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Invited Paper

The Duties and Some Challenges Confronting Clinical Medical Physicists in Africa

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Introduction

Physics is a natural science subject dedicated to the search for facts about the natural laws and phenomena, ie the principles and laws that have evolved from observations and measurements of natural phenomena. As a part of natural science, Medicine is the quest for understanding one particular thing; the human body, its structures and functions under all conditions of health and sickness. This quest has led to the application of physical theories, concepts and models of human health and sickness that have been helpful in detecting and diagnosing sicknesses, and designing therapy techniques to alleviate pain and suffering and to restore the body to a state of good health. Hence there evolved a marriage between Physics and Medicine. The field of Medical Physics as we know it today started with the discovery of x-rays and radioactivity in the 1890s. The first radiograph was taken by the physicist, Wilhelm Conrad Roentgen (1845-1923) at Wurzburg University laboratory in Germany. As a reward of his scientific discovery, he received the first Nobel Prize in Physics in 1901. Since then, applications of the theories, concepts and principles of Physics have greatly increased and today, it has developed to the specialty of Medical Physics. Medical Physicists make three profound contributions to Medicine, employing ionizing and non-ionizing radiations for the prevention, diagnosis and treatment of human diseases and disabilities. The roles of a Medical Physicist today have become indispensable in virtually all the specialized areas of Medicine, Medical Science and Technology [1].

The African Medical Physicist in the course of the discharge of his/her legitimate duties and playing of constitutional roles, is confronted with a catalogue of problems and challenges that are diverse in nature [2]. The major roles and challenges of the Medical Physicists, especially in the African continent, are what the author has tried to briefly describe in this invited paper. Most of the challenges described, borne out of personal experiences and those of others, are related to the trends in technological development. These challenges, which are evolving continually, have to be expected, prepared for and confronted headlong. This is considered necessary due to the present rate of advancement and technological development not only in Physics, but also in Medicine and Medical Sciences globally and in Africa in particular.

Duties of a Medical Physicist

The major roles of a Medical Physicist may be grouped into three, viz, Consultation/Clinical Services, Education/Training and Research. Each of these roles offers unique opportunities for Medical Physicists to positively influence clinical applications, teaching and research on the techniques and the technology of clinical and industrial applications of ionizing and non-ionizing radiations.

(a) Consultation/Clinical Services

Shortly after the discovery of x-rays and radioactivity, radiations found medical applications. Not so long thereafter, Medical Physicists began collaborating and engaging in partnership with physicians and other health professionals in the uses of radiations to improve human health and patient well-being. This partnership has grown tighter and more inter-dependent as the technologies of diagnostic and therapeutic Radiology and Nuclear Medicine become more and more complex. In cancer management for example, Medical Physicists as consultants use diagnostic images for simulation of treatments, produce treatment plans, conduct quality control (QC) on imaging and treatment facilities, conduct radiation machine calibration, manage radiation protection and safety programmes, provide scientific and clinical advice which has direct bearing on the management and safety of patients [3, 4]. They apply Physics concepts and methods to achieve the effectiveness, quality and safety of diagnostic and therapeutic techniques and procedures. They introduce and develop new procedures for the benefit of patients. These activities take the form of consultation with physicians and other clinical personnel. Their activities cover wide frontiers in Medicine, including cancers, heart diseases and mental illnesses. In cancer management, they work primarily on procedures involving use of ionizing radiations. They develop and apply high energy radiation machines and new techniques for precise calibration and calculation of patient radiation doses and dose distribution. These services include Nuclear Medicine centers where naked ionizing radiation sources are employed in forms of solid, liquid and gas. Some Medical Physicists are engaged in the industries, managing the ionizing radiation generating sources and facilities. They also serve as radiation safety officers and advisers.

The delivery of services to patients in Radiodiagnosis, Radiation Oncology and Nuclear Medicine is a highly demanding and technologically complex enterprise that requires intense involvement of Medical Physicists at all levels. As radiation treatments become more precise through external beam conformal techniques and internal source Brachytherapy methods, Medical Physicists are becoming increasingly responsible for designing, deploying and monitoring the treatments using sophisticated instrumentation, tools and computer-based systems [5]. As new imaging technologies and improvement in the existing technologies are introduced into Radiology, physicists are to ensure that these innovations perform as intended and yield the information that contributes to optimal patient care. Physicists are responsible for assessing equipment performance and verifying that it is efficient, effective and safe for clinical uses. These responsibilities present physicists with enhanced opportunities for leadership in the clinical setting.

(b) Research

Medical Physicists play vital and often leading roles in Medical and Medical Science research. The invention in 1931 of the first clinical cyclotron by E. O. Lawrence (a Nuclear Physicist) and the eventual first production of artificial radioactive Iodine in 1934 led to tighter research collaboration with his brother, J. Lawrence (a Physician) and other physicists and physicians in the study and management of the cancer of the thyroid as publicly announced in 1946 [6]. Medical Physicists have driven the research frontiers of diagnostic and therapeutic applications of ionizing and non-ionizing radiations forward. Physicists discovered x-rays and radioactivity, characterized different radiations, developed radiation detectors, designed radiation sources, quantified radiation doses and assisted in early clinical applications of radiations [7]. Medical Physicists helped develop high-energy x- and γ-ray treatment machines, computed tomography, single photon emission tomography (SPECT) and positron emission tomography (PET), gray-scale and real-time ultrasound, magnetic resonance imaging (MRI), and low-,medium- and high-dose rate Brachytherapy facilities. These research efforts continue today, and range from development of new imaging methods to improvement of quality in the clinical applications of existing technologies. Research outcomes are rapidly promoting diagnostic Radiology, Radiation Oncology and Nuclear Medicine into greater heights in imaging and treatment of diseases. Conventional methods of imaging are changing at an amazing speed. Research findings have and are still contributing unfathomably to the improvement in the calculation of radiation doses and dose distribution in Radiotherapy. Newer techniques and devices are being developed from time to time for the quality assurance (QA) and quality control (QC) of treatment and imaging facilities [8-12]. Today radiological studies are shifting focus to molecular imaging, which is the study of normal and abnormal tissues at the cellular and molecular levels [13, 14]. These studies employ new methods using optical and near-infrared, terahertz, microwave, electron paramagnetic resonance, magnetoencephalography and fluorescence for imaging. The applications of these imaging methods in Radiotherapy treatment planning, delivery and patient monitoring have greatly enhanced the level of precision achieved more than ever before. These applications, combined with conformal Radiotherapy methods such as Intensity-Modulated Radiation Therapy (IMRT), image-guided Radiotherapy,

inverse treatment planning and treatment delivery gated to accommodate respiration, improve the exactness of treatment delivery. These advances have the potential to move Radiation Oncology from physically-based to biologically-based conformal therapy. They offer research opportunities for Medical Physicists working with their scientific and medical colleagues. The rate of evolution of science and techniques in diagnostic and therapeutic Radiology, including Nuclear Medicine, has never been greater. The impact of research findings and the consequences on the quality of patient care have great potentials.

(c) Teaching

Often, Medical Physicists, apart from hospital services, have faculty appointments at Universities and Medical Colleges, where they train young Medical Physicists, Radiodiagnosis, Nuclear Medicine and Radiotherapy Residents, Physicians, Medical students, Radiographers, Radiation Oncology Nurses, Medical and Biomedical Technologists and Technicians, who operate and maintain the different radiation generating equipment used for diagnosis and treatment. Medical Physics is a vital part of the cost effective health care of the future as the pressure on healthcare professionals to make the industry more cost effective is increasing every day. Physicists have always had a major teaching role in Radiodiagnosis, Radiation Oncology and Nuclear Medicine.

Major Common Challenges Confronting Clinical Medical Physics Practices in Africa

The duties and the performance of a Medical Physicist require adequate education and training. Training, retraining and continuing education greatly influence the competency and efficiency in the discharge of responsibilities and this is a major challenge in Africa. To have the required prerequisite qualification of Master of Science in Medical Physics for enlistment in Medical Physics residency programme, candidates have to attend a University where such courses exist. There are basic courses and units that must be taken and passed as recommended by the International Atomic Energy Agency (IAEA) [15]. These courses include Radiotherapy Physics, Radiodiagnostic Physics, Radiation Protection, Radiation Detection and Spectrometry, Dosimetry, Mathematical Analysis and Statistics, Computer programming among others. The problem is that the courses run by the Universities and how they are run is at the prerogative of the Universities. This creates a big problem of uniformity and standards in the education and training of individuals entering and practicing Medical Physics. Inadequacy, non-uniformity in education and training programmes make it difficult to establish and enforce standards. This undermines the ability of Medical Physicists to respond to the many opportunities available to them today, and to additional opportunities that will arise in the future. Some possible job opportunities for example, demand that a candidate must have taken and passed Anatomy (and Physiology in some cases) course(s) as prerequisites for recognition as a Medical Physicist.

There is paucity of qualified, skilled Medical Physicists in Africa to effectively man the activities in the three areas of Radiotherapy, Radiodiagnosis and Nuclear Medicine just like in many other countries [16]. Most African Clinical Medical Physicists were trained abroad and few of these are engaged in hospital services doing mainly clinical work. There is lack of adequate number of indigenous training centres and facilities. The cost involved to obtain clinical training from a recognised training centre is high. Most hospitals, private and public, rather prefer to employ already trained Medical Physicists than sponsoring training. While it is true and commendable that the International Atomic Energy Agency (IAEA) and World Health Organization (WHO) train qualified Medical Physicists, African governments and other relevant agencies should not ignore local training which should be adapted to local and environmental conditions and peculiarities. Federation of African Medical Physics Organization (FAMPO), the regional professional body of the continent, since inception has been playing commendable roles in terms of information dissemination, coordination and promotion of the profession in the continent. These are achieved by liaising with other Institutions such as the International Organization for Medical Physics (IOMP), IAEA, WHO, American Association of Physicists in Medicine (AAPM), European Federation of Medical Physics (EFOMP), etc. As a result of these constitutional roles, the professionals in the continent are not left behind concerning the latest information, activities and recent developments related to the profession at the global level. FAMPO is definitely aware of the myriad of challenges militating against the practice of the profession in the continent.

Fortunately, the International Labour Organization (ILO) has recognised Medical Physics as a profession. From experience, it takes quite a while for most national authorities to recognize new professions. A lot has to be done by the national professional bodies at local, and FAMPO at continental levels for proper recognition. One of the major steps is publicity for adequate public awareness and another is professional activities that demonstrate the importance of the roles of Medical Physicists. It would be a lot easier to receive recognition and support for the profession once governments appreciate the indispensable Medical Physics roles in

health management. The author looks forward to a time when all African national leaders would recognise and appreciate FAMPO and Medical Physics profession to the extent that they would devote some resources, on annual basis, for the training and development of the profession. The author looks forward to a time when many more African countries would have adequate number of medical facilities with modern equipment, such that FAMPO would be in a position to organize standard professional trainings that will be fully local, adequate and cheaper than going abroad. Partnership and memorandum of understanding may also be developed with machine manufacturers and vendors for support and to facilitate training. This will be in addition to the currently enjoyed supports from different professional bodies from developed countries.

Medical Physics is a rapidly developing profession; hence the need to undertake continuous professional development programmes from time to time in order to keep up-to-date in the field. This is for the benefit of the individuals, the health institutions and the patients. The national Medical Physics professional organizations should make it compulsory for practicing clinical Medical Physicists to participate in a formal, continuous and assessed professional development scheme established by the body, in order to maintain their certification or license to practice. Continuing professional development may consist of a range of learning activities which Medical Physicists participate in to ensure that they retain their capacity to practice safely, effectively and legally. It may be in the forms of refresher courses, conferences, workshops and self-directed learning. It may also involve a wide range of activities, both professional and academic which contribute to the development and further education.

Education, continuing education and training are not cheap. Another challenge is that most health Institutions are not readily supportive financially, to sponsor continuing education of Medical Physicists. The National professional body may have a role to play along this line, educating the employers about the importance of continuing education for better efficiency and quality services of their Medical Physics staff and for the benefit of their patients. National professional bodies may adopt the policy that will make lack of continuing education lead to a revocation of the practicing licence and thus make the health Institution loose the services of the Physicists. The nation's watchdog charged with the safe and peaceful applications of atomic energy may assist in enforcing this by withdrawing the accreditation of any service center that does not sponsor continuing education of the staff engaged in the clinical uses of ionizing radiation.

Little or in some cases, no support is given to training Medical Physicists by individual governments and private Institutions. The law governing the use of ionizing radiation is still weak in most African countries. Most hospitals have no budget for training, retraining, continuous education or to fund conferences. Most of the conferences are usually supported by international organisations like the IAEA and the WHO. Access to such training information and opportunity to participate are very difficult because there are always a limited number of participants admissible each year.

Medical Physics has gained tremendous popularity since the last two decades, and the trend continues to date. Unfortunately, there is still a high level of ignorance about the role of a Medical Physicist in many of the African governmental circles, among hospital managers and health ministries. The lack of official recognition of the profession in most of these countries, leads to lack of the national and international professional bodies governing and regulating the activities of the practice of Medical Physics. Consequence to the lack of recognition, the remuneration of clinical Medical Physicists is generally poor, and not commensurate with the level and quality of services rendered, and this could be discouraging. National professional bodies need to come closer and unite efforts in the popularization and promotion of this novel profession. Lack of funds, sponsors, and inadequacy of equipment for training and research significantly inhibit the proficiency of Medical Physicists, especially in areas of dosimetry, dose assessment and radiation monitoring. This has limited in no small measure, the participation in research and publications in reputable, widely circulated academic and professional journals.

A Peep into the Future of Medical Physics Professional Practice in Africa

(a) Artificial Intelligence and Training in Software

Medical Physics is a dynamic field and technological development; new ideas and methods evolve on a daily basis. Quite a number of radiological procedures today in diagnostic, therapeutic or Nuclear Medicine, have been, and are being computerized and automated. As a matter of fact, automation is the most current trend now as well as application of Artificial Intelligence (AI) in almost all the areas of Medical Sciences and Technology, and Radiotherapy procedures are not excluded [17]. Automation and AI are increasingly applied for contouring, auto planning, QC and treatment plan checks. In order that the African Medical Physicists can continue to flow in the direction of emerging technology and to be professionally relevant tomorrow, there is the

need for education and training in computer programming, automation and AI. This training could take the form of self development or continuing education. Some knowledge in software development and some computer languages will be helpful along this line. Some foreign Institutions run programmes in these areas. A lot of educative information and resources are also obtainable through online resources [18-20].

(b) Keep abreast of modern technological development at all times

On a regular basis, new technologies are emerging through newer models of medical diagnostic and therapy facilities [21]. The forms of Linear Accelerator (LINAC), Magnetic Resonance Imaging (MRI), Ultrasound (U-S) Computerized Tomography (CT) facilities of two decades ago are completely different from those of today. New, faster and more precise algorithms continue to emerge that simplify the tasks of the Medical Physicist in treatment simulation, planning, machine calibration and dose distribution calculations. The QC of some LINAC, CT and MRI models are already automated. This development is in the right direction, especially for the routine and frequent measurements conducted by the Physicist. Examples of such measurements include patient-specific QA, treatment plan checks, weekly chart checks and patient-specific measurements. Clinical Medical Physicists have plenty of challenges and opportunities to use their training and the acquired skills in these techniques for patient benefit.

(c) Computerized systems and need for manual verifications

One of the routine duties of clinical medical physicists is to check patient-specific charts. This includes both plan review prior to the first treatment and ongoing weekly checks. On many occasions, physicists could find issues with the treatment plans such as missing couch or omitting density overwrite for contrast agent. In less frequent cases, physicists may detect big errors like missing wedge or wrong image set for planning, which could jeopardize the patient's safety. Independent plan reviews are critical to the quality and safety of patient care [22]. As part of QA and QC procedures, it is strongly advised that once a while, for example once a month, quick manual dose calculations be made and compared with the computer values. Faulty computer calculations are not common, but they are possible. When they occur, they could lead to serious consequences over a period of time before detection. Monthly manual cross checking will help in early detection of errors and prevent radiation accidents in form of over-dosage or under-dosage of many patients over an extended period of time.

(d) Training in Engineering and minor repairs

New techniques for imaging, treatment planning and radiation dose delivery systems will be necessary and will require the efforts of Medical Physicists to design, test, and implement these procedures. The manufacturer, the engineer and others conduct some tests, the physicist will perform some other tests personally, review and analyze the entire spectrum of tests and compare results with those by automated techniques. Clinical Medical Physicists also play a very important role when a treatment machine is down or has issues. Physicists need to discuss with service engineers to diagnose the problem and develop a repair plan. QA procedures are often required before the machine is released back for patient treatments and they must be performed by qualified clinical Medical Physicists after the repairs. Some jurisdictions require the specific approval of the Medical Physicist post-repair, prior to returning the LINAC for clinical use. The degree of the Physicist's involvement could vary depending on the competence of the service engineer. Regardless, a proactive and dedicated physicist can speed up the process for a faster return of the machine for patient care. Even though Medical Physicists are not trained to repair machines, they can help to identify the cause of the issues by their analytical skills and familiarity with the machine from routine QA experiences. In fact, it is not out of place if the physicist can undergo some elementary engineering training for minor repairs of the machine. At times a minor technical problem may unnecessarily delay treatments because the resident engineer is unavoidably absent. However such training is not meant to replace the services of the dedicated engineer.

Recommendations and Conclusion

i. Patient management involves expertise in diverse fields. It is recommended for African Medical Physicists to develop interface more and better with other clinical colleagues, Radiologists, Radiation Oncologists and maintain good rapport for mutual professional benefits and disease quality management.

ii. There is the need for Medical Physicists to demonstrate scientific excellence, positioning themselves as the indispensable link, seasoned experts, and their roles should not be limited to conduct of QA and QC but to continue to educate themselves and their peers.

iii. In clinical services, they should assume leadership and strengthen the links between clinical work, research and education and keep themselves at the forefront of technological development.

iv. They should be actively involved in new radiation facility acquisition processes and take active part in protocol decisions.

In conclusion, as a result of the major technological developments in Radiodiagnosis, Radiation Oncology and Nuclear Medicine over the past decades, the roles of Medical Physicists have expanded. Medical Physicists have been partners with other health professionals in these disciplines. Today each of these professionals is experiencing another major transformation in the services provided to patients. These transformations open new opportunities for Medical Physicists to expand their contributions to research, education and clinical services, and to increase the ability to help the other clinical colleagues deliver safer and more efficient services.

Medical Physics can be one of the most challenging and rewarding applications of Physics in the society today. The historical development is marked by the numerous significant scientific and technological accomplishments driven by an unprecedented interdisciplinary collaboration between Physicists and Physicians [23]. In most African countries today, the dire need is to provide high quality physics support in clinical routines. National and regional Medical Physics professional bodies need to play the important role of creating awareness and proper communications with governments, relevant authorities and other stakeholders.

Medical Physics is an interesting profession and exciting to young minds. It is highly demanding in terms of skill and competency acquisition. African young Medical Physicists need to brace up and confront the militating challenges squarely. Appeal goes to different African governments and authorities to recognize, appreciate and support the development of the profession for the sake of their cherished citizens, patients in particular.

Education, training and continuing education requirements for qualified Medical Physicists should be vigorously pursued and harmonized in the continent. African Medical Physicists, despite all the hurdles, economic and infrastructural limitations, should always update their knowledge in order to remain relevant and meet the professional good practice standards not only in the continent, but also across the globe.

Abbreviations

LINAC: Linear Accelerator; MRI: Magnetic Resonance Imaging; U-S: Ultrasound; CT: Computerized Tomography; QA: Quality assurance; QC: Quality Control (QC).

Author Contributions

All authors contributed equally to this study and gave their final approval.

Competing Interests

The authors have declared that no competing interest exists.

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