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A Review of the Activities of Medical Physics in Biomedical Research

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Abstract

Many modalities are now commonly adopted in Biomedical Research and services more especially now that the whole world is looking for multidisciplinary approach in tackling some of the emerging diseases that are affecting humans, animals and their environment. Medical Physics remains one of the active disciplines in the development of Biomedical research over the years but little is known about the roles and contributions of Medical Physicists in Biomedical Research especially in Nigeria where little or no attention is given to the profession, hence the essence of this paper detailing the various roles and contributions of Medical Physics in Biomedical Research.

Keywords: Medical physics; Biomedical research; Radiation; Telemedical physics

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Introduction

Medical Physics is the application of Physics principles to the diagnosis, prevention, and control of illness, disease and disability [1]. Also it is a branch of Physics that is associated with the practice of medicine. It deals mainly, but not exclusively, with the use of ionizing radiation in diagnosis and treatment of human disease. Medical Physicists contribute to maintaining and improving quality, safety and cost effectiveness of healthcare services through patient-oriented activities requiring expert action, involvement or advice regarding the specification, selection, acceptance, and testing, commissioning, quality assurance/ control and optimized clinical use of medical radiological devices [2]. Medical Physics has the responsibility of developing new devices and procedure that solve medical and other health related problems by combining their recent discoveries in Engineering, Biology, Nanotechnology and Medicine to improve human health through multidisciplinary activities that bring together the principles of physics and concepts to medicine and biomedical research [3]. The scientific issues of concern in relation to Medical Physics and associated Biomedical Research are complex and may be confusing for people who are not professionally involved with them, hence the need to bring out the roles and contributions of Medical physics to biomedical Research. This review focuses on the Roles of Medical Physicists in Clinical trials, Veterinary research, Telemedical Physics, Radiation Physics, ionization, and the future of Medical Physics in Biomedical research. The practice of Medical Physics includes the use of principles and accepted protocols of physics to assure the correct quality, quantity, and placement of radiation during the performance of a radiological procedure [4]. Medical physics has a long standing history; though it is very difficult to determine the origins of some historical events. Some are of the belief that Medical Physics has been in existence between 2500-3000BCE when people were using fire to treat some diseases [5]. The use of the term Medical Physics was first coined in the year 1778 in Paris. The term was introduced by the general secretary of the societe royale de medicine [6]. The discovery of X-rays in 1895 by Wilhelm

Rontgen brought the concept of Medical Physics to the public domain and marked the beginning of Radiation Medical Physics [7]. There are some historical connections between Physics and medicine as recorded from ancient civilization [8]. A record from a famous Egyptian mentioned the treatment of breast abscesses by cauterization, and Hippocrates was able to demonstrate how skin temperature distributions could be mapped by using clay. Also from literature, another famous Greek physician, Herophilus, used a water clock to measure the pulse rate, thus applying the Physics of time metrology to clinical assessment [9]. The discovery of microscope in the early 17th century and the pioneering work of Santorio Sanctorius between (1561-1536) on biomedical measurement of temperature, pulse rate and body mass are clear examples of the development of medical Physics [10]. Sanctorious developed the theory of insensible perspiration which accounts for the difference between material added and material excreted. This theory helps physiologists to have more understanding of the value of physiological measurements [11]. Medical physics gained better grand recognition in the 19th century, with thorough investigation of mechanical, thermal, electrical, optical and acoustical processes in the body [8]. The contributions of the likes of Thomas Young (1773-1829), a great Scientist known for his work on capillary action, interference and the wave theory of light. He was also very famous for his contribution to the physiology of vision. Hermann Von Helmholtz (1821-1849) invented the ophthalmoscope and he was fondly referred to as the founder of ophthalmology [8]. At that time some of these discoveries and basic researches had little effect on medical practice, but one practical development that had a lasting importance was the invention of the most iconic of medical instruments, the stethoscope by Rene Laennec (1781-1826) [5].

Types of medical physicists

Majorly, there are two categories of Medical Physicists that are both involved in the application of physics to challenges within biomedical environment; they however, work in different settings though their services are complimentary. The first category work in biomedical environment or as consultants to hospitals, the second in academia and industry [12]. Those working in biomedical environment are to ensure the effective, safe, efficient and scientific use of medical devices through the use of their Physics expertise within the biomedical areas [13].

The concept of radiation physics

Recalling the basic knowledge of matter; it is anything that has weight and can occupy space. Observable matter is made up of discrete components known as atoms and molecules. Atoms are divisible into particles such as protons, electrons and neutrons. The other elementary particles are part of the fabric of nature, but they are more elusive and do not directly from stable atoms or molecules. When a particle or group of particles is accelerated, it can reach high energies and travel a large distance in a very short time. In the light of the above, Radiation Physics is simply the collection of elementary particles that have sufficient energy that interrupt their path [14]. Radiation includes both ionizing and non-ionizing radiation such as electromagnetic radiation, particulate radiation, and ultrasound. These modalities, used for diagnostic or therapeutic purposes when prescribed by a properly qualified practitioner, are herein described as radiological procedures.

Ionization radiation-The evolving roles in biomedical research

The use of radioactive trace substances and ionizing radiation is common in biomedical research. Most of the advances in biomedical research in the recent time are as the result of ionization radiation that brought about the integration of computer imaging, development of digital diagnostic techniques and incorporation of computers into the therapeutic dose delivery in high-energy linear accelerator.

One of the uses of ionization radiation in biomedical research is radiation treatment planning. This has undergone tremendous advances in recent years; from development of absolute and relative dosimetry techniques to improved theoretical understanding of basic radiation interactions with human tissues and the introduction of Monte Carlo techniques in the determination of dose distributions resulting from penetration of ionizing radiation [15]. In hospitals, doctors, dentists are not left out in the use of ionizing radiation as they use varieties of nuclear materials and procedures to diagnose, monitor and treat a wide range of assorted metabolic processes and medical conditions in humans. The most common of these medical procedures involve the use of X-rays, a type of radiation that can pass through the skin. When X-rayed, our bones and other structures cast shadows because they are denser than our skin and the shadows can be detected on photographic film.

Telemedical physics a tool for biomedical research

Telemedical physics simply refers to the application of physics principles to the diagnosis, prevention and control of illness at a distance. It is also the performance of medical physics at a distance. The telemedical physics applications are relatively obvious, such as the direct review of radiologic images using remote workstation [16].

There are several uses of telemedical physics which are not so obvious but are however very important in biomedical research. For example, telemedical physics plays major roles in small regional health care facilities that do not has the equipment or staffing resources found in large centers. Also, satellite biomedical research laboratories working in conjunction with major biomedical centers can have real time access to most of the expertise available at a central facility. This is made possible through the use of teleconferencing to facilitate chart rounds, quality assurance conferences and routine meetings resulting in little inconvenience to the participants [16]. Telemedical physics has been in existence in biomedical research long before the advent of computer-based communication had become widespread. Prominent among medical physics practice at a distance over the year is 'remote dosimetry'. The dosimetric

material used in remote dosimetry is called thermoluminescent dosimetry (TLD). This material has the capacity of storing dosimetric information for relatively long period of time and can withstand handling by parcel delivery services. In most remote dosimetry system, the thermoluminescent dosimeters are mailed to the remote site along with instructions to irradiate them to specified doses. The dosimeters are then returned to the service provider where the doses are readout. Several institutions perform fee-for service remote dosimetry, this enables physicists to verify the accuracy of their dosimetry when ion chamber inter comparisons are not feasible. It also provides the capability of an in vivo patient dosimetry in centers that do not have in-house TLD system [16].

The roles of medical physics in clinical trial

Clinical trials according to World Health Organization (WHO) is any research study that prospectively assigns human participants or group of humans to one or more health related interventions to evaluate the effects on health outcomes. (http://www.who.int/ictrp/en).

For any clinical trial to be effective, the health related intervention must be clearly, concisely and precisely defined [17].

The roles of medical physicists in any clinical trial are enormous and these include the following;

i. Development of equipment specifications

ii. Simulation and radiation measurement

iii. They also have the exclusive responsibility of providing evidence of compliance of equipment for radiation therapy treatment, radiation detection with regulatory and accreditation agency's rules and recommendation

iv. Provision of advice to clinicians regarding the appropriateness of diagnostic investigations and the presentation and interpretation of non-standard or novel data.

The technical details of the protocols are of general interest in the clinical trial as they are usually written with a wide range of equipment in mind to maximize the chances of clinics to contribute and increase accrual. Also, there are many clinical trials protocols which require the use of complex technology, have Medical Physicists as Co-Investigators and Co-Authors. Their inputs are essential in defining the technological approaches allowed and specifying exactly what a particular procedure must achieve (http://www.rto.org/)

Medical Physicists are very familiar with risk management because of their involvement in radiation protection. This put them in a better position to provide risk management and advice for clinical trials in particular as it pertains to technological aspects [18]. In all medical settings and specialties, safety is always considered first over cost. Thus the active involvement of Medical Physicists in treatment planning has greatly enhanced the quality and safety of routine procedures. The interaction of ionizing radiation with a body is a complex process that requires a strong understanding of Physics principles and knowledge. Therefore the inclusion of Medical Physicists in the treatment planning is adequately appropriate for efficient delivery [19].

Specific roles of medical physicists in veterinary research

The distinctive roles and responsibilities of Medical Physicists in Veterinary research revolve around the scientific, effective, safe and efficient use of medical devices/equipment [12]. They are involved in the introduction, adaptation and optimization of medical devices and medical device use protocol for individual samples or group of samples [13]. This can further be reviewed under the following:

1. **Technical supervision of equipment operation and maintenance:** Medical Physicists supervise the preventive and corrective maintenance, repair and calibration of diagnostic, therapeutic and measuring equipment and are also responsible for documenting the relevant information. They work in collaboration with service Engineers in developing and maintaining a quality management program for all of the equipment for optimal performance [20].

2. **Calibration and verification of measurement instrument:** Medical Physicists are responsible for the calibration of the Instrument the Veterinarian use. They are also responsible for following recommended standards or code of practice and keeping appropriate calibration records. They have the sole responsibility of developing procedures to determine the stability of the Instrument for Veterinary clinical use [21].

3. **Clinical computing and networking:** They have the knowledge and skills to assist in the Veterinary clinical use of information system. That is, reviewing or processing computer workstations or record and verifying systems and to perform basic computer system management and administrative task.

4. **Record and documentation:** They provide the documentation required and maintain the records of their area of work, providing evidence of compliance of equipment and procedures with the appropriate accreditation agency's recommendation [21].

5. **Research and development:** In Veterinary research, Medical Physicists evaluate new technologies and investigate the adoption of new procedures, assisting in the training of other staff for their implementation. They support the physical and technical aspects of Veterinary research and often have a leading role in Veterinary research team, particularly in centers of high technological complexity. They play an all-important role in Veterinary clinical protocols used in applied research. They carry out research and development in Medical Physics, Instrumentation and monitor current advances in specific areas of research and design project plans with good future plans, experimental methodology and estimate time frame [20].

The role of medical physics in maintaining standards

Leading and managing the upholding of quality standards in the use of Medical Devices -particularly critical examination, acceptance testing, commissioning, constancy testing, calibration and maintenance of medical devices and the accuracy of physical methods used in clinical applications [19]. Going further, it is very important to know the meaning of the above concepts of critical examination, acceptance testing, commissioning, constancy testing and calibration as they relate with roles and functions of Medical physicists.

i. **Critical examination**: This refers to those tests and checks that are carried out to ensure that the safety features and warning devices on a medical device are operating correctly and that the device is safe for use.

ii. **Acceptance testing**: This refers to the tests that are carried out when a new device is delivered to the hospital to ensure that its specifications are the same as those in the contract of sale

iii. **Commissioning**: These are the tests carried out to ensure that the device is ready for clinical use

iv. **Constancy testing**: Those routine tests carried out to ensure that the device specifications do not deteriorate with time

In addition to the above roles of Medical physics in clinical settings they also participate actively in research and health technology assessments involving medical devices [19].

Problems and challenges of medical physics in Nigeria

The inadequate supply of Clinically Qualified Medical Physicists in all specialties of biomedical science is a worldwide problem that is well recognized and it is most severe in the developing nations of the world and Nigeria in particular. The continuous complexity of both diagnostic and treatment equipment coupled with the rising of the expectation of good health care in all parts of the world as well as the implementation of radiation safety standards are contributing to worsen this lack of Clinically Qualified Medical Physicists [22].

Medical Physicists in Nigeria are not Clinically Qualified as the profession is facing challenges in the academia, healthcare sector and the government policies. In the academia, it is a pity that only a few institutions in Nigeria offers Medical physics at undergraduate level (23). Training of Medical physicists in Nigeria is not regulated by any national body, the effect of which is that, universities are free to choose the content of what they offer and allow the market to decide which model is most suitable and appealing. This approach is in complete contrast to medical studies, in which the circular content is regulated by various professional and state bodies. The government policies are in no way favoring the profession as there is a continuous delayed action at the National Assembly on the Medical physics Bill which fully compliment the academic program when it is finally passed into law and diligently implemented [19].

The prospect of medical physics in the clinical environment

The sustainability and the future of Medical physics in the clinical setting is a function of the ability of medical physicists to contributes significantly by transforming scientific advances in the laboratory into clinical applications [24]. The prospect of Medical Physics in the clinical setting lies in its ability to contribute to the rational use of treatment, medication and the task of health promotion and diseases management in the health care sectors.

There is also the need for them to learn more about molecular biology and to take advantage of the opportunities available in the development of new technology, new therapeutic and diagnostic procedures.

Conclusion

Medical Physics has long had an integral role in biomedical research. Thus the specialized knowledge which Medical Physicists possess can neither be replaced by technicians nor by any advanced software run on computer. In recent years, Medical physicists have increasingly stepped up their involvement in direct clinical obligations, treatment planning, risk management, equipment maintenance, instrumentation and clinical trials. The target of Medical Physicists in biomedical research has become extremely broadened with more emphasis on improving both the skills and the role they play in transferring laboratory findings into valuable tools that help to improve health care.

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