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Survey of the Occupational and Patients Biological Risks in Magnetic Resonance Imaging Departments

Short title: Biological Risks in MRI Departments

Batil Alonazi

Prince Sattam Bin Abdulaziz University, College of Applied Medical Sciences, Radiology and Medical Imaging Department, P.O.Box 422, Alkharj 11942, Saudi Arabia
E-mail: bk.alonazi@psau.edu.sa

Abstract: Background: Technologists are exposed to a strong magnetic field (1.5-3.0 Tesla), higher than the earth magnetic field (≈0.5mT). In addition to that, the exposure to the radiofrequency (RF) may create currents producing skin burns. This study's objective was to assess the magnetic resonance imaging (MRI) safety practices in specific departments in Saudi Arabia in the Riyadh region, evaluate the incidence of biological effects and health implications of the electromagnetic fields present during MR scans, and to detect the occupational hazards. Methods: A survey questionnaire was designed and used to stimulate the target population's views on aspects of MRI safety and detected risks. The survey's target population includes consultants, radiologists, technologists, patients, and others who underwent MRI procedures. Results: A total of 28 technologists were responded from the five hospitals. The study results showed that 50% of the technologist reported various levels of effects, including vertigo and lack of concentration. It is well documented that exposure to MRI requires special consideration due to high magnetic field exposure. Conclusions: This study's main findings are that radiology nurses and patients in MRI units are highly exposed to the magnetic field, especially before and after MRI examination. Any department did not report projectile hazards. Staff is exposed to various degrees of radiation risks. No incident or accident was reported in all investigated hospitals. The staff is well protected in light of the current practice.

Keywords: MRI; molecular imaging; radiofrequency exposure; static magnetic field; biological hazard

1. INTRODUCTION

Human beings are subjected to continuous exposure to the earth's magnetic field ((≈ 0.5 mT) and a broad range of electromagnetic fields (EMF) every day. Within recent decades, exposures to EMF in the MHz region (VHF – UHF, 30 – 3000 MHz) have increased

continuously due to the enormous number of novel wireless applications (**Idris et al., 2020; Finlay et al., 2010**). The electromagnetic spectrum covers electromagnetic waves with frequencies ranging from below one Hz to above 1025 Hz, corresponding to wavelengths from thousands of km down to a fraction of an atomic nucleus's size. This frequency range is divided into separate bands according to energy, frequency, and wavelength. The best-known examples in everyday life are radio and television broadcasting services, mobile phone communication services, and computer networks.

In a medical framework, typical EMF sources are magnetic resonance imaging (MRI), hyperthermia cancer treatments, and diathermy in muscle relaxation (Physical therapy). The exposure levels for all EMFs must be limited to prevent adverse health effects on our bodies. Several national and international organizations have issued guidelines for determining exposures for the general public, patients, and occupational staff (e.g., The International Commission on Non-Ionizing Radiation Protection (ICNIRP) (**ICNIRP, 2014**) and the Institute of Electrical and Electronics Engineers (IEEE) (**IEEE, 2006**). The process can be vaguely compared to, for example, limiting exposure to bacteria in the food industry or managing the toxicity of tap water. Gamma rays, X-rays, and high ultraviolet are classified as ionizing radiation as their photons have enough energy to ionize atoms, causing chemical reactions. Exposure to these rays can be a health hazard, causing radiation sickness, DNA damage, and cancer. Radiation of visible light wavelengths and lower are called non-ionizing radiation as they cannot cause these effects.

Since the introduction of MRI in diagnostic examinations in the 1980s, the number of people exposed to EMF has increased. MRI machine utilizes a blend of low and high frequency electromagnetic and strong static fields to deliver the patient's image. While it is well established that ionizing radiations impose risks to human health and the environment, not much is known about EMF's possible effects relevant to patient safety. However, MRI is a diagnostic technique widely used in medicine and showing a growing impact in cardiology. Today, a significant number of available MR scanners and routine clinical applications do not even explain how many exams are performed in the world (**Delfino, 2014**).

Delfino, 2014 reported that EMF generated during MRI diagnostic scans has genotoxic effects in micronuclei (MN) induction. Although preliminary evidence suggests that an increased MN frequency is associated with early events in carcinogenesis (**Dewland et al., 201**3), previous studies still contradicting and cannot fully confirm the presence of health hazards from MRI, as the genetic damage also seems reversible after 48 hours. Limited data are available in Saudi Arabia regarding MRI risks and accidents. Patients and staff are exposed to various sources of hazards at the MRI department including: static magnetic and gradient fields, acoustic noise, radiofrequency (FR), and helium and nitrogen cooling gases. Staff exposed to magnetic field up to 3000 mT (3T), which is higher 6000 time than the safe magnetic field (0.5 mT or 5 gauss). To our knowledge, this is the first study designed to provide a survey regarding MRI safety and patients and occupational hazards. The main risk is from ferromagnetic objects inside the room, metallic implants.This study's objective was to assess the magnetic resonance imaging (MRI) safety practices in specific departments in Saudi Arabia in the Riyadh region, evaluate the incidence of biological effects and health

implications of the electromagnetic fields present during MR scans, and to detect the occupational hazards.

2. MATERIALS AND METHODS

Research Design:

A survey questionnaire was designed and used to stimulate the target population's views on aspects of MRI safety and detected risks. The survey's target population includes consultants, radiologists, technologists, and patients, and others who have undergone MRI procedures. A quantitative descriptive study was conducted where radiologic technologists are working with MRI System in five hospitals (A, B, C, D, and E) in Riyadh region (KSA) for the study, in Alkharj and Riyadh. The study involved the use of a questionnaire for data collection. The questionnaire was chosen as a method for data collection because of its appropriateness in answering the research questions and achieving the study's aim. Questionnaires are also easy to administer and for collecting data from a large number of employees. Besides, they provide data that can efficiently be coded and analyzed using statistical methods, making it easy to conduct comparisons. Survey questionnaires also enable one to study multiple variables simultaneously hence saving on time. The questionnaire contained items on MRI risk, level of education, radiographer's acquaintance with new technologies and radiation-related to radiography, level of experience, type of incentives and self-gratifying programs provided by the facility are employed, and on management functionality. The questionnaires were distributed to the radiology employees at five hospitals. The study composed of three questionnaires

A: ***Occupational exposure*** included questions about MRI safety issues for workers

B: ***Patients questionnaire*****:** The participants will grad their responses on each item using to allow the individual to express how much they agree or disagree with a particular statement

C**:** ***MRI system and safety****:* This section contains questions regarding MRI systems and safety criteria, and request form analysis.

Study populations

Participants for this study are radiology employees and patients. A total of 28 samples were collected from the five hospitals. The study used purposive sampling so that only those that work with the MRI system will be included in the selection. Data will be analyzed using descriptive statistics and inferential statistics, particularly Excel. The results are presented using tables and graphs to increase understanding. Descriptive analysis will be used in the study include frequencies, percentages, means, and standard deviations.

3. RESULTS

A total of 28 samples were collected in this study (Table 1). The process required an official approach to collect the data.

Table 2 shows the response of the four hospitals regarding safety and administrative measures at these departments. All hospitals agreed that the necessary safety regulations are

followed in seven parameters: Site access restrictions (MR zones), Contrast agent safety, sedation, emergency procedures, patient communication, and written policies and protocols. Other parameters showed wide variation in response even at the same hospital. Table 3 shows staff exposure to the magnetic field and RF field during image acquisition. 50% sample (3 staff out of 6) at hospital B reported various side effects, including vertigo, headache, earache, and concentration problems. It is important to note that the staff works in different magnetic field strength, including 0.5, 1.5, and 3 Tesla. Unlikely to experience any side effects with 0.5 tesla due to the limited strength of the magnetic field. In RCH, no side effects were reported in all questionnaires, illustrating that the current practice involves no staff risk. This might be due to workload or accurate safety levels. In hospital D, only two staff reported side effects due to magnetic field exposure. These effects include vertigo, sleepiness, and tiredness—staff who said these effects to have different years of experience working in an MRI environment. Finally, in hospital C, no effects were reported due to MR exposure.

4. DISCUSSION

A general literature review was used to make a descriptive, structured questionnaire. The study's purpose was to assess the risks and measures available to staff and patients involved in an MRI examination. The data were collected in this study were conducted in five hospitals. The weakness that we faced some hospitals refused to provide us data regarding MRI safety and questionnaires. However, this study's strength was that the authors' cooperation made the work more comfortable with the communication between authors who completed the job and made the course more reliable. The resulting analysis identified two main categories: MRI-related risks as well as patient and staff safety. MRI-related risks describe the effect of magnetic field exposure to patient and staff, the dangerous and fatal attraction of ferromagnetic objects, and the risk of heating and dislocating implants during MRI examinations. Patients and staff safety describe the importance of providing the right patient and staff information, the benefits of safety training, and the importance of effective communication between radiology nurse and patient. All questions have a different story with different details. This study showed comprehensive levels of responses to the effects resulted from MR Fields and other risks hazards from MR. However, In hospital B, 50% of the technologist reported various effects, including vertigo and lack of concentration. It is well documented that exposure to MRI requires special consideration due to high magnetic field exposure.

The result shows no MRI-related accidents occurring in MRI units due to the proximity of ferromagnetic objects to the magnet and safety guidelines for unplanned MRI examinations (tables 1-3). In Literature, since the first MRI projectile tank accident happened in 1987, the electronic coded security alarm was not in place. MRI warning sign was not clear and visible on the door, and the MRI door was not closed (**Shellock et al., 2014**). Also, it is suggested that radiology nurses should not work alone because lone working at MRI unit could be a potential occupational risk. Hence, it is recommended that two radiology nurses do at the MRI unit to support each other and in case of an accident or emergency.Patients may experience minorfaintness or sensory irritations (metallic taste)especially duringcouch

movement, which induces current due to the presence of the strong magnetic field. The gradient magnet in this study is 30mT with switching frequency 1kHz.This high frequency lead to current induction in the patient's body (based on speed of frequency switching and gradient coil strength). In addition to that minor effects may occur such as peripheral nerve stimulation (Table 2). The strong RF (Frequency=125MH), which is necessary for hydrogen nucleiexcitation, can induces eddy currents in conductive materialsincluding human body (patients or staff) and other conducting and ferromagnetic materials. In some cases, RF may induce skin burns if patients has Tattoos, permanent eyeliner. The loud noise in the MRI caused by switching of the gradients coil, which yieldsloud noise (≈ 105dB), based on the imaging protocol and sequences. In this study, all patients supplied with hearing protection materials during a scan including ear plugs and headphones, according to the department protocols and safety instructions. In superconducting magnets, to maintain superconductivity of the current, cold liquid helium in -269 ^{0}C is used. The main hazard include frostbite (skin irritation due to the cold condition) andasphyxia (Helium replace oxygen causing oxygen deficiency). However, in this study, in all five hospital, this kind of effects never happened. These effects may experience during magnet quench process or helium filling. Furthermore, according to the American College of Radiology (ACR) plan states that to prevent any MRI-related accident, patients and staff willing to go to zone 4 (MRI room) must be interviewed and screened thoroughly for any dangerous ferromagnetic objects. Also, in Sweden, there is a law that aims to promote high patient safety in the MRI area and general health care environment (**Nierop et al., 2014**). Patients and staff have to be escorted by a specialized and trained radiology nurse to the magnet room. The door to the MRI room must be locked whenever the radiology nurse is not present. Also, having a ferromagnetic detector with an alarm in the MRI room can provide an extra safety level for patients, radiology nurses, and other staff (**Petzel, 2012**). Therefore patients, radiology nurses, and all personnel involved must exercise extreme caution with all ferromagnetic objects at all times, because magnet is always on. According to **Shellock&Karacozoff, 2013**, patients' undisclosed implants during a pre-MRI screening could result in a severe or fatal injury. Thus any patient who did not revealan implant may put himself in severe danger. **Durbridge's 2017** study showed that patients and staff could be at risk of exposure from magnetic fields, especially radiology nurses who work very close to the most exposed magnet scanner. Patients could also be exposed when they are in and out of the MRI scanner, before and after the examination. According to Nierop et al., 2014, the latest version of MRI scanners, such as 7 T, 8 T & 9.4 T, produce more exposure to patients and radiology nurses due to the magnet's strength. To provide a safe MRI environment for both patient and radiology nurse and other staff who are entering and exiting the magnet room, safety guidelines, standards, and regulations exist to ensure the safe operation of MRI scanners in the United States (**Tejedor-Viñuela et al., 2004**). Therefore, radiology nurses and other staff entering the unit must use great care to protect themselves and provide a safe MRI environment for patients.

Additionally, medical errors still occur, and as shown in the result, 50% of reported human errors are caused by poor communication. Suppose accidents occur in the MRI environment due to poor communication. In that case, it will affect both the patient and the radiology nurse

physically and emotionally and cause damages to the scanner and equipment around (Hanson, 2016, Karpowicz, 2007). Therefore, good communication between patients and radiology nurses is essential because the time spent at a hospital or medical center undergoing MRI examination is usually stressful for patients. Good communication between patient and radiology nurse plays an indispensable role before and during MRI examination for the patient to be more cooperative during the procedure. Effective communication is essential and improves morale, increases efficiency, and creates a healthy working environment between co-workers and between patients and radiology nurses. Most importantly, it will create a safe MRI working environment (**Tejedor-Viñuela, 2006**).

All hospitals and medical centers must provide a safe environment for patients and staff in the MRI scanner's presence. They should establish, document, and implement MRI safety protocol to avoid any incidents from occurring Safety training provides radiology nurses and other staff with the vital knowledge of the risk and hazards associated with MRI and, most importantly, how to prevent incidents from occurring (**Kanal et al., 2007**). Staff development and training are one of the most vital components in the MRI department. Trained staff will be better equipped to handle patient inquiries and to inform the patients of the MRI procedure. Therefore, it is vital that staff in a safe work environment without any unnecessary risk and anxiety.

5. CONCLUSION

This study's main findings are that radiology nurses and patients in MRI units are highly exposed to magnetic fields, especially before and after MRI examination. Any department did not report projectile hazards. Staff is exposed to various degrees of radiation risks. No incident or accident was reported in all investigated hospitals. The staff is well protected in light of the current practice. Special staff training is required to improve their culture and knowledge regarding safety issues in the MR environment. Detailed information regarding MR safety should be written in bold font to be readable from a distance. Metal detectors should be implemented in all departments, in addition to handheld metal detectors.

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Highlights

- Safety and protection were assessed in five MRI departments
- Staff and patients experiences common side effects of magnetic field exposure
- No accident or incident was reported in the last 10 years
- All departments has strict safety protocols.

- Training of staff is necessary to improve departmental safety

Table 1 Study population

No	Hospital	Staff Questionnaire	Patients questionnaires	Request Form questionnaire
1	A	5	1	1
2	B	5	1	1
3	C	3	1	1
4	D	5	1	1
5	E	0	1	1
Total		18	5	5

Table 2. Patients biological effects from four hospitals				
	A	**B**	C	D
Hospital	Yes-No (%)	Yes-No (%)	Yes-No (%)	Yes-No (%)
Designated MR medical director	100-0	100-0	67-33	80-20
Site access restrictions (MR zones)	100-0	100-0	100-0	100-0
Documented MR safety education/training for all personnel	80-20%	100-0	33-67	100-0
Patient and non-MR personnel screening	100-0	100-0	67-33	60-40
Pediatric patients	100-0	80-20	100-0	100-0
Magnet quench	100-0	0-100	100-0	80-20
Cryogen safety	100-0	80-/20	33-67	80-20
acoustic noise	100-0	40-60	33-67	40-60
Pregnant patient and staff	100-0%	40-60	100-0	80-20
Contrast agent safety	100-0	100-0	100-0	100-0
Sedations	100-0	100-0	100-0	100-0
Thermal burns	80-20	0-100	0-100	0-100
Emergency code procedures	100-0	100-0	100-0	100-0
Device and object screening	100-0	100-0	100-0	80-20
Designation of MR safe/MR conditional status	100-0	100-0	67-33	100-0
Reporting of MR safety incidents or adverse incidents	100-0	100-0	67-33-	100-0%
Patient communication	100-0	100-0	100-0	100-0
Infection control and medical waste	100-0	100-0	67-33	100-0
Written policies are present and readily available to facility staff	100-0	100-0	100-0	100-0
Written policies are reviewed and updated on a regular basis	100-0	100-0	100-0	100-0
Facility has appropriate MR safety warning signs and methods of	100-0	100-0	100-0	100-0

controlled access				

Table 3 : Technologists electromagnetic field effects and machine characteristics

Hospital	Five Hospitals	employee No.	
occupation	Technologist		
Years of experience in MRI	2.5-10 years		
type of machine	0.5-1.5-3 T		
Are there procedures in place to ensure the adequate screening of participants prior to scanning?			yes
Is a hand-held high-strength magnet available for screening purposes?			yes
What steps are in place to screen for pregnancy?			check the lab test and consent
What special precautions are in place for infant scanning?			his parents is well sedated
Are there approaches in place for screening for repeat scans?			yes
Are training, operating and emergency procedures in place to help ensure participant safety?			yes
Is hearing adequately protected?			yes
Is there any history of incident in facility (metal projectile, etc			no
Is safety zones clearly specified			yes
Do you believe that you are affected by working in MRI (select the suitable response)		yes	vertigo, earache
Are you satisfied with the safety			yes