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MEDICAL PHYSICS EDUCATION AND TRAINING: OPPORTUNITIES AND CHALLENGES - AN OVERVIEW OF INTERNATIONAL ACTIVITIES FOR "MEETING THE NEEDS"

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While ionizing radiation has been used for over 100 years, in the last half-century we have seen dramatic improvements in the diagnosis and treatment of cancer, as well as other conditions such as cardiac ablation. Just 20 years ago, many of the cures we consider common today would have been miraculous. Much of our success comes from advances in science and technology that have helped us understand the nature of the disease, detect it earlier, calculate and measure radiation dose more accurately, and deliver it more precisely to where it is needed.

Medical physicists have brought scientific advancement and technological developments to medicine, especially in diagnosis and treatment of cancer patients. They have brought a unique perspective – that of a scientist trained in physics, including radiological and clinical physics – to cancer care. As part of a professional team, they play an important role in the safe delivery of radiation and in the development and implementation of quality assurance (QA) programs. In radiation therapy, medical physicists are as concerned with the radiation treatment outcome as radiation oncologists. Their first responsibility is to the patient. They strive to assure accurate delivery of treatment prescription (within 5%) to the target of interest while minimizing the dose to the surrounding uninvolved organs/tissues. They employ the best possible radiation treatment given the state of current technology, skills of the staff, and the resources available in the radiation oncology department. In 3D conformal treatments, because of potential serious injury due to dose escalation, they consider individual patient-specific data by employing proper imaging and image fusion techniques to calculate and deliver the optimal radiation treatment technique. Even though 10% error in radiation dose may double chance of disease recurrence, accurate delivery of radiation is essential in relieving pain, controlling tumor growth, and increasing survival rates as well.

Medical physicists prepare complex equipment to be used for delivery of radiation. They calibrate radiation beams from radiation producing equipment such as Cobalt machines, linear accelerators, simulators, CT-Sims, as well as brachytherapy sources and equipment such as low-, medium-, and high- dose rate (LDR, MDR, and HDR) units by measuring and analyzing the radiation dosage following national and international Codes of Practice. They input the radiation beam characteristic and source data to treatment planning computers and examine their accuracy in generating dose distributions. They need to understand the limitations of the complex calculation algorithms of the treatment planning systems. They must test and validate their accuracy under all possible conditions and/or configurations to assure proper dose calculation for the patient. Moreover, they have to be directly involved with calculation and delivery of complex treatment procedures such as intravascular brachytherapy, implants involving HDR units, stereotactic radiosurgery (SRS), and IMRT (intensity modulated radiation therapy) procedures. They must establish protocols for radiation procedures and evaluate radiation outcomes. As part of quality assurance measures, they must routinely check and monitor radiation producing equipment, radioactive sources, imaging machines, electronic portal imaging devices (EPID), and any other equipment / devices employed in cancer diagnosis and treatment. Moreover, they are involved with the education of the medical dosimetrists and radiation oncologists. They also train hospital staff such as radiation therapists / technologists and nurses in the proper handling of radiation producing equipment and radioactive materials in order to avoid harmful practices.

Therefore, without the knowledge and skills of the medical physicists, patients could be misdiagnosed and the treatment machine could miss the target or deliver the wrong radiation dose to the patient –

the hospital staff as well as the general public could also be exposed to unwarranted radiation. To prevent this, qualified medical physicists need to be present at any radiation facility. In Europe, the EU (European Union) members follow the European Commission's Medical Exposure Directive [97/43/EURATOM (MED), 1997] that requires the services of a qualified medical physicist at any radiation facility. Many professional organizations, including IOMP, concur with this Directive and recommend that it be adopted globally. In light of this increasing need for medical physicists and the growing responsibilities that have resulted from the ever-increasing complexity in biomedical and biophysics technology, proper education and training of medical physicists has become an extremely difficult challenge for many academic centers especially in developing countries. The existing academic and clinical residency programs in medical physics are not sufficient and/or adequate to meet the monotonically rising demand for qualified medical physicists worldwide.

Initially, a few decades ago, medical physics was considered to be applied physics and was being taught at a few splinter physics departments. But now it is being considered as one of the most precise health sciences and is being taught at medical physics departments; some are affiliated to medical schools as well. For instance in the US, the first fully-fledged medical physics department, affiliated with a medical school, was established at the University of Wisconsin - Madison in 1980. Since then, even though more medical physics departments have been established in the US and various parts of the world, the numbers of graduates are not sufficient to meet the needs especially in developing countries where the cancer population is rising. A possible solution is to establish regional medical physics programs such as the one that is being developed by IAEA for Africa under the African Regional Cooperative Agreement (AFRA) for the Member States. Another possible solution is to provide training to the trainers. An example of this model of "training the trainers" is the AAPM/IOMP International Scientific Exchange Programs (ISEP) that have been offered to many medical physicists in many developing countries since 1992.

In recent years, as the Medical Physics discipline and profession have matured, the roles and responsibilities of medical physicists as well as the requirements for educational and training programs have been more clearly defined by various national and international organizations. The terminology "qualified medical physicist" (QMP) has been introduced to designate an individual who is competent and legally authorized to practice in one or more of the sub-fields of medical physics. Moreover, certification and registration of the medical physicists by the professional organizations (such as American Board of Radiology or American Board of Medical Physics) in the appropriate sub-field(s) as well as continuing medical education (CME) and continuing professional development (CPD) for maintenance of certification (MOC) have become essential. Standards of practice have been developed by scientific and professional organizations such as AAPM (American Association of Physicists in Medicine), ACMP (American College of Medical Physics), and ACR (American College of Radiology), and EU Directives. Medical physicists have to meet the established minimum required standards. The standards are needed to harmonize education and training of medical physicists in order to assure high quality patient care. Lastly, the skills and training of medical physicists need to be updated on an ongoing basis in order that they may function effectively and independently.

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2	P. Andreo	The role of the IAEA codes of practice in the radiation dosimetry dissemination chain
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3	J.P. Seuntjens	Review of calorimeter-based absorbed dose to water standards
4	S. Duane	A comparison of graphite standard calorimeters in megavoltage photon and electron beams
5	A. Krauss	The future PTB primary standard for absorbed dose to water in ^{60}Co-radiation
6	J. Daures	Graphite calorimeter, the primary standard of absorbed dose at BNM-LNHB
7	M. Pieksma	Measurements of k_Q beam quality correction factors for the NE2611A chamber in high-energy photon beams using the NMi water calorimeter
8	G. Stucki	The METAS absorbed dose to water calibration service for high energy photon and electron beam radiotherapy
9P	M.R. McEwen	A portable graphite calorimeter for measuring absorbed dose in the radiotherapy clinic
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13	D.T. Burns	The calculation of wall and non-uniformity correction factors for the BIPM air-kerma standard for ^{60}Co using the Monte Carlo code PENELOPE
12	T. Kurosawa	Monte Carlo simulation for correction of cavity ionization chamber wall effects
15	H.-M. Kramer	Measurement of absorbed dose to water for low and medium energy x-rays
17P	F. Hobeila	Effect of XCOM photoelectric cross-sections on dosimetric quantities calculated with EGSnrc
14P	I.A. Kharitonov	Air kerma national standard of Russian Federation for x-ray and gamma radiation. Activity SSDL/VNIIM in medical radiation dosimetry field
16P	M. Vijayam	Status of air kerma and absorbed dose standards in India
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142	J. van Dyk	Megavoltage radiation therapy: meeting the technological needs
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20	L.N. Rodrigues	Implementation of the new IAEA code of practice in Brazil
21	A. Kosunen	A Finnish national code of practice for reference dosimetry of radiation therapy
22	K.E. Rosser	The UK code of practice for kV x-ray dosimetry
23	H. Bjerke	The Norwegian system for implementing the IAEA code of practice based on absorbed dose to water
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27	G.H. Hartmann	Testing of the new IAEA code of practice TRS-398 with photons and electrons at the German Cancer Research Center Heidelberg, Germany
28	M.R. McEwen	Absorbed dose calibration factors for parallel-plate chambers in high energy photon beams
29	K.J. Stewart	A novel micro liquid ionization chamber for clinical dosimetry
30	K. Derikum	Correcting for ion recombination effects in ionisation chambers consistently in continuous and pulsed radiation
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35P	M. Arib	The effect of waterproofing sleeves on the response of farmer like ionization chambers
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