Current status and future trends of medical physics in Mexico

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Abstract. Medical Physics is an area that applies the principles of physics to medicine, particularly in the prevention, diagnosis and treatment of diseases using ionizing and non-ionizing radiation. The main attractive of medical physics is that it has a direct impact on the quality and safety of medical care in humans; this social component with direct implications for the population is of high value for Mexico. This paper describes the concepts of medical physics, trends and the current status of this discipline as a profession, which is directly related to the efforts of clinical research. It is also described what is, in my opinion, the future of medical physics in Mexico, emphasizing the fact that this field requires a substantial boost from universities and hospitals to recruit highly qualified young medical physicists and the support from government agencies such as Secretaria de Salud, Instituto Mexicano del Seguro Social and Instituto de Seguridad y Servicios Sociales para los Trabajadores del Estado through clinical research projects that allow the necessary evolution of medical physics into the hospital setting.

1. Introduction

Until the early twentieth century the attention of health problems was almost exclusive domain of the medical profession. However, based on the traditional concept of health as a state of bio-psycho-social well-being and not merely the absence of disease, from then and even more today, both nationally and internationally, the participation of professionals from other disciplines in medicine to solve health problems is becoming more common and more relevant.

In particular, applications of physics in medicine have been increasing in variety and quantity so that new diagnostic and treatment modalities have required that the number of physicists in hospitals be increased and their academic and clinical training suit to the demands of advanced technologies, giving rise to an interdisciplinary profession that allows addressing multiple therapeutic and diagnostic techniques, and provides the scientific basis for understanding, implementation and development of these technologies that are revolutionizing the practice of medicine, as well as the ability to establish criteria for the appropriate use of physical agents used in medicine ensuring the quality of the technical aspects involved in the processes, the effectiveness and quality of the data, thus reducing the likelihood of accidents in medical applications of radiation. This discipline is known as Medical Physics.
2. **History**

During the decade of the 50s, in some European countries such as the UK and Sweden a new discipline, known as medical physics, was emerged. Medical physicists are scientists who apply their knowledge of physics to medicine, as made at their time, Roentgen, Becquerel and the Curies, especially in the field of diagnostic radiology and radiotherapy. Currently, the number of medical physicists in the world exceeds 20,000 and continues to increase with advancing technological development.

Cancer treatment in Mexico began around the twenties and consisted mainly of the use of Radium. This activity was performed by radiologists [1]. The arrival of the physicists to hospitals in Mexico was directly associated with the acquisition of the first radiotherapy equipment in the mid-twentieth century. In 1956 the first $^{60}$Co irradiator was installed at the National Institute of Cancerology [2] where the first department of Medical Physics of the country was created.

As pioneering examples of professional organization in medical physics, in May 1962 the Mexican Association of Physicists in Hospital (precursor of the current Mexican Association of Medical Physics) was founded. In those early days, and due to the lack of formal programs of specialization, most local physicists and engineers acquired their training with everyday experience. But fast forward in the complexity of the equipment made clear the need for a specific and rigorous training.

In the 1970s, with the invention of the first CT scanner, radiation physics changed again [3]. Today, much of the equipment used in this field is computerized, and is now being applied imaging techniques at the cellular level, so being able to identify the molecules that play a critical role in the development of certain diseases long before the clinical symptoms appear.

3. **What is Medical Physics?**

Medical Physics is an area that includes all applications of principles and techniques of physics to medicine, particularly in the prevention, diagnosis and treatment of diseases. The most attractive aspect of this branch of physics is that it has a direct impact on the quality and safety of medical care in humans; this social component with direct implications for the population is high.

Medical Physics is defined accurately by the International Organization for Medical Physics (IOMP) as follows [4]: “Medical Physics is an interdisciplinary science that from knowledge, methods and techniques of physics, helps solve current problems of medicine, primarily in regard to medical imaging, radiotherapy, nuclear medicine and radiation protection”. These application areas are not exclusive, but in practice determined the existence of the figure of “Medical Physicist” in hospitals, clinics, and other areas of the practice of medicine.

Therefore, medical physics ranging from the design of equipment and procedures for diagnosis and therapy to the development of computational algorithms to understand and explain the behavior of the human body, basing on the study, research and development of ionizing radiation, non-ionizing radiation, magnetic resonance, ultrasound, biophysics, bioengineering and imaging processing.

The possibility of researching for invent and optimize advanced techniques that use ionizing radiation, visible light, electromagnetic fields or biomaterials, in synergy with the extraordinary recent development of computing resources, makes of medical physicist a specialty of high
scientific attraction for a current physicist, since it is the branch of physics of fastest growing nowadays.

4. Current Status of Medical Physics in Mexico

According to data provided by the National Health and Nutrition Survey 2012-Encuesta Nacional de Salud y Nutrición 2012- (ENSANUT 2012) [5] The population pyramid in our country, which currently has 117 million people whose life expectancy is 75.6 years, has been moving gradually showing a widening in the age groups older than 70. This situation has meant, in general, an increase in the demand for preventive and curative health services for those age groups in which the incidence of chronic degenerative diseases and cancer are higher.

In Mexico 128 000 new cancer cases per year are reported. This figure could rise to 150 thousand well considering that there are 25% of new cases not recorded, of which 78 000 die (60-61%) [6]. A shocking information that places Mexico in a difficult situation is that in the medium term is forecast that in the next two decades one of every two men and one in three women will have a diagnosis of cancer [7].

Until 2011, our country had 0.7 radiotherapy centers per million inhabitants; ie 83 radiotherapy centers with 223 irradiators (47 $^{60}$Co, 65 LINACs, 10 IMRT, 7 RCS, 2 Gammaknifes, 47 Automatic brachytherapy and 45 Manual brachytherapy) which means 5.6 LINAC per million inhabitants [8]. In addition to these megavoltage radiotherapy systems (MV), Mexico has 157 nuclear medicine units where about 1.2 nuclear medicine studies are performed per million inhabitants (5000 SPECT studies per year), and about 7400 local radiology services with about 22 000 X-ray equipments (420 CT, 165 MRI and more than 600 mammography). In particular, the National Cancer Institute (INCan) published on its portal [8] that in 2011 the number of therapy sessions was about 63,000, while imaging studies totaling over 94,000.

In this context, the medical physicist, as part of a multidisciplinary health care team requires a formal university education. According to international recommendations, this education must be at least master's level [9]. In Mexico there are two graduate programs on Medical Physics which were created over 15 years ago. [10,11] (UNAM; Master, UAEMex, Master and Ph.D.) . To date these are the only graduate programs in the area, with more than 125 graduates (83 UNAM, 42 UAEMex). A high percentage of these professionals are working in radiotherapy departments (80%), and only a small fraction is associated with X-ray services (15 %), nuclear medicine or magnetic resonance (5%). These medical physicists have acquired their clinical training through everyday experience due to the absence of formal clinical residency programs in the country. Their professional activities involve health care, teaching and research. It should be emphasized their participation as a liaison with universities and research centers for the development of projects involving the use of medical infrastructure and medical facilities. This is critical because of the technological sophistication of the equipment involved in diagnosis and treatment of diseases. The medical physicist must ensure the proper operation of the equipment and its use through standard protocols, so that their use in research does not interfere with patient care or result in deterioration of equipment. The reality is that today, half a century after the start of RT in Mexico, there are still medical physicists practicing in medical services without receiving the desirable university education and/or clinical training.

Research on medical physics in Mexico is scarce. At least in part, this is due to the lack of degree in the area that allow linking academic activities with professional practice in hospitals. In addition to the research conducted using the infrastructure in hospitals, there are laboratories in universities and research centers. But because of the high cost of equipment necessary to perform
frontier research, their number is limited. However, the quality of research conducted in Mexico, in the area of medical physics, is at the level of international competition, but in terms of quantity is no doubt that the number of researchers is extremely small.

5. Future trends in Medical Physics in Mexico

Due to the rapid growth of radiotherapy and diagnostic radiology in our country, it takes on the order of 550 new medical physicists distributed as follows: 130 in radiotherapy, 400 in radio diagnostic and 20 in nuclear medicine. However, the future of medical physics in Mexico is linked not only to the modernization of existing health services, but also to the establishment of new hospitals, which must install high-tech equipment and incorporate medical physicists as part of multidisciplinary groups responsible for the diagnosis and treatment of patients. To strengthen research and development in the field of medical physics will be convenient to take the following actions:

- Encourage the development of academic programs (bachelor, specialist, master and doctorate) in medical physics at various universities and institutes of higher education in the country.
- Recruit young researchers with high-level preparation in medical physics in universities and in the health sector.
- Promote the creation of new medical physics laboratories in universities, research centers and hospitals with high technology having sufficient and appropriate government support.
- Increase collaboration agreements and the development of academic projects between universities and hospitals both domestic and foreign.
- Establish collaboration agreements with companies to have free access to new diagnostic and treatment equipment for conducting research.
- Increase communication links and cooperation with international organizations like the International Atomic Energy Agency (IAEA), the Pan American Health Organization (PAHO) and the World Health Organization (WHO).

These strategies, among others, will allow medical physicists have access to work with high-tech equipment, establish academic cooperation projects, making recommendations to improve the technology and conduct high-level research that results in the patient's welfare. For a long time, medical physicists have worked closely with physicians to exploit the diagnostic and therapeutic uses of radiation for the benefit of patients. Today, medical physicists play a crucial role in medical imaging in radiotherapy and nuclear medicine, to ensure the safety, convenience and efficiency of radiation-based clinical procedures.

In the field of radiation therapy, the clinical function of the physicist was greatly enhanced by the arrival of LINACs in the latter part of the last century, which requires much more attention to the computing dosimetry and treatment planning. In the past 30 years, the advent of computed generated images (CGI) has the task of data acquisition separate from the image generation and display. This separation creates an essential role for medical physicists to ensure that any abnormalities in the images is due to expressions of pathological conditions in the patient and not artifacts introduced by the process of image formation.

The complexity of both radiology and radiation therapy has increased dramatically in the past three decades, increasing the importance and usefulness of clinical medical physicists. To meet
this demand, the Universidad Autonoma Metropolitana-Iztapalapa (UAM-I) has decided to establish the program of “Specialization in Clinical Medical Physics” (Especializacion en Fisica Medica Clinica), which provides for the clinical training of the medical physicist in hospital by performing rotating and specialized residences.

6. Where is going the Medical Physics?

The Challenge of Medical Physics lies in a shift toward personalized therapies; i.e., to accurately personalized treatment to those patients who need it, avoiding treating those who do not. Medical Physics should be able to predict how, when and in whom the disease develops. This will be implemented in the future with the advent of advanced techniques in the areas of molecular imaging and adaptive radiotherapy, which offers an unprecedented opportunity to characterize tumor biology. This would guide the treatment based on the biological properties of each patient's disease. This concept considers changes in the treatment plan during the course of it due to anatomical and biological changes in irradiated tissues.

The ultimate goal is to develop a technique called biology guided radiotherapy (dose painting) [12], to incorporate biological information of the tissues, so that based on this technique, treatment plans are designed to deliver high doses of radiation with accuracy and precision in space and time. This technique can be implemented in the coming years in radiotherapy services by developing high precision and accuracy irradiation procedures (as: IMRT, helical tomotherapy, image-guided radiotherapy, adaptive radiotherapy, robotic radiotherapy, hadrontherapy, etc.) combined with sophisticated molecular imaging studies to identify the form, distribution, composition and biological response of different tissues to radiation.

Another great progress to develop personalized treatments is the use of intense beams of high energy antiparticles for irradiation of neoplastic tissues, where antiparticles annihilate locally releasing a lot of energy, greatly increasing the dose to the irradiated volume. Currently, the only successful application of antimatter in medicine is in nuclear medicine studies by positron emission tomography (PET), so the use of antiparticles is a challenge for the future, which due to the high cost and complexity of the involved technology could probably be a reality within decades.

7. Conclusion

As is evident, a number of new and emerging technologies appear regularly for possible medical applications that require skill and knowledge of the medical physicist to be developed and applied in clinical practice. The Medical Physicist not currently have the necessary knowledge in biology, genetics and molecular engineering to meet this complex area of development. Therefore, an important part of the development of medical physics is the establishment of programs for the training of medical physicists involving research and clinical practice.

In our country, to cope with this challenge, the Universidad Autónoma Metropolitana is making efforts to contribute to the training of specialists in Clinical Medical Physics by establishing the Specialty in Clinical Medical Physics which provides for the clinical training of the medical physicist in hospital by performing rotating and specialized residences.

In conclusion, the success of the Medical Physics in the immediate future lies in exploring the interface between diagnostic imaging and radiotherapy and exploiting the potential of expanding the horizons of the discipline oriented to personalized therapies. This will be possible only through medical physics training programs involving hospital practice in direct contact with the patients.

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