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MRI safety practices: Ensuring patient and staff well- being in the magnetic environment

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Abstract

Back ground: Developing a magnetic resonance imaging (MR) safety protocol is essential to guaranteeing patient and staff safety during MR imaging. A core safety council and a wider safety committee made up of all-important stakeholders are part of the organizational structure. Together, these groups strive to establish a strong safety policies and procedures, enforce device regulations for entry into the MR setting, build MR safety zones, address intraoperative MR concerns, ensure safe scanning parameters and guarantee appropriate communication among all parties involved in the MR environment.

Aim: The purpose of the current review is illustrating and understanding safety instructions and protocols for maintaining a good safety practice and ensure patient and staff well being safety in magnetic environment.

Method: A systematic review is maintained from electronic databases in English language and from published papers from 2009 to 2021.

Result: 13 articles was selected and reviewed based on inclusion criteria and focus on the various policies of safety practice to ensure patient and staff well-being safety in magnetic environment.

Conclusion: The literature that was retrieved indicates that safety guidelines for patient safety and staff well-being in magnetic environment have been established according to the current body of knowledge.

Keywords: “safety practice”, “magnetic resonance”, “patient safety”, “Quality”, “magnetic environment”.

Introduction

MRI is a diagnostic test that is commonly used globally. However, Implants that are not approved for use in magnetic resonance imaging (MRI) may move due to attraction or alignment with the primary magnetic field, heat up due to radiofrequency deposition, or malfunction. MR Safe implant scanning may cause serious illness or even death. thus, MR Conditional devices can only be safely scanned in the right circumstances. Limitations may be placed on the field strength, gradient field strength, particular absorption rate, or scanned body area, among other things **(Yong et al.,2019).**

Imaging centers and hospitals must prioritize providing a secure environment for MRI scans. For this reason, it's essential to create and maintain a strong magnetic resonance (MR) security policy to protect both patients and MR staff **(Sotardi et al.,2021).**

Even though healthcare settings are inherently dangerous, modern approaches to patient safety have moved from emphasizing the elimination of human error to creating strong systems and processes that produce safe outcomes.

The static magnetic field (B0), the gradient magnetic field (dB/dt), and the radiofrequency (RF) electromagnetic field are the three main physical forces used in MRI that can pose a risk to patient and staff safety. Due to these forces, the main risks in the MR environment are burns, projectiles, loosening ferromagnetic implants, and malfunctioning or failing medical devices **(Johnston et al.,2009).**

Despite not requiring exposure to hazardous ionizing radiation, magnetic resonance imaging (MRI) is a safe non-invasive imaging technique that does require exposure to static magnetic fields, time-varying electromagnetic field gradients, and pulsed radiofrequency electromagnetic fields. Numerous possible risks arise from exposure to these various kinds of electromagnetic fields. When any material is introduced into the field's proximity, these electromagnetic fields will interact with its properties. The majority of this interaction with living biological tissue occurs at the cellular level. Magnetic susceptibility determines how a material interacts with something that cannot be magnetized indefinitely **(Crook, Robinson.,2009).**

To avoid avoidable harm and to adhere to safety regulations at MR imaging sites, radiologists must need to be conscious of these risks and know how to mitigate them for themselves, their colleagues, and their patients. Radiologists need to have a basic understanding of the physics and hardware of MR imaging in order to comprehend the origins of safety rules and to avoid widespread misunderstandings that could endanger safety **(Hartweg V.,2015).**

Since, every part of the MR imaging machine has the potential to cause harm to both staff and patients. so, One essential and vital component in preventing mishaps related to MR imaging is the separation of the environment into four separate, clearly marked zones, with progressively greater entry restrictions and more supervision for higher zones. Every MR imaging facility needs to have a written emergency plan in place for zone IV **(Tsai et al.,2015).**

Literature Review

Purpose of the review: -

The objective of this systematic review is illustrating and understanding safety instructions and protocols for maintaining a good safety practice and ensure patient and staff well-being safety in magnetic environment. Subsequently, discussions the methods and approaches for creating an MR safety issue tailored to RT are covered.

Search design: Inclusion and exclusion standards

This research paper includes: original research studies and reviews (qualitative and quantitative outcomes) describing the safety policies, instructions and protocol for maintain patient and medical staff safety across magnetic environment, Research studies released between 2009 to 2021 that were written in English, human subjects and no geographical restrictions were considered. Exclusion standards include: Publications without peer review, webcasts, conference abstracts, and case reports were not included.

The Data Extraction and Quality Assessment

The authors of the review independently analyzed, extracted and abstracted the data from the 13 publications that met the inclusion criteria. The extracted data included the main study objectives, features, inclusion criteria, methodology and outcomes. The procedure comprised evaluation of previous studies about MRI safety polices in magnetic environment We used standard methods that were suitable for the individual study designs to evaluate the quality of the included data. Findings from the included studies were narratively synthesized.

Methodology

There were thirteen articles included in the review. using Google Scholar and reviewing the CINAHIL, PubMed, Medline, and Scopus databases. In addition, The British Institute of Radiology, the Royal College of Radiologists, the Society of Radiographers, the Institution of Engineering and Technology, and IMRSER (the Institute for Magnetic Resonance Safety, Education, and Research) were among the related websites that were looked up. English was the language used for the studies. The terms that were employed in the search were "radiology," "safety practice," "safety polices," "magnetic resonance image," "patient safety," "health staff safety protocol," "magnetic environment". To find more research, a manual review of the reference lists of the pertinent papers was done.

Result

There were 367 articles located from 2009 to September 2023. In which 2019 articles did not meet the inclusion criteria, consequently 148 full-text publications were found. After further revision and filtration, 13 articles were finally included in the systematic review.

Most of the reviewed articles found that A lower number of workplace accidents has been linked to increased safety awareness. Most authors also emphasized the importance of safety checklists, protocols, and provider training.

Three reviews of 13 documented the adverse effect occurred in patient, which burns was the most prevalent.

A personal monitoring campaign was conducted by some papers, where workers wore personal recording devices based on three-axis Hall-effect probes and, in certain cases, induction coils, to measure and record static and time-varying magnetic fields throughout their work shift. Other papers measured the magnetic fields in the areas around MR scanners where workers may be exposed.

Discussion

Various international committees and organizations have developed safety guidelines. Below which no harmful health effects should occur in healthy adult workers, the International Commission on Non-Ionizing Radiation Protection (ICNIRP) has recommended basic restrictions for occupational exposure.

Magnetic field shielding

Based on the study in 2018 of Romeo and other colleagues; the magnetic field shielding It can be either active or passive to lessen the fringe field. Ferromagnetic plating is inserted into the magnet room's walls or floor to provide passive shielding, which focuses the magnetic flux lines in a specific area. Active shielding partially cancels out the external field by using superconducting windings outside the inner main magnet windings in the opposite direction **(Romeo et al.,2018).**

But neither technology, particularly in very strong field installations, fully captures the fringe fields. Therefore, there is stringent access control in the vicinity of the scanner. A set of guidelines was released by a panel of experts from the American College of Radiology **(Kanal et al.,2013).**

Safety regulation

New recommendations regarding static magnetic field exposure in the workplace and the general public were released by ICNIRP in 2009. The reported limits for occupational exposure were 8 T for limbs and controlled environments, and 2 T for the head and trunk. These are the most60 recent restrictions. In order to protect employees and the general public from low-frequency (1 Hz to 100 kHz) electric and magnetic field exposure, the ICNIRP released a document in 2010 about exposure to changing electric and magnetic fields over time **(ICNIRP., 2009.; ICNIRP., 2010).**

On June 26, 2013, the Parliament and Council adopted the final revised Directive 2013/35/EU, which was then published in the European Union's Official Journal. The new Directive's Articles 10 and 14 identified a number of professional categories for which there are exceptions to the exposure limits. These categories include workers who are involved in the development, maintenance, testing, installation, testing, and research of MR equipment used for patient care in the healthcare industry, in addition, members of the armed forces in operation and specific industrial applications **(EU Directive.,2013).**

Concerns about safety related to B0

Superconducting magnets are frequently used in clinical MRI scanners; therefore, it is important to consider the constant presence of the static magnetic field and the related safety risks.

According to Song et al.'s 2018 estimate, 10–20% of MRI patients have medical devices implanted. When ferromagnetic objects—such as medical implants and devices—are exposed to a static magnetic field, they experience both translational and rotational forces **(Song et al.,2018).**

It's crucial that individuals possessing implants and other medical equipment aren't needlessly denied MRIs in spite of these risks. Such patients can be able to have an MRI examination if they have a precise understanding of the makeup of these objects and how they behave in the MRI environment **(Shellock FG., 2020).**

Individuals are showing up with a growing array of implantable devices as technology advances, and the MRI technician must be capable of locating the most relevant data regarding the safety of the apparatus. Additionally, it is essential to understand how to apply and interpret any MR conditions, such as B0 and dB/dx limitations, to a specific workplace scan (**Mittendorff et al.,2021).**

Concerns about safety related to radio frequency

According to reports from 2019, thermal injury accounted for 59% of the MRI adverse effect database maintained by the FDA, and burns have been found to be the most prevalent kind of adverse incident detected by MRI. **(Delfino et al.,2019).** The main causes of burns from MRI scanning are materials that are electrically conductive and enter the scanner, contact with RF coils directly, proximity burns from touching the bore of the scanner, and electrical loops created by the patient's body **(U.S Food & Drug Administration.,2016).**

In order to prevent burns, MRI technician should be aware of the causes of burns and follow recommended practices, which include changing the patient out of street clothes, using pads to prevent skin-to-skin and skin-to-bore contact, ensuring that the patient has no leads or monitors come into contact with the patient's skin, keeping legs and arms straight, and placing a heat sink over any tattoos inside the RF coil **Mittendorff et al.,2021).**

Concerns about safety relating to gradient magnetic fields

Both the patient and any caregivers if stayed in the scanning chamber will subjected to gradient magnetic fields during the MRI performation. Early accounts of the ensuing tinnitus and hearing loss have identified the related acoustic noise as a particular MRI hazard. When the acoustic threshold exposure limits are higher than 99dB, the IEC mandates the use of hearing protection. **(New Zealand College and Royal Australian of Radiologists.,2017).** Since most MRI machines will go over this threshold, everyone who stays in the MRI scanning chamber during an examination must wear hearing protection and use it correctly. In recent years, vendors have recommended using a combination of headphones and earplugs because properly fitting earplugs only provide about 20dB attenuation **(Delfino et al.,2019)**.

The MRI technician must be proficient in fitting earplugs and ensure that the patient follows through on this. Additionally, they have to make sure that anyone staying in the scanning chamber for the examination has access to and is wearing the proper hearing protection. The MRI technician must identify the risk factors for PNS and, if required, take preventative action to lessen the patient's discomfort **(Westbrook and Talbot.,2018).**

The layout of the MRI facility, the number of patients scanned during a shift, the specific tasks performed, individual behavior, and the degree of standardization of the procedures are some examples of the other factors that affect exposure in addition to the specific activity performed. Relatively large variability in exposure can be highlighted between different worker categories as well as among workers having similar job tasks or performing the same job on different days **(Batistatou et al.,2016).**

Because of this variability, it is not possible to directly compare the findings of various studies that were conducted using various assessment techniques. Therefore, in order to better characterize the exposure patterns and pinpoint the variables influencing such exposure variability, the EMF exposure assessment in a given MRI plant should always be linked to an examination of the particular tasks and procedures used, for instance, utilizing data from observational studies.

In order to to evaluate the safety of of MRIs for both patients and workers, as well as to assess how each field component interacts with implanted medical devices, mathematical modeling has emerged as a crucial tool **(Kabil et al.,2016).** This is one of the primary concerns regarding MRI safety for both the general public and workers, for which the necessary safety precautions and measures are needed. The numerical approaches capitalize on the availability of increasingly sophisticated numerical anatomical human models, which accurately characterize the dielectric properties of various tissues in addition, the recent rapid development of new numerical algorithms combined with relatively inexpensive powerful computational resources (e.g., graphic processing units). **(Bottauscio et al.,2015).**

The exposure to Gradient MFs and RF fields was the subject of only a few numbers of papers that focused on electromagnetic computational methods. This is primarily because personnel are only exposed to RF field components in very specific circumstances, such as during MR-guided interventional procedures or for MR scans involving children and neonates. However, it is anticipated that these circumstances will arise more frequently as MRI usage increases. Consequently, more research should be done to understand how bodies interact with RF and gradient magnetic fields in typical occupational exposure scenarios.

Conclusion

The human body and the magnetic fields used in an MRI examination have intricate interactions, but these interactions are becoming more and more significant for both the safety of present MRI procedures in addition, the development of new techniques and technologies.

The potential for electromagnetic field exposure (EMFs) of various frequency ranges, with varying temporal variations and field strengths, should be fully disclosed to MRI workers. Additionally, the outcomes of the risk assessment, which include applicable regulations, exposure levels measured or calculated, and mitigation strategies, should be communicated to them. Workers also need to be trained in handling potential workplace risks, such as the potential for fleeting symptoms and sensations, as well as how to recognize and report negative effects of exposure.

The risk assessment process for employees exposed to magnetic and electromagnetic fields when utilizing magnetic resonance imaging (MRI) environments still requires a great deal of work. To enable comparison of assessment results across scenarios where various working procedures are employed, accurate standardization of the procedures for both monitoring and numerical studies should be established. Different risk assessment methodologies can yield complementary information that serves as the foundation for upcoming epidemiological research.

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