes to confirm the assertion that the personnel were unwilling to comply with safety and security protocols at the unit. This assertion was corroborated during the interview about the absence of coded access keys for staff in accordance with international best practices found in the literature (Kanal et al., 2007; Junk and Gilk, 2005; Shellock and Crues, 2004).It was also observed that patients were only made to change into gowns placed in the changing room of the MRI unit and all metallic opacities removed from them before entering the scanning room. A metal detector screening coupled with visual observation was the only form of screening that was done at the unit aside patients filling out an MRI screening form. There were no in - built detectors in the building to give off any alarm as an indication of the presence of a metallic substance (Gould, 2008). The study also showed that there were no lockers for both staff and patients to keep their valuables that may be ferrous in nature even though 57.1% of the respondents claimed that there were such facilities. The only available option for the staff was to keep their items in the rest room or bring them to the control panel area for safekeeping; which is not completely safety - assured. With regards to patients, their valuables were either kept in the changing rooms or brought to the control panel area. A positive observation made was the availability and use of an MR-compatible wheelchairs and trolleys. This development may be described as the reactive response by the management to the wheelchair incident that occurred at the unit as captured in the problem statement.The staff were also more vigi-

lant and non ambulatory patients were thus transferred onto MRI safe wheelchairs and trolley before being sent to the scanning room.

It was reported by 57.1% of the respondents that the MRI equipment was regularly checked by the hospital authorities. However, it was established that these checks were not regular according to the standardized quarterly quality checks and maintenance scheme. The irregularity of the quality assurance checks could be a contributing factor to the frequent breakdowns of the equipment a view held by the respondents as contained in Table 3 on page 14

It was observed that patients were asked to complete MRI history and assessment forms to determine if they have conditions that were contraindicated to MRI procedure. However, non- patients including referring clinicians entering the unit did not complete this form. With the exception of the screening forms, no other safety and security documentation for both patients and staff were available in contravention of standardised policies and guidelines (Ferris *et al.*, 2007).

It was found that occasionally anaesthetists were assigned to the MRI unit for required procedures. This could explain why majority of the respondents were unaware of the presence of anaesthetic services at the radiography department.

6.4. MRI training and unit design features

The study revealed (as shown in table 4 on page 15) that there was a huge training gap in the use of MRI equipment. This was evident from the low general knowledge in MRI exhibited by the respondents, which was collaborated during the interview. The knowledge defect was also demonstrated by the fact that most of the respondent did not provide accurate responses to the questionnaires, a situation which may be attributable to the lack of policies and guidelines.

The study also found out that the design of the MRI suite did not conform to the basic design feature of a well laid out MRI unit as described by various organisations including the Joint Commission on the Accreditation of Health Organisations (JCAHO); International Building Code (IBC); Occupational Safety and Health Administration (OSHA)}. The defect in the design of the unit may be as a result of its mergence with the Computed Tomography (CT-scan) unit and other imaging modality units. The old CT- scan unit was collapsed and expanded to make room for the MRI unit and other imaging units thus preventing the ideal design of an MRI unit to be built out.

6.5. General knowledge about MRI

The responses on the general knowledge on MRI confirmed the training defect. It is possible that the few radiographers who had some knowledge about MRI acquired it through personal effort and on the job observations. Thus the absence of a framework for operational safety of the MRI could be a major issue that militates against the effective practice of safety at the MRI unit in the radiology department of the hospital.

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6.6. Summary

Safety of patients and staff around the MRI unit is a critical issue in the practice of diagnostic radiology due to the high magnetic fields and radiofrequencies associated with the operations of the MRI scanner. Magnetic field associated with the MRI scanner is 10,000 times higher than the earth's magnetic field; therefore a detection of the smallest amount of ferrous in any material is essential. It is therefore essential that radiographers take practical steps to identify any unknown material in or on any patient or staff that may be ferrous in nature or magnetic-sensitive.

The creation of an attitude of safety screening, however, requires a firm commitment of both senior management and staff of the hospital, which must be communicated through policies and local rules.

7. Conclusions

7.1. Based on the findings of the study, the following conclusions are drawn;

- Poor documentation of safety issues at the department was noted.
- Safety screening was practiced to some extent but there were no written local rules or policies that actually specify what a radiographer should do routinely. There was therefore no standard of practice in the department.
- The safety screening undertaken in the MRI unit was done primarily on patients, overlooking the risks posed by other individuals and co - workers who come to the MRI unit
- There was lack of an effective and efficient policy and guidelines in the hospital in general and the radiography department in particular.
- The inappropriate design feature of the MRI suite was also seen to be a hindrance to effective safety screening practices.
- This research is the first of its kind to be conducted at the MRI unit of KBTH. It is our considered view that further work needs to be carried out to validate the assumption that the frequent accidents and breakdowns at the MRI unit is as a result of the lack of safety policies and operating guidelines at the unit. It would also me necessary to extend such a study to the other MRI units in the country to determine their safety and security levels,

7.2. Limitations of the study

This study was conducted exclusively in the Korle Bu Teaching Hospital with a study population of thirty one radiographers. Although KBTH is the leading referral hospital in Ghana, making generalizations about radiographers nationwide has to be done with caution since the sample may not be truly representative of the entire population. There are a very limited number of MRI scanners in the country with the one at Korle – Bu Teaching Hospital being

the first. Hence this might not reflect the safety practice that take place at the other units since the other few may have the different designs which may meet international standards

7.3. Recommendations

- As a matter of urgency, professional bodies and Korle Bu Teaching Hospital should collaborate to produce a framework for the operational safety of MRI unit for the radiology department. In this framework, the department should come out with policy manuals and guidelines which would include specific safety issues which relate to the Ghanaian setting, training programmes to enhance the knowledge base of the radiographers. This should be reviewed regularly to meet the rapid advancement to the MRI technology.
- To equip the radiographers with practical experience in the use of MRI, the periodic rotation should be effectively implemented or more radiographers should be encouraged to upgrade themselves in the operations of MRI.
- The curriculum of the Diagnostic Radiography programme of the University should be thoroughly reviewed to cover the operational safety issues of the MRI. The practical examinations conducted during the final year should include all aspect of the medical imaging modalities and not only the conventional radiography. This is will equip the students with adequate practical experience of all the imaging modalities.

Appendix I

A photograph of the wheelchair that got trapped in the gantry of the MRI Scanner on the 12th of May, 2010 at the Korle Bu Teaching Hospital, Accra. Ghana



Figure 2.

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Appendix II

MRI Incidents in different parts of the World



Figure 3.



Figure 4.



Figure 5.



Figure 6.

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