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Review Article

The Role of Diagnostic Medical Physics in Medicine: An Overview

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ABSTRACT

This paper provides a thorough overview of the vital role diagnostic medical physicists play in the medical field, focusing on diagnostic radiology. This paper investigates the relationship between medical practices and physics highlights the fundamental role that physics plays in understanding the cosmos and outlines the numerous applications of physics, including medical physics. The paper's main focus is on the many applications of medical physics, especially in diagnostic imaging, which includes nuclear medicine, radiation therapy, MRIs, CT scans, X-rays, and ultrasound. There is an in-depth discussion of specialized fields such as radiation protection, nuclear medicine, diagnostic radiology, and radiotherapy physics. The authors stress the importance of medical physics in the prevention, diagnosis, and treatment of disease, providing new technologies such as Positron-Emission Tomography (PET) that provide insights into structural and biological changes. The article outlines the duties of diagnostic medical physicists, including quality assurance and control as well as equipment evaluation and compliance. The critical role that radiation treatment programs play in preserving patient, staff and public safety is emphasized. The authors discuss how modern radiation therapy is becoming more complex and how important strong protocols are for patient safety. The important role that medical physicists play in guaranteeing the highest standards of medical care is highlighted, along with the European Union's efforts to standardize radiotherapy treatments among its member states. It is recommended that the health care system needs medical physicists to ensure the safety and protection of both patients and medical/ x-ray staff.

Keywords: Diagnostic, Medical Physics, Ultrasonic, Quality control, Equipment, Medical physicist

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INTRODUCTION

Physics, at its essence, delves into the examination of all phenomena existing within the physical realm, spanning from the tiniest subatomic particles to the vast expanses of the universe. Physicists strive to formulate conceptual and mathematical contexts that elucidate interactions among entities, irrespective of their size, contributing to a deeper comprehension of the universe's workings across various scales. Acquiring a knowledge in Physics provides an inclusive overview to established models in classical mechanics, thermodynamics, electromagnetism, and quantum mechanics, alongside the advances of computational and experimental skills essential for their application. There are different branches of Physics which include the followings: Astrophysics, Biophysics, Chemical Physics, Engineering Physics and Geophysics, Medical Physics and many other fields.

Medical physics: Medical Physics involves employing principles of physics in the field of medicine, utilizing these concepts and techniques for disease preclusion, diagnosis, and treatment. It plays a decisive role in medical practice, biomedical research, and the optimization of various health-related activities. Medical Physics encompasses specialized areas such as Radiotherapy physics, Diagnostic Radiology physics, Nuclear Medicine Physics, and Radiation Protection. Diagnostic Radiology and Nuclear Medicine are commonly combined under the umbrella termed "Diagnostic Imaging," although Nuclear Medicine also has therapeutic applications associated to Radiation Therapy (IAEA, 2023).

Medical Physics is a specialized field within physics that applies its principles and approaches to the detection, management, and treatment of human diseases. It is closely linked with medical electronics, bioengineering, and health physics. Key areas of emphasis include cancer treatment using ionizing radiation (radiation oncology), imaging through x-rays, ultrasound, and magnetic resonance (diagnostic radiology), as well as imaging and treatment involving radioisotopes (nuclear medicine). Furthermore, it addresses the shield of workers in radiation-related industries (health physics). Other research areas involve electroencephalography, electrocardiography, thermography, hyperthermia, optical imaging, and RF and laser surgery (Frenso, 2021).

Objectives of this Review Paper

The main aim of this study was to gather fundamental descriptive data concerning medical physicists engaged in diagnostic radiological related tasks, their specific activities within diagnostics, and ensuring the safety of personnel and patients.

Purpose of this Review

The purpose of reviewing diagnostic Medical Physics in Medicine is to comprehensively examine the role and significance of Medical Physicists in the field of diagnostics. This includes examining their contributions to various diagnostic imaging modalities, such as X-rays, CT scans, MRI, ultrasound, and nuclear medicine. Furthermore, the review aims to explore the responsibilities of medical physicists in ensuring the safety and efficacy of diagnostic procedures, evaluating equipment, complying with regulatory standards, and protecting the health of both patients and healthcare personnel.

Inclusion and Exclusion criteria for the selection of this Literature Review

Inclusion criteria for selecting the review study of diagnostic medical physics in medicine" may include:

Relevance: The topic should be directly linked to the field of medical physics and its applications in diagnostic medicine.

Scope*:* The review should encompass a wide range of diagnostic imaging modalities, including but not limited to X-rays, CT scans, MRI, ultrasound, and nuclear medicine.

Importance*:* The topic should address the significant role of medical physicists in ensuring the accuracy, safety, and effectiveness of diagnostic procedures.

Timeliness: Preference may be given to recent studies and developments in the field to ensure the review reflects current trends and advancements.

Accessibility: The literature and resources related to the topic should be readily available and accessible for review and analysis.

Exclusion criteria

Irrelevance: Topics unrelated to diagnostic medical physics or not directly contributing to the understanding of its role in medicine may be excluded.

Narrow scope*:* Studies focusing solely on specific aspects of medical physics or diagnostic imaging modalities without considering their broader implications may be excluded.

Outdated information: Studies with outdated or obsolete information that does not reflect current practices and technologies may be excluded.

Limited availability: Resources that are difficult to access or obtain may be excluded to ensure the feasibility of conducting a comprehensive review.

Lack of credibility: Sources lacking credibility or peer-reviewed research may be excluded to maintain the quality and reliability of the review.

Literature review

Vetter, (2004) conducted a research on Medical Physics and its role in medicine. The study found that Medical Physics specialists play a crucial role in protecting members of the public and patients from unwanted radiation exposure. Additionally, the researcher highlighted the significant contribution of medical physics to healthcare.

Cypel & Sunshine, (2004) In the study “Diagnostic Medical Physicists and their clinical activities”. Offers insights into the clinical diagnostic radiology-related tasks performed by Medical Physicists, which constitute a significant aspect of medical imaging work. Jeraj, (2009) Conducted a research on "Future of Physics in Medicine and Biology" the researcher also highlighted the role of Medical physics in substantial transformations, especially given the rapid advancements in biological sciences, the emergence of more intricate research necessitating interdisciplinary collaboration, and a growing demand for translational research.

Gallo & Veronese,(2022) : the researcher make this research on "Applications of Medical Physics" and found that Medical Physics has great applications on the field of medicine and recommended that there is need for more research on this field.

Diagnostic Imaging: Encompasses a diverse set of methods and tools employed to study the internal structures of the body, assisting healthcare professionals in detecting injuries and diseases for specific diagnosis and treatment planning. These techniques range from straightforward X-rays for detecting fractures to intricate procedures targeting organs like the brain, heart, or lungs.

Typically, diagnostic imaging procedures are painless and do not require invasive measures. It's important to note that, depending on the specific test, individuals may be exposed to minimal amounts of radiation (VMP, 2024).

The Role of Medical Physics in Medicine

Nuclear Medicine employs radiopharmaceuticals for the diagnosis and treatment of diseases, offering a distinctive approach by providing insights into both structural and biological changes. This form of imaging finds applications in various medical fields, including neurology, cardiology, and oncology. According to the Society of Nuclear Medicine, approximately 16 million nuclear medicine imaging and therapeutic procedures are conducted yearly in the United States.

A notable imaging modality within nuclear medicine is Positron-Emission Tomography (PET), which has proven instrumental in identifying and understanding diseases such as cancer, heart ailments, and neurological disorders like Parkinson's and Alzheimer's disease. The applications of physics in the field of medicine have been expansively exploited, resulting in the development of several well-known technologies. Some famous applications include:

X-Rays and CT Scans: Radiography comprises the use of a focused X-ray beam to produce images on film by passing through the targeted area. Moreover, CT scans use repetitive X-ray scans to produce high-resolution, three-dimensional or quadruple computed tomography (CT) images, enabling the investigation of dynamic processes.

Computer Tomography (CT) Perfusion: CT scans not only provide anatomical images but can also offer comprehensive information on tissue perfusion via perfusion scans. By introducing a contrast agent and showing repeated imaging at short intervals, 4-D images are generated, facilitating the analysis of hemodynamic parameters such as blood flow and volume.

Magnetic Resonance Imaging (MRI): This non-invasive imaging technique uses static magnetic fields, magnetic gradients, and computer-generated radio waves to produce high-quality 3-D images. MRI procedures cerebral blood flow and analyzes soft tissue structures by exploiting differences in tissue relaxation times.

Ultrasound: Employing high-frequency sound waves, ultrasound creates non-invasive images of various tissues and organs by measuring reflections caused by differences in mechanical properties. Ultrasound is advantageous for its efficiency, cost-effectiveness, safety, and ease of use, and it is also used therapeutically for measures like tissue removal and targeted injections.

Nuclear Medicine: This area involves the use of radioactive materials to observe physiological processes and deliver targeted therapeutic doses. Radioactive material is introduced into the body, absorbed by the organ or tissue under investigation, and detected by a gamma camera to analyze organ function. Nuclear medicine is particularly useful for early cancer recognition.

Radiation Therapy: This treatment method carries ionizing radiation to eradicate cancer cells or tumors inside the body. Medical imaging is vital during the complete radiation therapy process to safeguard precise and safe delivery of radiation, as well as to assess any anatomical variations made by the treatment (VNMEC, 2019).

Equipment Evaluation and Compliance

A key responsibility of a diagnostic medical physicist is to guarantee the secure functioning of devices producing radiation and diagnostic radiation sensors. This includes tasks such as framing specifications for imaging equipment, evaluating the radiation released by equipment before its clinical deployment, and confirming compliance with regulatory and accreditation standards. Also, the role covers evaluating the accuracy and performance of all software, algorithms, data, and computer systems associated to radiation-producing equipment (VMP, 2024).

The major concerns of experimental medical physicists in diagnostic radiology are image quality, radiation dose, and radiation safety. Consequently, there is a focused on scanner features which directly or indirectly effect one of these concerns. Importance is placed on recital characteristics that can be computed by a medical physicist by means of widely obtainable tools and devices. Testing methods is one of suitable methods. Some procedures may require modification to address unique design features of a given scanner. The skilled physicist will find that different tests can be combined to make best use of limited scanner access time (AAPM, 1993).

Radiation shielding is a paramount aspect in certifying the safety of patients, staff, and the public during the implementation of a radiation treatment program. In radiotherapy, the sources of radiation pose potential dangers to those within or near the facility if not managed properly. Radiation safety contains two critical elements: a facility designed for intrinsic safety with adequate shielding, and additional physical safety and security measures to avoid unintended exposure. Comprehensive guidelines and measures are integral for maintaining low radiation exposure for staff, considering social and economic factors. Regulatory authorities firmly control the use of ionizing radiation for any purpose, including therapy, in most jurisdictions. When planning a radiotherapy facility or making changes to an existing one, consultation with the national regulatory authority is the preliminary step. Regulations stipulate minimum design criteria, annual and instantaneous dose equivalent rates, required interlocks, and other safety measures. The architectural design, predominantly the shielding design, is intricate and pivotal. In this phase, partnership with a clinically qualified medical physicist, along with the radiation oncology team, is important. Influences such as the number of daily treatments and the variety of radiotherapy techniques presented should be considered. If progressive treatment techniques are planned, referencing recent peer-reviewed literature during facility design is advisable. Construction activities can only begin once regulatory approval is obtained (IAEA, 2023).

Quality Control (QC) and Quality Assurance (QA)

The implication of Quality Control (QC) and Assurance (QA) is rising due to the increasing intricacy of present-day radiotherapy and the raised radiation doses. Prioritizing patient safety, the implementation of robust and consistent protocols stands out as an effective measure. The European Union has taken stages to regulate medical procedures and training across its member nations, aiming not only to improve quality and safety but also to guarantee uniform quality standards for radiotherapy treatments across Europe. Accordingly, these initiatives are driving a trend toward standardization in both planning and delivery of radiotherapy. The responsibility of QA & QC predominantly falls on the medical physics department, where a designated quality officer is often appointed in larger hospitals. This quality officer may be a physicist, oncologist, or a specialist such as a public health expert, and they could be an in-house member or an external consultant. In contemporary contexts, the concept of "quality" has broadened, but the fundamental objective remains consistent: to provide the highest standard of medical care (Malicki, 2015).

Protection of Patient

Medical physicists have an additional duty relating to the radiation protection of patients. Although measures have long been in place to safeguard staff, ensuring patient protection against unintended and accidental exposure is correspondingly crucial. Although radiotherapy is generally safe, public concerns about radiation effects magnify even minor incidents with minimal injuries in the media. To address these concerns, the European Union (EU) has reinforced the existing legal framework and introduced a new directive, the Basic Safety Standards (BSS), directing all EU member countries to establish regulations preventing unintended patient exposure and assessing associated risks. The BSS explicitly emphasizes the role of medical physicists in these standards, stressing their active involvement in the process. Medical physicists are deemed indispensable for averting and addressing situations that could risk the well-being of both staff and patients. Remarkably, in some countries, regulations do not stipulate that the Radiation Protection Officer (RPO) must be a medical physicist or even hold a university degree (Malicki, 2015).

The Need for Physicists in Diagnostic Radiology

Medical physicists play a crucial role in the contemporary healthcare landscape, particularly in the realm of diagnostic radiology, where they are specialized and commonly known as "Diagnostic Radiology Medical Physicists." Collaborating within the Diagnostic Radiology Department alongside radiologists and diagnostic radiographers, they form an interdisciplinary team dedicated to ensuring safe and effective diagnostic procedures through various medical imaging modalities.

These professionals significantly contribute to the secure and efficient diagnosis of patients by leveraging their expertise in physics, specifically in imaging science, encompassing image formation, characterization, radiation physics, and its interaction with human tissue. Their profound understanding of the intricate technologies inherent in modern imaging equipment is pivotal for the successful implementation of medical imaging procedures. The responsibilities of diagnostic radiology medical physicists span dosimetry, image quality, optimization, research, teaching, radiation safety, quality assurance, and equipment management (International Atomic Energy Agency, 2010).

Education and Training

Medical physicists possess the expertise to educate both medical physics and diagnostic radiology staff on the impacts of radiation. Additionally, they play a collaborative role in the procurement of equipment systems. Furthermore, these professionals are responsible for overseeing the administration and acquisition of equipment (Caruana *et al*., 2008).

Figure 1: imaging in medical physics (source: Duke University, 2024)

Figure 2: Clinical Imaging with Physics student (source**:** Duke University, 2024)

RESULT

This paper provides a comprehensive overview of the pivotal role played by diagnostic medical physicists in the field of medicine, with a particular emphasis on diagnostic radiology. These specialized professionals, known as "Diagnostic Radiology Medical Physicists," contribute pointedly to the safe and effective diagnosis of patients through their expertise in physics, encompassing imaging science, radiation physics, and the intricacies of modern imaging equipment. Their multifaceted responsibilities, ranging from dosimetry and image quality to research, teaching, and equipment management, underscore their indispensable role in ensuring the success of medical imaging procedures.

The study also highlights the broader contributions made by medical physicists to radiation therapy, nuclear medicine, and diagnostic imaging, among other medical specialties. Key uses of physics in medical technology are covered in the discussion, including nuclear medicine, radiation therapy, MRIs, CT scans, X-rays, and ultrasound. The significance of quality control, compliance, and equipment evaluation in the field of diagnostic radiology is emphasized, highlighting the vital role those diagnostic medical physicists play in ensuring the safe operation of radiation-producing devices. It also acknowledges the educational dimension and the role those medical physicists play in training personnel in diagnostic radiology and medical physics, as well as their joint involvement in the acquisition and management of equipment systems.

CONCLUSION

In conclusion, the paper highlights how vital diagnostic medical physicists are to modern healthcare, stressing their critical roles in patient safety, precise diagnosis, and technological advancement. The closing remarks reaffirm the crucial part these experts play in the complex nexus of physics and medicine, greatly enhancing the caliber and security of medical procedures.

Recommendations

1. Integrated Training Programs: Provide thorough and well-rounded educational initiatives that help close the knowledge gap between diagnostic radiology and medical physics. The interdisciplinary aspect of the field should be emphasized in these programs, encouraging cooperation between radiologists, medical physicists, and other healthcare specialists.

2. Continued Professional Development: Provide systems for medical physicists' ongoing professional development. This includes frequent conferences, workshops, and training sessions to keep them informed about the most recent developments in radiation safety procedures, regulatory standards, and diagnostic imaging technology.
3. Standardization of Protocols: Promote the standardization of diagnostic radiology practices and procedures. This raises the bar for patient care overall by guaranteeing uniformity in radiation safety, quality control procedures, and imaging practices among healthcare facilities.

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