DEVELOPMENT OF MEDICAL PHYSICS IN RWANDA: ONGOING CONTRIBUTION FROM IAEA, GONO UNIVERSITY AND ICTP

J. D. Kamanzi[1], L. Rangira[1], H. A. Azhari[1,2], S. Tuyizere[3], J. Makuraza[3], G. A. Zakaria[1,2,4]

[1]Department of Medical Physics and Biomedical Engineering, Gono University, Dhaka, Bangladesh
[2]South Asia Centre for Medical Physics and Cancer Research (SCMPCR), Dhaka, Bangladesh
[3]University of Rwanda, College of Science and Technology, Kigali, Rwanda
[4]Department of Biomedical Engineering, Faculty EMW, Anhalt University of Applied Sciences, Koethen, Germany

Abstract— **Medical physics in Rwanda has long been obscured mainly by the absence of radiotherapy and nuclear medicine facilities in the country, however, the recent establishment of the first country's radiotherapy centre triggered the urgent need for medical physicists in the country's healthcare system to support the national expanding radiological services. Currently, medical physics development in Rwanda is in its initial phase where the first cohort of students, trainees and pioneers of this profession are continuously undertaking medical physics education and training from various Universities in the world, through cooperation with different international institutions and organisations (currently: IAEA, Gono University and ICTP). The first batch comprises seven (7) Rwandan students. Of these, the first two (2) students have completed their academic program and currently doing clinical training in collaboration with IAEA; the next two (2) more students are doing their master's thesis work at Gono University/Bangladesh; while the remaining three students (3) are waiting to start their academic program early next year at ICTP-college on medical physics. Nevertheless, medical physics education and training in Rwanda and East Africa region is still relying heavily on the international scholarship and/or limited to few of those with substantial wealth to afford the international education cost. Furthermore, the lack of medical physics education programs in the whole region continues to constrain the interests of many East African young generations who are keen to join this profession. Therefore, the establishment of a medical physics education program at least in one of the East African countries (as proposed in Kigali/Rwanda) can be the ideal way to bridge the existing gap between current status and the required professional development.**

Keywords—**Medical Physics, Rwanda, IAEA, Gono University, ICTP.**

I. Introduction

Medical Physics is an applied branch of physics devoted to the application of concepts and methods of physics to the diagnosis and treatment of human disease. Medical physicists are in practice dedicated to the improvement of the quality and safety of patients in different fields such as radiation therapy, nuclear medicine, diagnostic radiology and radiation protection [1]. Medical physics further plays an essential role in radiation oncology and it has been identified as one of the key areas that need to be developed in order to improve healthcare services provision [2]. However, the shortage and/or full absence of qualified medical physicists in developing countries, and Rwanda in particular, imposes serious constraints on professional development and modern healthcare standards which requires a particular attention [3]. Medical physics profession and its recognition in the Rwandan healthcare system have long been obscured mainly by the absence of radiotherapy and nuclear medicine facilities in the country. Currently, Rwanda is among the African countries in which there are no available national qualified medical physicists but with continuously updating technology in modern medical imaging, radiotherapy and radiation protection in civil services.

Being the second-most populous continent, Africa is also the least developed continent in the framework of medical physics resources, equipment and qualified professional staff. The continent possesses 54 countries among which 32 states (about 59%) have available medical physicists with/without medical physics societies, while the remaining 22 countries including Rwanda (about 41%) do not have qualified medical physicists at the time of this publication [4]. Figure 1 indicates African countries with (white colour) and without (red colour) qualified medical physicists (*Islands and archipelagos are not indicated on this map*). The black half-cycle indicates the Rwanda country on the African map.

Figure 1: The African countries with available medical physicists (in white colour) and without medical physicists (in red colour), at time of this publication [5]. On the map, Rwanda is marked by the black half-cycle.

For the development of medical physics in Rwanda, education and training, residency programs as well as accreditation and certification procedures need to be realised. Therefore, this study reviews the educational efforts of the ongoing education and training of the first cohort of students and pioneers of medical physics in Rwanda from different educational institutions in the world. For instance, the collaboration with the International Atomic Energy Agency (IAEA) through the University of Ghana, the Gono University through its Medical Physics and Biomedical Engineering department and the Abdus Salam International Centre for Theoretical Physics (ICTP), College on medical physics through the 2-years Master of Advanced studies in Medical Physics (MMP) program. Furthermore, this study reviews the national wide imaging capacity together with the available radiotherapy equipment and explores the importance of medical physics professionals in the Rwandan healthcare system, as per WHOs' guidelines, one million people needs one linear accelerator (linac) with two (2) medical physicists per linac. The purpose of this study is to provide an overview on the medical physics development in Rwanda, highlighting the importance of medical physics professionals in the country's healthcare system with the goal to guide and enhance the medical physics recognition in the country. The study describes the ongoing contribution from the mentioned international institutions and organisations to train the first batch of Rwandan medical physicists and further propose the future prospective of the medical physics profession in the country.

Rwanda is a small sub-Saharan, landlocked country that lies to the south of the equator in the East-Central African region. It is a low-and middle-income country of 12.5 million population, with a current life expectancy of 67 years and gross national income per capita (GNI) of US$820 according to the World Bank [5, 6]. Known for its breath-taking scenery, Rwanda is often referred to as the land of a thousand hills (in French: "*le pays des mille collines*") because the country is characterised by undulating hilly and mountainous terrain, with rainforest on the western heights and heavy-cultivated fields in the valleys below. The country is geographically bounded to the north by Uganda, to the east by Tanzania, to the south by Burundi, and to the west by the Democratic Republic of the Congo (DRC) and Lake Kivu. The Rwandan population is largely agricultural workers, with more varied occupations within the capital city, Kigali. Rwanda is as well known for its traumatic history, including the 1994 Tutsi ethnic genocide, as for its courageous recovery to become a stable, well-run and reunited country. In just a few years, Rwanda has successfully managed to exit fragility with promising growth rates, emerging in 2020 as a "frontier economy," with access to global markets and private finance.

II. RWANDAN HEALTHCARE SYSTEM

Rwanda has made remarkable progress in rebuilding its healthcare system over the recent years by placing the health and wellbeing of the people at the forefront of the agenda. The country has one of the best organised healthcare systems in Africa, where all citizens (local communities) are able to obtain community-based healthcare insurance through a system called "*mutuelles de santé*" [7]. The healthcare insurance payment rate varies on a sliding scale according to family wealth, with the poorest family entitled to free healthcare insurance, while the wealthiest paying premiums of US$8 per adult. Every year more than 80% of the population is covered by this scheme. Moreover, there are separate national healthcare insurance schemes for private, public servants and soldiers. The patient's care is provided from the bottom of the pyramid structure by the Community Health Worker (CHWs). From the CHWs, the case can be scaled up to a *health post* (over 1000 health posts exist in the country). Then, the beneficiary will be sent to a *health centr*e (about 600 health centres in the country), from health centres the patient can be referred to a district hospital (39 in the country). At the top of the pyramid, there are four (4) *provincial hospitals* and seven (7) *referral hospitals*. Patients can only use these hospitals if they are referred through this network [8].

III. INFRASTRUCTURE

The genocide of 1994 left the country's healthcare infrastructures devastated. In the post-genocide period, Rwanda has had an uphill climb in the recovery of its healthcare infrastructures. The country has currently infrastructures for medical imaging situated in the private and public (government) centres, and one government radiation therapy facility. There are different medical imaging facilities in Rwanda with them having machines such as CT, MRI, X-ray, C-arm and ultrasound (Table 1). However, the country's imaging capacity is still under the needed level but it is continuously being upgraded to modern medical imaging infrastructures day by day.

The radiotherapy unit in Rwanda known as Rwanda Cancer Centre (RCC) is based at Rwanda Military Hospital (RMH) in Kigali city and started treating patients in early 2019. It is equipped with two Elekta linear accelerators (6 and 10 MV) and a dedicated CT scan. The facility is able to use the advanced treatment technique, Volumetric Modulated Arc Therapy (VMAT), which delivers the prescribed dose of radiation to the cancerous tissue while sparing the critical structure. Till now, above 800 patients have been treated, with more than 50% of treated patients treatment expenses have been covered by local community healthcare insurance "Mutuelle de Sante" while others have been privately funded. Currently, the centre is averaging 50 patients per day but with the full capability to treat up to 150 patients per day [9]. The centre is planning to add a high-

dose-rate brachytherapy machine in the future in order to cover full cancer treatment for patients in need of brachytherapy. Furthermore, the Rwanda government is planning to continue building the required healthcare infrastructures, acquire the most advanced equipment for cancer treatment and build the first country's modern cancer hospital which will be dedicated to provide the full comprehensive cancer patients care and research. Going forward on cancer-fighting, among the suggested strategic priorities for Rwanda's cancer system in the next 5 years include upgrading the existing imaging capacity and establishing the nuclear medicine department equipped with PET/CT scan for diagnosis and treatment of diseases. This obviously imposes an urgent need for highly qualified professionals including medical physicists and the development of education, training programs and political policies for standard service delivery and effective use of these facilities.

The Rwandan radiotherapy centre complemented the already existing chemotherapy unit in operation, the Butaro Cancer of Excellence, that is based at Butaro district hospital located in rural area of the Rwandan northern province. This has been providing comprehensive cancer care since 2012, from initial pathology to curative treatment and palliative care, with the exception of radiotherapy [10-12].

Table1: Medical equipment for medical imaging and radiation therapy in Rwanda.

Equipment	Total
PET/CT	None
Co-60 Teletherapy Machine	None
Linear Accelerators	2
Brachytherapy	None
MRI scanner	2
CT Simulator	1
Diagnostic CT scanner	10
C-Arm Fluoroscopy	6
Mammography	5
Standard Radiology	>60
Interventional Radiology	None
Dental X-ray	-
Ultrasound	>80

IV. CANCER STATUS IN RWANDA

Cancer is among the global leading causes of death and disability worldwide, claiming over 70% of its victims in low-and middle-income countries, where prevention and treatment facilities still remain limited [13, 14]. This has become a burden to the forefront, especially in low-and middle-income countries, and the Rwandan government has been working hard to identify the possible solutions which tackled the vast financial and human resource requirements in fighting cancer and related diseases. There is no long-term precise data on cancer incidence and morbidity in Rwanda mainly because cancer-specific and population-based registry was recently resumed in 2018. Merely, the 2018s' estimates from the International Agency for Research on Cancer (IARC) indicate the incidence in Rwanda to be 10,704 new cancer diagnoses, where 4520 cases among men and 6,184 cases among women were registered and the country's annual cancer mortality rates stood at 7,662 (above 70%) [15]. In addition, 50% to 60% of all cancer patients required radiotherapy in the course of their treatment [16]. The most commonly occurring cancer types in Rwandan society per gender are breast and cervix uteri cancers for females and prostate for males, with common types such as colorectum, head and neck, liver, stomach cancers, etc occurring in both genders [15].

To deal with cancer incidence and its control, Rwanda has recently in 2020 launched officially the country's 5-year national cancer control plan, the national cancer registry and the national cancer management guidelines, the three key milestones for the success of the established cancer centre, which aim to reduce cancer mortality and morbidity nationwide. Moreover, the Rwandan ministry of health organises different cancer awareness and/or cancer screening programs across the country for its prevention, as cancer prevention is the most cost-effective and sustainable intervention to control the disease. Through these cancer awareness programs; people are continuously sensitised on the cancer risk factors and how to implement prevention methods into their everyday lives.

V. MEDICAL PHYSICS IN RWANDA

The roles and responsibilities of medical physicists are very crucial with respect to medical exposure, patient protection and safety in divergent areas that typically include radiation oncology, diagnostic radiology and nuclear medicine. Furthermore, the safe and effective implementation of novel technologies in radiation medicine requires medical physics support [17, 18]. There is a day-to-day development of medical infrastructures which employ ionising radiation in Rwandan private and public healthcare sectors. Such vast applications highlight the need for a trained workforce that includes medical physicists and the recent establishment of a radiotherapy centre triggered the national-wide need for clinically qualified medical physicists to run and monitor these facilities, and further provide support to all needed radiological services. However, there is no national clinically qualified medical physicist (CQMP) available today. The responsibilities of medical physicists in the national radiotherapy centre are currently being fulfilled by one foreign medical physicist from the Ivory coast.

The shortage and/or absence of clinically qualified medical physicists in the country obviously highlights the lack of full access to physics expert's support for the available radiation therapy facilities and the diagnostic radiological services as recommended by international standards [19, 20]. Nevertheless, the developments in medical physics in Rwanda and the region cannot be successively achieved without the collaboration with

regional bodies and international organisations such as the Federation of African Medical Physics Organisations (FAMPO), the International Atomic Energy Agency (IAEA), the International Organisation of Medical Physics (IOMP), as well as with international universities/institutions, etc. In this regard, through different collaborations, the first batch of Rwandan young generation is being trained in order to start a medical physics profession in the country and contribute to regional professional development. The following subsections give a brief description of each ongoing education and training, the involved partnership and students' experience. Contributions are listed according to the year of establishment (i.e., from the first to the recent).

A. International Atomic Energy Agency (IAEA) Contribution

Rwanda has become an IAEA member state since September 2012 and signed the first Country Program Framework (CPF) in May 2017. This aimed towards leveraging nuclear technologies for development in areas of agriculture and health care, as well as radiation safety & security and human capacity building. Since then, Rwanda has received the Agency's invaluable contribution in promoting nuclear technology for peaceful uses. For instance, the IAEA provides technical support to accompany the government efforts that ensure the highest nuclear safety standards and application of the best practices in utilising nuclear technologies for development.

The IAEA continued support to build and strengthen human capacity towards the development of medical physics in Rwanda has started in 2017, in response to the urgent need for adequately trained medical physicists in the country healthcare delivery system to support the national expanding radiological services. This was done through the Agency's collaboration with Rwanda Utilities Regulatory Authority (RURA) and Rwanda Biomedical Centre (RBC). Initially, this started with providing scholarships for two Rwandan students, named TUYIZERE Sarathiel and MAKURAZA Joseph, with a physics background, to pursue medical physics education and training at the University of Ghana (UG). The University of Ghana offers well-structured and coordinated medical physics education and training that follows the IAEA's harmonised regional syllabus for academic and clinical training. This involves a two-year academic program and a one-year clinical internship in an accredited hospital/clinic/institution. Moreover, the University of Ghana was recognised by IAEA as a regional designated centre for medical physics training within the African region [21, 22]. Both students successfully completed the 2-years academic program and they are currently doing full time supervised clinical training at Institute Nationale d'Oncologie (INO) in Rabat-Morocco.

B. Gono University Contribution through its Medical Physics and Biomedical Engineering (MPBME) Department

The Global Health Catalyst took initiatives to support the medical physics development in Low-and middle-income countries of Africa, specifically Rwanda. This was done through a collaboration initiated by the former Rwandan Minister of Health (MOH), Dr. Diane Gashumba, with the coordinator of the University Medicine Mannheim (UMM), Prof. Dr. Frederick Wenz, shown in Figure 2. This collaboration is under the umbrella of the Global Health Catalyst based in Harvard Medical School in Boston, it aims to ultimately initiate and develop the radiation medicine profession in Africa, especially Rwanda through providing adequate training to the young generation who will be among the pioneers and coordinators of the professional activities. By referring to Germany's pioneering work to the development of medical physics in Bangladesh, there is a hope that this collaboration will help to bridge the existing gap between current status and the required development of medical physics in Rwanda and the region. During the conference the founder of medical physics in Bangladesh, Prof. Zakaria offered Dr. Gashumba the scholarship for two students from Rwanda to study medical physics at Gono University in Bangladesh. For this collaboration, Prof. Zakaria along with some important members (Prof. Wilfred Ngwa, Prof. Ahmed Elzawawy and others) of Global Health Catalyst (shown in Figure 3) had a 5 days official visit in Kigali/Rwanda during the 25th -29th October 2018 period for evaluating the country's situation and further cooperation.

Fig. 2: Group photo: Collaboration between the Low-and Middle-Income Countries (Rwandan Minister of Health, Dr. Diane Gashumba) with the Global Health Catalyst and the University Medicine Mannheim (Prof. Frederick Wenz) at the Global Health Catalyst Conference in UMM, Mannheim from 31th August to 2nd September 2018 (In photo: Prof. Wilfred Ngwa, Prof. Stephen Avery, Dipl.-Ing. Volker Steil, Prof. Golam Abu Zakaria and others)

Fig. 3: Group photo of the invitees: Prof. Dr. Wilfred Ngwa, Prof. Dr. Luca Incrocci, Dr. Johannes Schweizer, Prof. Dr. Ahmed Elzawawy, Prof. Dr. Golam Abu Zakaria with the former Rwandan Health Minister, Dr. Diane Gashumba, and her team in November 2018 in Kigali.

The initial phase of this collaboration started with training two fresh physics graduate students from Rwanda, named KAMANZI Jean D'amour and RANGIRA Laurent shown in Figure 4, with a full scholarship at Gono University in the Medical Physics and Biomedical Engineering (MPBME) department. The two students are currently doing the last master's coursework and thesis in the medical physics-related field and expecting to complete the academic program by May 2021. Figure 4 shows students from Rwanda with MPBME department authorities: Prof. Zakaria giving them welcome and Prof. Dr. Azhari during practical session.

Fig. 4: Two students from Rwanda in the MPBME department with Prof Zakaria (upper photo) and with Chairman, Prof. Dr. Hasin Anupama Azhari of MPBME (lower photo).

Gono University is one of the biggest private universities in Bangladesh located in Savar near Dhaka capital city. It was established on 14th July 1998 by Gonoshasthya Kendra (GK) public charitable trust, with the purpose to provide a high quality of education which meets the demands of the modern age. The Gono University's unique department in the whole country, Medical Physics and Biomedical Engineering (MPBME), was founded in 2000 in cooperation with Heidelberg University from Germany, German cancer research centre (DKFZ) and University Medicine Mannheim (UMM) from Germany [23]. The MPBME department started initially with providing post graduate courses (2-years MSc. program in 4 semesters) in medical physics and biomedical engineering, with respect to knowledge and competence at local, national and international level. Since the 2005 year, the MPBME department offers education from honours (4-years BSc. program in 8 semesters) to master's level and above 150 students have completed their program from this department and are further offering services in divergent fields [24]. Moreover, the MPBME department has invaluable cooperation with national, regional and international universities and hospitals in Germany, China and India. This provides a great opportunity for MPBME students to perform their practical training, to undertake advanced studies and research in collaboration with experts in the field.

On the way toward building a strong professional career, the two students from Rwanda participated in the hands-on workshop on "Dosimetry of Small Fields in External Beam Therapy: Reference and Relative Dose Determination" from 2nd to 4th October 2019, organised by the South Asia Centre for Medical Physics and Cancer Research (SCMPCR) and they successfully passed the workshop examination. This workshop was accredited by European Board for Accreditation in Medical Physics (EBAMP) as a CPD event for medical physicists at EQF level 7 with 37 CPD points and IOMP in category 1 with total 35 CPD points [25]. At completion of the education program, the students are ambitious to serve their community and contribute to the development of medical physics in their home country (i.e., Rwanda) and the African region. Figure 5 indicates the SCMPCR 5th Hands on Workshop (HW-05) attendees with two students from Rwanda.

Fig. 5: The participants of the SCMPCR 5th hands-on workshop (HW-05) including the two students from Rwanda, in October 2019.

C. The ICTP-College on Medical Physics Contribution

The Abdus Salam International Centre for Theoretical Physics (ICTP), College of Medical Physics has been successively training medical physicists from developing countries through the 2-years Master of Advanced studies in Medical Physics (MMP) program. The ICTP trainees have enormously contributed to the development of the medical physics profession in their home countries, through their pioneering activities such as the establishment of academic departments and societies; leading and coordinating medical physics activities as well as comprehensive patient's healthcare provision [26]. Recently, for the first time three (3) Rwandan national students have got an incredible opportunity to take medical physics education and training at ICTP-college on medical physics, Trieste, Italy. This marks a forward milestone towards the country's medical physics development which will be strengthened by the student's experience after closing their studies. The ICTP training is further witnessed to be the backbone of medical physics development in many Low-and Middle-Income (LMI) countries. Therefore, having this opportunity for Rwandan nationals to be trained at ICTP centre will equip them with relevant knowledge that is needed regionally in order to boost the standard healthcare provision and contribute to what regional scientists are doing towards rising-up and harmonising the medical physics profession in Africa. All three students were confirmed for the 2021/2022 academic year and they are currently processing the necessary documents for starting their academic program, which is supposed to begin in February 2021.

VI. DEVELOPMENT OF QUALIFIED MEDICAL PHYSICISTS (QMP) IN RWANDA WITH INTERNATIONAL MEDICAL PHYSICS CERTIFICATION BOARD (IMPCB) EXAM-2021

Medical Physicists must demonstrate skills and competencies requirements in order to develop the ability of working independently in their area of specialisation and also need to be certified by an appropriate professional certification body so as to ensure the best quality of service provision. Furthermore, the medical physics certification is very important in order to achieve and maintain the professional standards required by today's health care. In this regard, the first batch of Rwandan postgraduate medical physicists will sit for the IMPCB written exam Part I which will take place after the 21st Asia-Oceania Congress of Medical Physics (AOCMP) "Science for Radiation Medicine" on 10th -12th December 2021 in Bangladesh. The International Medical Physics Certification Board (IMPCB) is a 3-parts exam (i.e., two written and one oral) similar to the American Board of Radiology (ABR) designed to support medical physics activities, through defining and assessing minimum professional standards of medical physicists for improving their practice in all part of the world especially in countries or regions that do not have certification bodies as well as already existing national programs in IOMP member states [27a,b]. This is achieved by conducting the examination to test the candidate's competence for board certification in the field of medical physics and successful candidates are awarded certification. Therefore, when it is achieved, the IMPCB certification will be an added value to the medical physics development in the country and the region. This will further inspire other regional colleagues and peers to sit for the exam in order to look for the international licence to practice their profession.

VII. IMPLICATION OF EDUCATION AND TRAINING ON MEDICAL PHYSICS DEVELOPMENT IN RWANDA AND THE REGION

As per IAEA TCS 56 guidelines, medical physicists' specialised education, training and competencies are basically required in order to apply concepts and techniques of physics in medicine [28]. It is further stated that an appropriate academic qualification in medical physics (or equivalent) at the postgraduate level is mandatory for a clinically qualified medical physicist (CQMP) [29, 30]. Education and training are further the important factors that strongly support medical physics activities and it is highly recommended that medical physicists need to have continuous professional development which can be achieved by obtaining the appropriate educational qualification [31].

Currently the medical physics education and training in Rwanda and the East African region rely heavily on the international institution and organisations such as IAEA, ICTP and individual contribution like Gono University, which requires qualified students to go abroad in varying countries for their studies. This has historically imposed serious limitations on those who are keen and interested to join this profession due to the insufficiency of scholarship opportunities or lack of substantial wealth to afford the international study cost. Despite the advanced and standardised educational institutions available in this region, none of them offers medical physics training at the moment and this also continues to be among the factors hampering the development and recognition of medical physics in this region. Therefore, the establishment of a medical physics education and training program at least in one of the East African countries (as proposed in Kigali/Rwanda) will be the ideal and promising way to sustainably develop the medical physics profession among regional countries. This can be successively achieved if the states governments continuously work together with the regional bodies and international entities/associations such as the AFRA, FAMPO, IAEA, IOMP, etc, to set a country-by-country basis regulations for the radiation protection procedures and proper legislation of the medical physics among the national professions.

The present era of the information revolution has resulted in a huge amount of educational material (electronic medical physics lectures and teaching files) freely available to students and trainees. This has promoted further medical physics education and training throughout the world and all involved initiatives deserve special congratulations for their

contributions towards establishing educational resources and making them freely accessible. For instance, medical radiation physics (x-ray diagnostic radiology, nuclear medicine, radiotherapy, ultrasound and magnetic resonance imaging) training modules developed by a consortium of European universities and hospitals through EMERALD and EMIT projects are being extensively used to support medical physics education all over the world [32, 33]. Many other available materials from IAEA and WHO are providing a remarkable contribution to medical physics education and training of young medical physicists from developing countries. These resources can be explored in case any medical physics education and training program is established in the East Africa region. This will significantly boost the medical physics development among the regional countries, through providing the necessary skill level and staff in the field.

VIII. Summary and future professional prospective

Medical physics profession has undergone tremendous development in the past century where major discoveries and inventions revolutionised the practice of medicine. The existing novel technologies are driving the growth of healthcare delivery with cutting-edge biomedical research, and the role of medical physicists have been recognised in the baseline. Despite the recognised physics support with respect to international standards in providing comprehensive cancer care and medical imaging, the medical physics profession is still under the level of recognition and totally absent in many Low-and Middle-Income countries including Rwanda. The inclusion of the medical physics profession into the International Labour Organisation (ILO) classification as an occupation (ICSO-08, under physicists and astronomers) has proved a forward step towards its development and recognition worldwide [34].

So far in Rwanda medical physics is being initiated where the first cohort of medical physics students are being trained from different universities across the world, through collaboration with different international organisations and institutions. This proves the professional foundation, which needs extensive and pioneering work to be done by the first country's batch of medical physicists in order to attain the required field development for their society's benefits, nation and the region. The future of medical physics in Rwanda highly needs much collegial collaboration between the national medical physicists that will be available with the regional and international medical physicists and organisations so as to learn from each other's experience. The provision of high-quality physics support in national services will inherently require the local government authorities to play a very important role such as establishing effective long-term policy goals that support the available medical physicists in national healthcare institutions. Issues such as planification of a country-based program for adequate medical physics education and training will be highly needed in the future in order to assist the proper learning engagement that will develop the required skills level and staff for the national and regional field perspectives. Moreover, the establishment of a national medical physics society should be among the prior goals of the first national medical physicist's batch. This will play an important role in coordinating their local activities with regional bodies, setting proper communications with higher authorities and creating awareness, as well as establishing policies, guidelines while assuring good professional productivity.

As there are no available CQMPs in Rwanda at present, the government should facilitate and support the first batch of medical physicists already holding postgraduate qualifications to undertake clinical training in various regional and international accredited hospitals, in order to complement their academic education program and gain practical skills in various medical physics subfields necessary to work in hospitals. They should also be facilitated to participate in different residency programs and to attend different regional and international continuous professional development (CPD) programs in order to upgrade their knowledge needed for standard service provision.

For further cooperation, the South Asia Centre for Medical Physics and Cancer Research (SCMPCR), the Gono University and the University Medicine Mannheim (UMM) combined are planning in the next collaboration phase to include African students especially the Rwandan students for medical physics education and training through different sponsorships. This will promote medical physics education, training, delivery of clinical services and research in Rwanda and the region. Through this collaboration Rwandan students and residents will get opportunities to upgrade their knowledge through participating in different multidisciplinary hands-on training and education programs organised by SCMPCR. Moreover, the SCMPCR in collaboration with Germany will help in the establishment of medical physics education and training for the East and Central African region, which is proposed to be based in Kigali/Rwanda and hosted at the ICTP's partner institute, the East African Institute for Fundamental research (ICTP-EAIFR). This regional-based education will provide concrete and effective professional development among countries in this region and the continent. Many keen and interested students will get the opportunity to start their career development pathway in medical physics with a near-based education. The proper planification and detailed guidelines such as the academic collaboration and exchange program between international universities/institutions that are involved in this cooperation will be addressed in this collaboration phase.

Acknowledgment

The authors would like to acknowledge the continuous support from the IAEA towards the development of medical physics in Rwanda and the region. We must record our special thanks to the MPBME department on

behalf of Gono University for their initiatives to support the development of medical physics in Rwanda. The heartfelt appreciations go to ICTP College on Medical Physics for their untiring efforts towards the medical physics development in low-and middle-income countries and especially for providing an incredible opportunity for Rwandan students to undertake medical physics education and training at this Centre. The authors do further express sincere gratitude to the Government of Rwanda, including the Rwandan Ministry of Health, the Rwanda Utilities Regulatory Authority (RURA) and Rwanda Biomedical Centre (RBC) for their continuous effort for seeking the international collaborations which help citizens to start their career pathway in medical physics and contribute to regional professional development. Special thanks also go to all brothers and colleagues (including UWITONZE Emmanuel and others) who provided the information needed for this article.

REFERENCES

1. Jessica B. C., Christopher T. B, Steven F. B. et al. (2018) AAPM medical physics practice guideline 10.a.: Scope of practice for clinical medical physics. J Appl Clin Med Phys; 19:6:11–25.
2. Zaidi H. (2008) Medical physics in developing countries: looking for a better world. Biomed Imaging and Interv J., 4(1): e29.
3. Bruce T. (2004) The shortage of radiotherapy physicists. J Am Coll Radiol; 1(4):280-2.
4. Ige T.A., Hasford F., Tabakov S. (2020). Medical physics development in Africa-status, education, challenges, future. Med Phys Int, SI, History of Medical Physics 3.
5. National Institute of Statistics Rwanda: Statistical YearBook 2017. https://www.statistics.gov.rw/publication/statistical-yearbook-2017.
6. Trading Economics. GNI per capita; Atlas method (US dollar) in Rwanda. Available at: http://www.tradingeconomics.com/rwanda/gni-per-capita-atlas-method-us-dollar-wb-data.html. Accessed August 23, 2020.
7. World Health Organization (WHO) (2008). "Sharing the burden of sickness: mutual health insurance in Rwanda". Bulletin of the World Health Organization. 86 (11): 817–908.
8. World Health Organization: Rwanda: the beacon of Universal Health Coverage in Africa. https://www.afro.who.int/news/rwanda-beacon-universal-healthcoverage- Africa
9. Rubagumya F., Chavarri A. C., Manirakiza A. et al (2020) State of Cancer Control in Rwanda: Past, Present, and Future Opportunities. JCO Global Oncol 6:1171-1177.
10. Shulman LN, Mpunga T, Tapela N, et al. (2014) Bringing cancer care to the poor: Experiences from Rwanda. Nat Rev Cancer 14:815-821.
11. Tapela NM, Mpunga T, Hedt-Gauthier B, et al. (2016) Pursuing equity in cancer care: Implementation, challenges and preliminary findings of a public cancer referral center in rural Rwanda. BMC Cancer 16:237.
12. Stulac S., Binagwaho A., Tapela N. M., et al. (2015) Capacity building for oncology programmes in sub-Saharan Africa: The Rwanda experience. Lancet Oncol 16: e405-e413.
13. Farmer P., Frenk J., Knaul F.M. et al. (2010) Expansion of cancer care and control in countries of low and middle income: A call to action. Lancet; 376(9747):1186–93.
14. Bray F., Jemal A., Grey N., et al. (2012) Global cancer transitions according to the Human Development Index (2008-2030): A population-based study. Lancet Oncol 13:790-801.
15. Ferlay J., Soerjomataram I., Ervik M, et al. (2015) GLOBOCAN 2012 v1.0, Cancer Incidence and Mortality Worldwide: IARC Cancer Base No. 11. International Agency for Research on Cancer, Lyon, France.
16. Maud H., Lowell. T. N., Shekinah E. N. C., et al. (2018) International radiotherapy referrals from rural Rwanda: Implementation processes and early clinical outcomes. J Glob Oncol 4:1-12.
17. International Atomic Energy Agency, IAEA (2011) Radiation Protection and Safety of Radiation Sources: International Basic Safety Standards - Interim Edition, General Safety Requirements Part 3, IAEA, Vienna.
18. International Commission on Radiological Protection, ICRP (2001). Prevention of accidental exposures to patients undergoing radiotherapy. Publication 86. Exeter: Pergamon Press.
19. AAPM. The Role of a Physicist in Radiation Oncology. 1993; Report No. 38.
20. AAPM. The Role of the Clinical Medical Physicist in Diagnostic Radiology. 1994; Report No. 42.
21. Kyeremeh P.O., Acquah G.F., Atuwo-Ampoh V.D. et al. (2017) Capacity building of medical physics in Ghana and Africa. Med. Phys. Int. vol.5, No.2.
22. Hasford F., Inkoom S., Kyere A.K. et al. (2019) Medical Physics Education and Training in Ghana. Med. Phys. Int. vol.7, No.3.
23. Azhari H. A., Zakaria G. A., Hartmann G. H (2009). Medical Physics Education in Bangladesh and Cooperation with Germany. IFMBE Proceedings 25/XII, pp. 173–176.
24. Azhari H. A., Zakaria G. A., Hartmann G. H (2014) Education of Medical Physics and Biomedical Engineering at Gono University in Bangladesh. Med. Phys. Int. vol.2, No.1.
25. South Asia Centre for Medical Physics and Cancer Research (SCMPCR) Newsletter (2020), Vol 2, No. 1
26. Tabakov S., Sprawls P., Benini A. et al. (2019) International College on Medical Physics at ICTP–30 Years Support for the Colleagues in Low- and Middle-Income Countries. Med. Phys. Int. vol.7, No.1.
27. a. Kron T., Wu R., Carmel J. et al. (2020) The International Medical Physics Certification Board (IMPCB): Objectives, History and Achievements in the First Decade. Med. Phys. Int. vol.8, No.2.
    b. Kron T., Wu R., Orton C. et al. (2018) The International Medical Physics Certification Board (IMPCB): Confidence in Competency that is important but difficult to assess. ASM Congress, poster number R-0084.
28. International Atomic Energy Agency, IAEA (2011) Training Course Series (TCS) No. 56, Postgraduate Medical Physics Academic Programmes, IAEA, Vienna.
29. Tabakov S., Sprawls P., Kirisanachinda A. et al. (2011). IOMP Model Curriculum for Postgraduate (MSc-level) Education Programme on Medical Physics. Medical Physics and Engineering Education Training p8-24.
30. International Atomic Energy Agency (2013) Roles and Responsibilities, and Education and Training Requirements for Clinically Qualified Medical Physicists, IAEA Human Health Series No. 25. IAEA, Vienna.
31. Stelios C., Isidoro J., Pesznyak C. et al (2016) The European Federation of Organisations for Medical Physics Policy Statement No. 10.1: Recommended Guidelines on National Schemes for Continuing Professional Development of Medical Physicists. Physica Medica 32, 7-11.
32. Anders B. J., Tabakov S., Victoria A. et al. (2005) EMERALD and EMIT–Worldwide computer aided education and training packages in medical physics. CAL-laborate.
33. Aitken V, Tabakov S. (2005) Evaluation of the e-Learning material developed by EMERALD and EMIT for diagnostic imaging and radiotherapy. Med Eng Phys; 27(7):633-9.
34. Smith, P. H. S., Nusslin, F. (2013) Benefits to medical physics from the recent inclusion of medical physicists in the international classification of standard occupations (ISCO-08), Med. Phys. Int. vol.1, No.1.

Contacts of the corresponding author:

Author: Kamanzi Jean D'amour
Institute: Gono University
Street: Nolam
City: Dhaka
Country: Bangladesh
Email: jkamanzi17@gmail.com