SJ Medical Imaging and Radiology Africa
Vol. 1 No. 9 (2024): September 2024 Issue
https://doi.org/10.51168/3by79k65
Original Article

MAGNETIC RESONANCE IMAGING IN UGANDA; THE ROLE OF AN MRI PHYSICIST.

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Abstract
Magnetic Resonance Imaging (MRI) is crucial in contemporary healthcare, underscoring its non-invasive nature and broad applications. One of the essential professionals involved in MRI is an MRI Physicist. MRI Physicists are responsible for ensuring optimal system performance, safety, and quality, encompassing site planning, quality assurance, and patient safety. Noninvolvement of these professionals results in difficulty in addressing system malfunctions, image quality, daily safe operations, and choosing safe technical parameters.
This calls for comprehensive/collaborative interventions, including regulatory expansions, policy updates, and increased awareness of these professionals. Collaboration among government agencies, healthcare facilities, and private entities is crucial to overcoming the barriers and ensuring the provision of essential tools and equipment for MRI Physicists.
Addressing these issues is a pathway to improving accessibility, quality, and safety in MRI services, ultimately contributing to enhanced healthcare outcomes for the Ugandan population. Therefore, this paper aims to emphasize the pivotal role of an MRI Physicist and to raise awareness regarding the need to involve and employ Medical Physicists in the field of MRI in Uganda.

Key points
- MRI Physicists are key in ensuring optimal MRI system performance, safety, and quality of patient care.
- Despite the growing need for MRI physicists, there is less involvement of MRI physicists in Uganda.
- There are no policies that encourage the involvement of MRI Physicists in MRI clinical practice.
- The high cost of quality control (QC) equipment is a barrier to employing MRI physicists.
- There is a need for refresher training and fellowships to enhance MRI physicists' proficiency.

Keywords: *Magnetic Resonance Imaging, MRI Physicist, Medical Physicist, Uganda*
Submitted: *2024-07-08* ***Accepted:*** *2024-08-28*
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Background
Magnetic Resonance Imaging (MRI) is a non-invasive imaging technique with excellent soft tissue contrast that has applications in both physiological and functional assessments, including its use in radiotherapy treatment planning [1]. It has the advantage of non-exposure to ionizing radiation. MRI relies on a potent magnetic field, rapidly changing magnetic gradients, radiofrequency pulse waves, and advanced computing to produce detailed anatomical images. However, the high cost of MRI machines, exceeding $1.5 million, renders them inaccessible to approximately 70% of the global population [2-5]. MRI stands as a significant milestone in contemporary science and technology, evolving into an indispensable tool in brain science. Its applications range from diagnostic purposes to targeted imaging for identifying objectives, planning treatments, monitoring treatment progress, and adjusting strategies as needed [1]. The technology behind MRI is the result of collaborative efforts from researchers in diverse scientific fields, including mathematics, physics, information science, and electronics [6]. Despite its transformative impact, MRI is not devoid of risks, for example, any problem related to image quality can result in misdiagnosis. It's only a Physicist with technical knowledge to address such challenges. With advancing technology and growing clinical demands, there is a corresponding need for increased training of healthcare professionals in MRI safety to safeguard patients from potential risks associated with MRI procedures [2].
Professionals involved in MRI operations include Radiologists, MRI Technologists, Biomedical Engineers, Medical Physicists (MPs) particularly MRI Physicists, IT experts, and Computer Science technologists, among others. The function of an MRI physicist is not widely recognized in Uganda. The consideration of hiring an in-house clinical MRI physicist is often contemplated, especially when the equipment appears to be functioning

smoothly. However, the importance of an MRI physicist goes beyond the visible functioning of the machine, playing a crucial role in observing and addressing technical and safety aspects that may not be apparent to others.

Role of MRI Physicists.

MRI is highly intricate and demands specific considerations in site planning and installation due to factors such as magnetic and radiofrequency (RF) field shielding, information system channels, and cryogen venting. The expertise of the MRI physicist is crucial in this process. They collaborate with manufacturers, constructors, and users to ensure cost-effective purchasing and effective site planning [7].

Quality Assurance (QA) for MRI differs significantly from other modalities due to distinct mechanisms for image formation. Routine QA tests may not identify all MRI issues, emphasizing the need for specialized expertise. MRI Physicists possess comprehensive knowledge of MRI technology, including diverse systems and imaging software. They develop and implement quality control checks, interpret MRI test results, and understand system limitations. An MRI Physicist is adept at calibration processes, algorithm limitations, first-line troubleshooting, and maintenance, contributing to clinical operation efficiency by addressing system malfunctions[7-9].

Various factors, such as patient motion and, the presence of metals, among others, can impact MRI image quality. MRI Physicists play a crucial role in optimizing MRI images for accurate diagnosis and treatment planning. MRI Physicists analyze MRI images to offer additional information for image quality, thus enhancing diagnosis, treatment planning, and disease management. Additionally, they provide training to MRI technicians on qualitative imaging techniques and pulse sequence compatibility to ensure proper imaging procedures[1, 9]. They provide safety training, develop safety policies and procedures, oversee daily safe operations, and support MRI technologists in assessing the safety of patient implants, often taking on this responsibility themselves[7, 9].

They actively contribute to the care of patients with MR conditional devices or implants. They conduct risk assessments, choose safe technical parameters and equipment, adjust imaging protocols as necessary, and supervise the entire imaging procedure. This expertise is indispensable for patients with such devices, ensuring they can undergo medically necessary MRI exams or procedures safely[10]

The pivotal responsibility of an MRI Physicist is therefore to ensure optimal performance of equipment, achieving the highest image quality, and mitigating potential risks to both patients and staff by the high static magnetic field inherent in MRI technology. This multifaceted role involves the comprehensive management of MRI systems to uphold safety standards, optimize imaging outcomes, and safeguard the well-being of individuals involved in the MRI process.

MRI Physicists in Uganda

With a population of 47 million people[11], Uganda has a strikingly low ratio of MRI availability, standing at 1 MRI per 4.7 million people. This stark inadequacy can be attributed to the formidable financial barriers associated with the acquisition and maintenance of MRI equipment, placing it beyond the means of the majority of healthcare facilities in the country. Further complicating matters is the lack of MRI Physicists within the facilities where these MRI units are located in Uganda. Currently, there is neither employment nor consultation with MRI Physicists, creating a significant void in the expertise needed for the safe and effective operation of these critical medical devices. The pressing need to address this deficiency is evident to improve the accessibility, quality, and safety of MRI services in the country.

Presently, Uganda boasts a contingent of 12 MPs, with 7 (58%) actively engaged in clinical roles within the realm of radiotherapy. Another 3 (25%) contribute to academic pursuits, specifically in the field of radiology across various universities, while the remaining 2 (17%) are clinically involved in diagnostic radiology. Even though MRI is predominantly utilized as a diagnostic tool in Uganda, none of the five MPs working in radiology settings are presently engaged in any aspects related to MRI.

It is noteworthy that MRI also plays a crucial role in image-guided treatment procedures in radiotherapy, but as of now, Uganda has not acquired any MRI specifically designed for these particular therapeutic uses. Consequently, the MPs working in radiotherapy are currently not utilized in the realm of MRI technology within this department. The consequences for not involving MRI Physicists in Uganda have occurred but none has been documented. There have been several MRI incidents that have occurred worldwide but they have been severely underreported [12]. Some of these incidents include; burns, projectiles, misdiagnosis due to poor image quality, machine malfunctions, etc. A significant challenge lies in the shortage of MP personnel with the expertise and access to MRI facilities. Many of the reported system breakdowns and prolonged downtimes could have been prevented through regular quality control (QC) and maintenance checks, if MRI physicists were involved or if these tasks were overseen by qualified MPs [13]

The involvement of MPs in MRI-related activities is not only a challenge faced by Uganda but is prevalent across the entire African continent. As of a 2020 survey, there were about 1041 MPs in Africa [14] and according to a survey conducted in 2022 in only 32 out of 54 African countries, there were 1108 MRI equipment, and just a mere 2.9% of MPs in Africa are currently engaged in MRI work. These statistics portray a dilemma for the continent's healthcare landscape [15]. This underscores the urgent need for Uganda and the entire African region to acknowledge the crucial role of MPs and appreciate their

contributions in various facets of Radiology. This call emphasizes the importance of recognizing and leveraging the expertise of MPs to enhance healthcare services, particularly in the context of MRI technology.

Ministry of Health (MoH) Policy and Guidelines on the MRI in Uganda.

Under the Health Infrastructure Division in the National Medical Equipment Policy, there are two major sections with the mandate to formulate policies and guidelines on medical equipment and manage medical equipment among others. These sections are; the Civil Engineering Section and Electrical and Mechanical Engineering Section. Civil Engineering Section has the responsibility of supervising pre-installation works and ensuring that fixed medical equipment is installed correctly, whereas the Electrical and Mechanical Engineering Section is responsible for preparing specifications and ensuring that the ministry procures equipment that conforms to national and international standards and that the procured equipment is appropriate and acceptable by the users[16]. Some of these responsibilities are so technical and need the inclusiveness of a specialized professional like an MP who has all the technical knowledge on the science aspects of this equipment. The National Medical Equipment Policy does not in any way involve MPs which indicates poor acknowledgment of these professionals[16].

Perspectives towards the roles of MPs in MRI

The responsibilities outlined above are viewed from the perspective of MPs, with some being specified in guidelines and other relevant documents [17-21]. During the regular QA/QC activities for other modalities within centers that have MRI, we asked Radiographers, Radiologists, and Biomedical Engineers if they knew the roles of MPs or MRI physicists.

Out of 17 professionals we engaged, 5 were radiologists and 12 were radiographers from available 12 MRI facilities in Uganda. A total of 4 questions were structured and self-administered by the participants. 82% of the participants believe that MRI physicists have roles in most MRI aspects. From their responses we realized that none of their facilities have employed an MRI physicist, indicating that all facilities have not utilized this specialized role. 65% of the participants stated that medical physicists exclusively handle ionizing radiation which was proven to have adverse effects on humans. More than half of those asked, 53% cited that the primary reason for not employing MRI physicists is the costly nature of QC equipment they use in their work. Additionally, 47% of them indicated that they do not know why their facilities do not employ MRI physicists.

The responses from the professionals engaged show a wide gap in the awareness of who an MRI Physicist is and the necessity of involving such a professional in MRI aspects.

Implications for not involving MRI Physicists in MRI Practice

The shortage of MRI physicists can create safety risks and challenges for other MRI specialists. Their absence complicates coordination with manufacturers and site constructors during purchasing and installation, affecting cost-effectiveness and site planning. These processes need a deep understanding of MRI physics hence the need for MRI Physicists[22].

MRI is a complex system with many limitations, making it hard to identify issues without extensive physics knowledge. Without an MRI physicist, routine QC, troubleshooting, and maintenance become challenging, leaving in-service engineers without needed support, which directly negatively impacts clinical operations[7].

The absence of MRI physicists compromises the safety of equipment, patients, staff, and the public. Without them, there is no expert to provide safety training, risk assessment, policy development, or oversight of daily safe operations and appropriate imaging parameters. In Nigeria, many facilities lack the necessary personnel with the necessary training to conduct tests effectively[23]. This in part is attributed to the lack of MRI Physicists with the necessary knowledge to give such training.

Image quality is crucial for accurate diagnosis by radiologists. Without MRI physicists, there is no expert to optimize and analyze MRI images, leading to potential diagnostic errors and negatively affecting patient treatment outcomes[23].

Conclusion

Despite the MRI's transformative impact, challenges such as the high cost of equipment and the need for increased training in MRI safety persist. The roles of MRI Physicists are crucial in ensuring the performance, safety, and quality of MRI systems, encompassing site planning, quality assurance, optimization of imaging outcomes, and patient safety.

In Uganda, the lack of MRI units and the absence of MRI Physicists highlight a critical need for action. The insufficient recognition and employment of MPs in MRI and, the absence of regulatory framework and policies regarding MRI, create challenges for MRI services' accessibility, quality, and safety. Addressing these issues is seen as a pathway to improving accessibility, quality, and safety in MRI services, ultimately contributing to enhanced healthcare outcomes for the Ugandan population.

Recommendations

1. Involve MPs in MRI practice by developing policies and guidelines for the safe use of MRI equipment and emphasizing the roles of MRI Physicists. MRI Unforeseen breakdowns and prolonged downtimes could be prevented through regular quality control and maintenance checks conducted or supervised by qualified MPs.

2. The AEC ought to broaden its regulatory scope to include MRI, reassess guidelines and policies related to MRI operations, and mandate facilities to appoint MRI Physicists as a prerequisite for licensing.
3. The MoH of Uganda should update its policies and guidelines regarding the utilization of MRI. An improvement in acknowledgment of MPs is necessary by the MoH and the Public Service Commission.
4. MoH and AEC should make sure that all government facilities possessing MRI equipment have an in-house MP, and are adequately furnished with the necessary tools and equipment for MRI Physicists to perform their roles.
5. Thorough training of MPs/MRI Physicists through fellowships is essential to ensure their proficiency in the field of MRI.

Acknowledgments
We acknowledge Ernest Cook Ultrasound Research and Education Institute which is the primary affiliation of most of the co-authors and the corresponding author.

Abbreviations
IT – Information Technology
MoH – Ministry of Health
MP – Medical Physics
MRI – Magnetic Resonance Imaging
QA/QC – Quality Assurance/ Quality Control
RF – Radiofrequency

Ethics approval and consent to participate
Not applicable.

Consent for publication
Not applicable.

Availability of data and material
Not applicable

Conflict of interests
The authors declare no conflict of interest.

Funding
No funding

Authors' contributions
AM conceptualized the idea, wrote and reviewed the paper, ON did a literature search, wrote and reviewed the paper, RM did a literature search, and reviewed the paper after writing. DS did a literature search, and IK and MK wrote and reviewed the paper after writing. RN, GE, and RN reviewed and approved the paper, and RM and VN guided on the best way the paper can be written, read, and approved the paper.

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