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Radiology

SAFETY OF MRI TECHNOLOGY IN DIFFERENT MAGNETIC FIELDS

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ABSTRACT

Objectives: This study was conducted in order to analyze MRI safety in different magnetic strengths And aimed to fill gap present in current MRI literature, linking the basic theory with clinical practice.

Material and Methods: The present study, is descriptive and practice work to evaluate the safety of MRI examinations and discuss the finding results with similar studies found in literature. The sample group consist of 60 healthy adult ,diagnosed with different types and models of MRI systems in different power strengths commonly used 0.2T, 1.5T and 3T. Technique used is standard protocol for head scan .Others parameters including digital micro electronics devices to measure skin temperature and blood pressure . In addition to observations check list to record signs and symptoms which a beer during or after the MRI exam.

Data were collected from the period of September 2016 to May 2017 and analyzed statically using statistically package for social sciences (SPSS) program.

Results: The results achieved that ,there is an elevation in skin temperature associate with strength field, but not significant that can produce ill effect. And regarding biological changes in blood pressure, the data showed a slight increase demonstrated by higher field strengths and it increases by the increase in magnetic field however it's insignificant. Moreover most symptoms are shown by high field magnets 3T. Whereas the data provides 40% abnormal observations.

Conclusion: A recent study concluded that it was very difficult to prove the existence of significant biological effects. And the author thought that, the values obtained in this study are useful were it offer a detailed look at MRI technology, risks and patient safety and ended by recommended for using high filed strength, just according to the need to produce enough signal for an adequate imaging

KEYWORDS : MRI, imaging , Radiation effects, Safety, clinical Technology.

1- Introduction:

While MRI is considered to be inherently safe and non-invasive because it does not use ionizing radiation, However, as in any sanitary interventions, there are intrinsic hazards that must be understood, acknowledged and taken into consideration. These hazards are relative to all three types of fields, external magnetic fields (EMF), radio frequency electromagnetic energy (RF) and a gradient magnetic field (MF) which can affect patients, staff and other persons within the MR environment. (1)

Nuclear magnetic resonance (NMR) is used to selectively distinguish signals from certain atoms due to the magnetic behavior of their nuclei. Depending on the analysis of these signals and the atomic nucleus in question, known as magnetic resonance imaging (MRI). As the field of MRI as diagnostic procedures continues to grow, it estimate that there will be a constant need for more information to enable better visualization and healthy considerations of MRI safety(1) .To understand the origin of an NMR signal, it should be recalled that an atom is composed of a nucleus around which gravitate electrons. Suitable nuclei are certain isotopes such as carbon 13, phosphorous 31, nitrogen 15, oxygen 17 and fluorine 19, which are the most widely studied in NMR. MRI uses the resonance of hydrogen, which is present in large quantities in the body, particularly in the water molecule. The NMR technique is based on the use of a very intense permanent static field (B0), or generated by superconducting coils cooled by liquid helium or liquid nitrogen. In order to obtain an MRI image, gradient coils produce magnetic fields that are added together and are entrenched at B0. They are responsible for a rapid gradual variation of the magnetic field in space and enable the spatial coding of the image. Generally, MRI is regarded as a harmless procedure in clinical routine, operating without ionizing radiation and without harmful effects on the human body when the known precautions such as prevention of projectile effects are observed. The increasing dissemination of scanners with field strengths above 3 T has led to new discussions on possible bio-effects and damages caused by stronger magnetic fields or higher absorption inside the human body of the transmitted electromagnetic radiofrequency (RF) radiation necessary for tissue excitation (2).

During an MRI procedures, three types of MF are employed to produce images, a high static MF, which generates a net magnetization vector in the human body, that is a measure of the proton density, a gradient MF used to localize aligned protons inside the body, thus allowing spatial reconstruction of tissue sections into images and RF electromagnetic wave which energizes the magnetization vector allowing its detection by the MRI scanner, converting tissue properties into MR images. To assess the Safety associated with MRI environment and procedures, this study hypothesis that ,the MRI safety associates with the increase in the magnetic force used. (2)

2- Material and Methods

This a descriptive and practice study ,was conducted to evaluate the MRI safety in different magnetic fields. Data is collecting from practice human subjects. The data combined with the performance of clinical routine MRI sequences at different field strengths, including the application of gradient magnetic field switching and RF exposure in addition to the static magnetic field .Occupational including 60 adult outpatients aged 18-50 years underwent MRI scans used two types units permanent and superconductive magnets. The data obtained by comparing different magnetic fields commonly used in MR imaging which are, lower power (0.2T), Moderate power (1.5T), High power (3T). However different coils and equipment's with specific determination are the tools for the data collection. In addition to digital micro electronics devices to read thermal effect by measuring sub- lingual relative change in skin temperature from the standard (37°C) before and after the exam. Also electronic blood pressure measurement devise used for evaluating the blood pressure .All measurement for skin temperature and blood pressure were taken immediately before and after MRI acquisition they were performed , before patient left the MRI imaging room. The environmental conditions of various MRI systems that may affect the subject temperature change were also being considered . So the ambient temperature kept at normal and comfortable room level around 20 to22 °C and humidity not exceed 50 °C level . Other parameters including observations check list to record signs and symptoms which a beer during or after the MRI exam.

Data have been evaluated by using standard protocol for head scan with average exposed time approximately 20 min and specific absorption rate (ASR) not exceed of 4.0 W/kg.

The data collected in this study , carried out statistically by using statistically package for social sciences (SPSS) program to analyze the findings from the period of September 2016 to May 2017. For ethical consent all requirement for authorship have been met. And the author declare that Ethics Committee approval has been obtained for this study and for Disclosure ,the author declare that no conflicts of interest.

The goal of this research is to use MR imaging in good manner with

high safety to improve the way we practice radiological imaging. And the aim of the study is to test the MRI safety emerging from different magnetic strengths. Safety issues and discussions about biological effects associated with magnetic resonance imaging (MRI) have been conducted in the present work, with comparing of finding results with similar studies in the literature.

3- Results:

The results of the MRI procedure for thermal effect and others biological changes including blood pressure and up normal observations carried out for patients before and after the procedure are obtained and compared with results found in literature in discussion section, The relative change in skin temperature from the standard (37°C) measuring before and after MR scan obtained for low power of static magnetic field 0.2T which represented in Table(1) .And the relative changes for skin temperature from the standard obtained also for 1.5T system which represented the moderate magnetic field strength ,Table(2) . Also data obtained for 3T system which represented the higher magnetic field strength, Table(3). All of the results obtained for thermal warming temperature presents in Table(4) which show data comparison of MRI examinations for thermal effect for the combination of the three fields. Where it indicated that, although there is elevation in skin temperature but it is not significant that can produce ill effect and indicated that the elevation in skin temperature increase with the increased in strength field.

Temperature before &after exam	Frequency	Percent	Cumulative percent
37- 37	15.0	75.0	75.0
37-38	5.0	25.0	80.0
37-39	0	0	100.0
37-40	0	0	100.0
Missing System	0	0	
Total	20	100.0	

Table (1) shows relative change in skin temperature from the standard (37oC) for 0.2T field strength.

Temperature before &after exam	Frequency	Percent	Cumulative percent
37- 37	12.0	60.0	60.0
37-38	5.0	25.0	80.0
37-39	3	15.0	95.0
37-40	0	0	100.0
Missing System	0	0	
Total	20	100.0	

Table (2) shows relative change in skin temperature from the standard (37oC) for 1.5T field strength.

Temperature before &after exam	Frequency	Percent	Cumulative percent
37- 37	10.0	50.0	50.0
37-38	6.0	30.0	70.0
37-39	4	20.0	90.0
37-40	0	0	100.0
Missing System	0	0	
Total	20	100.0	

Table (3) shows relative change in skin temperature from the standard (37oC) for 3T field strength.

Magnetic field strength	Normal cases		Upnormal cases	
	Frequency	percent	Frequency	percent
0.2T	15	25.0	5.0	8.0
1.5T	12	20.0	8.0	13.3
3T	10	16.7	10.0	16.0
Total	37	61.7	23	38.3

Table(4) shows comparison of MRI examinations for thermal effects for the combination of the three fields.

Data obtained for assessment of blood pressure changes, was demonstrated by lower field for 0.2 T from the standard Bp (120/80) mm/hp showed in Table(5). Moderate power field of 1.5T presented in Table(6). The higher field 3T presented in Table(7). Table (8) showed comparing of blood pressure assessment by the combination of the three fields. Accordingly ,our results showed no significant hazard is seen after MRI imaging even at 3 T .

Blood pressure	Frequency	Percent	Valid Percent
120/80	20.0	100,0	100.0
120/85	0	0.0	0.0
130/90	0	0.0	0.0
140/90	0	0.0	0.0
Missing System	0	0	
Total	20	100.0	100.0

Table(5) shows relative change in blood pressure from the standard (120/80) mm/hp for 0.2T field strength.

Blood pressure	Frequency	Percent	Cumulative Percent
120/80	19.0	95.0	95.0
120/85	1	5.0	100.0
130/90	0	0.0	100.0
140/90	0	0.0	100.0
Missing System	0	0	
Total	20	100.0	

Table(6) shows relative change in blood pressure from the standard (120/80) mm/hp for 1.5 T field strength.

Blood pressure	Frequency	Percent	Cumulative Percent
120/80	18.0	90.0	90.0
120/85	2	10.0	95.0
130/90	0	0.0	100.0
140/90	0	0.0	100.0
Missing System	0	0	
Total	20	100.0	

Table(7) shows relative change in blood pressure from the standard (120/80) mm/hp for 3 T field strength.

Magnetic field strength	Normal cases		Upnormal cases	
	Frequency	percent	Frequency	percent
0.2T	20	33.3	0.0	0,0
1.5T	19	31.7	1.0	1.7
3T	18	30.0	2.0	3.3
Missing System	0	0	0	0
Total	57	95	3.0	5.0

Table(8) shows comparison of MRI examinations for changing in blood pressure for the combination of the three fields.

The results concerning biological changes obtained from this study, showed mild change in blood pressure added to mild abnormal feeling of some symptoms, such as vertigo, nausea, anxiety and headache are also found. Whereas the data determined no significant hazard is seen, nevertheless it does not assume absolute safety. The data summarized in Table (9) & Fig (1) which achieved that lower magnetic field is safe and not affected any symptoms by 100% normal . 15% of observations symptoms shown by superconductive moderate power 1.5T .The common symptoms showed by high field magnets 3T where the data 40% abnormal observations.

Magnetic field strength	Frequency	Percent
Permanent o.2 T	0	0.0
Superconductive 1.5 T	3	15.0
Superconductive 3 T	8	40.0
Total	11	18.3

Table(9) Summarized subjective observations demonstrated by different types of magnetic field strengths.

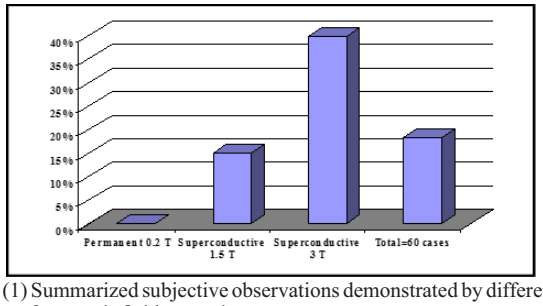

Fig (1) Summarized subjective observations demonstrated by different types of magnetic field strengths.

4-Discussion:

As a different electromagnetic fields affecting the body during an MR procedures and according to the results obtained in this study, which were displayed previously, the researcher found that the superconductive scanning with a high magnetic field strength, which has great value and high efficiency in demonstrating diagnostic information's ,have some bio-effect but there is no harmful result. This agree with reports review of (3) However, consideration should be taken about the elevation of temperature which increased by the increased power of magnetic field according to the data obtained in recent study.

The main safety issue with the radiofrequency (RF) pulses during the imaging process, concern the majority of RF power is transformed into heat within the patient's tissue. Absorption of energy from RF fields by tissues results in generation of heat due to resistive losses. A rise of 1oC is generally acceptable to a normal healthy body (4) . Human data obtained in this study regarding thermal effect consistent with this and established that higher signal field strength would raise the temperature of skin however, within the normal limits and not exceeds the standard safety considerations that limit body temperature raises to 1oC. Although the thermal effect from human data obtained in this study is 2oC from (37-39°C) and does not exceed the 40°C, the standard elevation for normal temperature tolerance by humans, this can be justified that no thermally induced ill effect from the slight elevation in skin temperature. However for too large field strength such as 3T a mild rise in temperature is found. The rate of RF deposition is represented in terms of specific absorption ratio (SAR) which is normally measure in W kg-1. The SAR actually is the mass normalized rate at which RF power is coupled to biological tissues. For a given pulse sequence, the SAR is dependent upon the radiation, amplitude, and number of RF pulses during each repetition time of the sequence. Biological effects caused by radiofrequency electromagnetic waves constitute the basis of contemporary international safety guidelines, also known as the ICNIRP Guidelines, (5) which reported Non-thermal effects, which are due to an unknown mechanism of direct magnetic field-tissue interaction. The recommendation of ICNIRP for examinations by magnetic resonance imaging, states that, in the case of pregnant women, children or persons with cardiovascular problems, in whom thermo regulation mechanisms are less efficient, it is recommended to take care not to exceed a temperature increase of 0.5 C. Another Study have demonstrated that examinations with a whole-body absorption rate of 6 W/kg averaged over 16 minutes are still tolerated by volunteers, although the clinical limit for "first-level mode" is currently lower at 4 W/k.(6). The RF field frequency in MRI is around 63.4 megahertz (MHz) for a 1.5 T device and around 127 MHz for a 3 T device. Limit values exist for the RF in MRI set by the European committee for electromechanical standardization (CENELEC), but such limits are mainly related to acute health effects caused by heating from this type of exposure. Limiting factors for the exposure of patients is also peripheral nerve stimulation (PNS) due to induced electric potentials. (7).

Regarding bio-effects of the static magnetic field (B0). The results concerning biological changes obtained from this study, showed mild change in blood pressure added to mild abnormal feeling of different symptoms, such as vertigo, nausea, anxiety and headache are also found and it increase as magnetic field increase. Whereas, the data determined no significant hazard is seen, nevertheless it does not assume absolute safety. This finding consistent with the recommendations of Food and Drug Administration (FDA), clinical basis for safety is for static magnetic field strength of up to 2 T. However, above this level, evidence of safety must be provided by the sponsor or device manufacturer prior to routine clinical use and it should not being so large that it exceeds the safety guidelines. For that , a recommendation given in recent study for using high filed strength, just according to the need to produce enough signal for an adequate imaging. The biological effects of static magnetic fields is one of the most controversial topics in the field of MR safety. It have been reported in several literature (8,9) that several structures within humans are affected by the static magnetic fields such as the retina, pineal gland, and some cells in the paranasal sinuses. However, the effects are not the same as harmful, or carcinogenic .The majority of these studies did not report positive results. In the current literature, (10,11) some sensory effects have been found associated with exposure to a static magnetic field. There was a statistically significant finding for sensations of nausea, vertigo, and metallic taste in subjects exposed to 1.5 and 4 T static magnetic fields, but no statistical significance was found for other effects such as headache, tinnitus, vomiting, and numbness. These have been agreed with the findings of this study, were the data obtained for assessment of relative sign and symptoms biological changes achieved that lower magnetic field is safe and not affected any symptoms and no significant symptoms from superconductive moderate power 1.5T. The common symptoms showed by high field magnets 3T where the data provide abnormal observations including vertigo, nausea, anxious, sweet, dizzy, headache, suffocation, metallic taste in mouth and temporary hearing loss. The main safety concerns with the time-varying magnetic field gradients are stimulate nerves and acoustic noise as has been confirmed by (12,13). Subjecting the human body to time-varying magnetic fields leads to induced electric fields and circulating currents in conductive tissues. At any particular location, the currents induced will be determined by the rate of change of the magnetic field and the local distribution of the body impedance, which is primarily resistive at frequencies below about 1 MHz.(14). The International Commission on nonionizing radiation protection has recommended to avoid nerve excitation in the patient. Numerous studies carried out over the past 30 years have indicated that the exposure to radiofrequency radiation may produce various physiological effects, due to RF energy-induced heating in tissues, including those associated with alterations in visual, auditory, endocrine, neural, cardiovascular ,immune ,reproductive, and developmental functions as confirmed by (15,16).

There are two major safety issues regarding the static magnetic fields used in MR: attraction of ferromagnetic material towards the magnet and biological changes. Devices made from ferromagnetic material such as surgical tools (e.g., aneurism clips scissors) and certain components of implantable medical devices (e.g. pacemakers and neuro-stimulators) will be attracted to the core of the main magnet and this effect is known as projectiles. The projectile effect caused the most serious accident reported to date (17,18,19) .Discussion of the major recognized mechanical risk and potential hazards associated with MR scanner in the presence of ferromagnetic devices and equipment, including biomedical implants , is out of scope of recent study.

5- Conclusion:

With the increasing spread of MR scanners with higher field strengths, the question of possible negative side effects on the human body has moved into the focus of interest. A recent study concluded that it was very difficult to prove the existence of significant biological effects. And for more safety ,the author recommended for using high filed strength, just according to the need to produce enough signal for an adequate imaging .The author also thought that, the values obtained in this study are useful were it offer a detailed look at MRI technology, risks and patient safety and maintain to improve the way of practice radiological imaging and technology to produce an educated and safety-aware of MRI medical team that can develop, implement and maintain an environment of effective and safety-focused patient care.

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