to join his medical physics laboratory at the University of Toronto as a post-doctoral Fellow. At first I was involved in applied physics research, studying targets and flattening filters of highenergy linear accelerators used in cancer therapy, and later on I joined Dr John R. Cunningham’s group at the Ontario Cancer Institute to gain experience in clinical physics. Dr. John R. Cunningham received the Coolidge Award in 1976 and Dr. Cunningham in 1988, thus, of the 35 Coolidge Awards given since 1972, two of which, nos. 1 and 32 were given to American medical physicists.

How is healthcare organized under the auspices of the renowned McGill University in Montreal where you have been working as director of the McGill Physics Unit, the McGill University Health Centre (MUHC) since 1979, as well as director of the Medical Physics Unit at McGill University since 1999?

The MUHC incorporates five McGill University teaching hospitals under one management organization and employs close to 10,000 people. The MUHC Medical Physics department provides clinical physics services to the hospital-based Radiation Oncology department, the Medical Physics Unit is an academic entity at McGill University offering M Sc and Ph D degrees in Medical Physics.

Our clinical and academic medical physics services are integrated well, and the research carried out by staff and graduate students is of an applied nature. Often the research results are rapidly translated into clinical service that directly benefits patients. Our department is well known for the excellent collaboration between physicists and clinicians that resulted in many new cancer treatment techniques. Stereotactic radiosurgery is a good example. McGill University, with Harvard University and with North American institutions using radiosurgery based systems, has developed several GammaDosimetry systems. The so-called multiple converging arcs technique introduced a few years before in Buenos Aires, Vicenza and Heidelberg; McGill developed its own unique technique together with the University of North Carolina in the 1980s. We must note, however, that proton beams and even heavy charged particle beams are currently making a come back with several cyclotrons and synchrotron’s being installed in major radiology centers around the world. It was started first by the GammaKnife in the late 1960s and then by linac-based radiosurgery in the 1980s. We must note, however, that proton beams and even heavy charged particle beams are currently making a come back with several cyclotrons and synchrotron’s being installed in major radiology centers around the world. In comparison with the GammaKnife and its multiple beams, Gamma knife being a fixed facility, the machine is commercially available and is installed in over 100 institutions around the world.

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Monte Carlo simulations played an important role during the recent AAPM meeting in Orlando with many presentations devoted fully or partially to this subject. What is the relationship between the Monte Carlo method and radiotherapy physics?

Monte Carlo calculation is a statistical process, and its accuracy depends on the number of events included in the calculation. The larger the number of events, the better the accuracy of the calculation and, of course, the longer the calculation time. With the ever-increasing power and speed of computers, Monte Carlo techniques are becoming of practical importance in radiation dosimetry and in calculations of dose distributions in patients treated with x-rays, gamma rays, or particle beams. While the current treatment planning techniques are based on a set of measurements carried out in water phantoms, practical Monte Carlo-based treatment planning algorithms that are currently under development in many research centers will base the calculations directly on data for a particular patient, thereby, in principle, significantly improving the accuracy of dose distribution calculations. Patient-specific Monte Carlo-based treatment planning systems are already commercially available; however, their routine implementation in radiotherapy clinics still hinges on many factors, such as: (1) adequate modeling of radiation sources; (2) solving some experimental problems involving living tissue inhomogeneities; (3) answering many important clinical questions; (4) updating the dose calculation algorithms; and (5) improving the computing hardware. It is expected that in the near future incorporation of predictive biological models for tumor growth and normal tissue complication into Monte Carlo-based dose calculation engines will form the standard approach to radiotherapy treatment planning.

In addition to the GammaKnife and isocentric linear-based radiosurgery, we should also mention two other linear-based techniques that can be used for radiosurgery: the CyberKnife and the TomoTherapy machine. Both are based on a miniature 6 MV linear accelerator, mounted on a robotic arm in the CyberKnife and in a CT-type gantry in the TomoTherapy machine. The two machines deliver accurate treatment without the use of a stereotactic frame and can be used for treatment of intracranial as well as extracranial lesions.

Medical physicists play an important role in the team of professionals delivering radiation to cancer patients. Would you briefly explain what medical physics is and what a medical physicist does?

Medical physics is a branch of physics concerned with the application of physics to medicine. It deals mainly, but not exclusively, with the use of ionizing radiation in diagnosis and treatment of human disease. In diagnostic procedures relatively low energy x-rays (diagnostic radiology) and gamma rays (nuclear medicine) are used; in therapeutic procedures most commonly high energy (megavoltage) x-rays and gamma rays or megavoltage electrons are used (radiation therapy also called radiation oncology or therapeutic radiology). During the past two decades medical physics has undergone a tremendous evolution, progressing from a branch of applied science on the fringes of physics into an important mainstream discipline that can now be placed on an equal footing with other more traditional branches of physics. The study and use of ionizing radiation in medicine started with these important discoveries: x-rays by Wilhelm Roentgen in 1895, nuclear radioactivity by Henri Becquerel in 1896, and radium by Pierre and Marie Curie in 1898. Since then, ionizing radiation has played an important role in atomic and nuclear physics, and has provided the impetus for the development of radiology and radiotherapy as medical specialties and medical physics as a specialty of physics. The discovery of natural radioactivity triggered subsequent discoveries of artificial radioactivity by Frederick and Irene Joliot-Curie in 1934 and nuclear fission by Otto Hahn, Fritz Strassmann, Lise Meitner, and Otto Frisch in 1939. The potential benefit of x-ray use in medicine for imaging and treatment of cancer was recognized within a few weeks of Roentgen’s discovery of x-rays. New medical specialties using radiology and radiotherapy evolved rapidly, both relying heavily on physicists for routine use of radiation as well as for development of new techniques and equipment. However, while radiology and radiotherapy have been recognized as medical professions since the early 1900s, medical physics has achieved professional status only in the second half of the last century. Initially most technological advances in the medical use of ionizing radiation were related to improvements in x-ray beam delivery, development of analog imaging techniques, optimization of image quality with concern for the destruction of normal tissues, the development of multiple isocentric machines for use in anatomic delivery of radiation, the introduction of Monte Carlo techniques to improved theoretical dosimetry, and the design of dose and dose-volume histograms for use in treatment planning. The essence of radiotherapy, therefor, is to balance the tumor dose with the dose to healthy tissues, concisely maximizing the tumor dose and minimizing the normal tissue dose. The higher the tumor dose, the higher the probability of tumor control; the lower the dose to surrounding healthy tissues, the lower the probability of normal tissue complications. Accurate dose delivery to the tumor, of course, implies accurate imaging and target localization in three dimensions (3D), as well as sophisticated treatment planning in 3D.
of the essential maxim of radiotherapy: “If you cannot see it, you cannot hit it.” To fulfill this basic principle effectively, the modern radiotherapy team consists of at least the following: radiation therapist, radiation oncologist, medical physicist and radiotherapy technologist. The radiation oncologist delineates the target volume, critical organs surrounding the tumor, and prescribes the total tumor dose and fractionation. The medical physicist is responsible for calibration of the radiotherapy equipment and calculation of the dose distribution in 3D, as well as for ensuring that the radiation equipment is safe and under the advance control of the radiation therapist. The radiation therapist provides the dose to the patient following the recommendations of the radiation oncologist. The radiation oncologist is responsible for treatment planning, radiation oncology, medical physicist and radiotherapy technologist. The radiation oncologist delineates the target volume, critical organs surrounding the tumor, and prescribes the total tumor dose and fractionation. In addition to radiation therapy, medical physicists are also involved with the medical imaging for general diagnosis of disease or specifically for target determination in radiotherapy. This imaging is carried out with: (1) relatively low-energy rays used in radiography, fluoroscopy, and computed tomography (CT) scanning; (2) ultrasound; (3) nuclear magnetic resonance imaging (MRI); (4) gamma rays in gamma cameras and single-photon emission computed tomography (SPECT); and (5) positron annihilation in positron emission tomography (PET). The majority of medical physicists currently work in radiotherapy; however, many newly graduated technologists continue to work in modern diagnostic imaging equipment such as CT, MRI, and PET.

How does one protect the patient and staff from the hazards posed by ionizing radiation?

Soon after the discovery of x-rays and natural radioactivity it became apparent that ionizing radiation cannot only be used for the diagnosis and treatment of disease but also to harm human tissue. Two scientific disciplines evolved from the study of the effects of ionizing radiation on biological tissue: radiobiology combining radiation physics and biology and health physics combining radiation hazards and protection. When biological cells are exposed to ionizing radiation we can observe biological effects between radiation and the atoms and molecules of the cells. The biological effects of radiation result mainly from damage to the DNA, which is the most critical target within the cell; however, there are also other cellular effects that, when damaged, may lead to cell death. The effects of radiation on the human population can be classified as either somatic or genetic. Somatic effects are those that are observed during the lifetime of the exposed individual. The effects are usually the result of radiation-induced genetic mutations in the DNA that may ultimately lead to cancer. Genetic effects manifest themselves as deterministic and stochastic defects. A stochastic effect is one in which the probability of occurring increases with increasing doses, but the severity in affected individuals is random. Cancer is the most common stochastic effect, but there are also other stochastic effects such as cataracts and skin cancer. Deterministic effects consist of a single cell death, in affected individuals (organ dysfunction, cataract formation).

It is obvious that ionizing radiation, despite its proven beneficial use in the diagnosis and treatment of human disease, must be used diligently and with care because of its potential for causing undesirable effects, even at very low doses. Before any diagnostic or therapeutic procedure involving ionizing radiation is used on a patient, it must be established that the potential diagnostic and therapeutic gains outweigh the small, but not negligible, radiation risk associated with the procedure. As far as staff concerned, strict national and international rules must be followed when installing, operating or servicing radiation emitting devices to ensure that the staff exposure does not exceed prescribed limits.

What are the most notable recent developments in radiotherapy?

There is no doubt that the introduction of the CT-scanner and virtual simulation into radiotherapy services over the last decade has triggered a greatly improved method for target definition and acquisition of patient data. This enabled reliable 3D dose distribution calculations, a decrease of target margins and concurrent escalation of prescribed doses, all of which improved the outcome of cancer treatment with respect to local recurrences. New treatment techniques, such as intensity-modulated radiotherapy (IMRT), have been developed on isocentric linacs equipped with multileaf collimators, and new machines, such as the CyberKnife and TomoTherapy, were introduced to allow conventional dose delivery. The treatment principle is an advanced form of conformal radiotherapy with the objective of conforming the dose distribution to the target volume and resulting, in increased tumor control probability and a decrease in acute and late normal tissue complication probability. The advantage of dose delivery with the new techniques has been limited by a risk of interfraction target movement relative to reference landmarks coupled with setup errors and other inaccuracies that add to this uncertainty. The standard approach has been to add margins to the target volume, but this is done at the expense of most of the potential benefits of the more precise delivery techniques.

It has recently become possible to image patient anatomy just before delivery of a fraction of radiotherapy, thus gaining precise determination of the location of the target volume on a daily basis. This incorporates imaging with dose delivery to the patient. It is known as image-guided radiotherapy (IGRT) and has the potential of ensuring that the relative positions of the target volume and the reference point for each treatment fraction are the same as in the treatment plan. IGRT thus allows reduced treatment margins, fewer treatment fractions, dose escalation and avoidance of geographical treatment misses.

Several IGRT systems are currently commercially available, all of them allowing post-treatment imaging immediately after a patient is positioned on the linac: treatment table for radiotherapy. Most notable of these are: (1) kilovoltage or megavoltage imaging systems integrated with an isocentric linac, referred to as cone-beam CT, (2) megavoltage CT with the TomoTherapy machine, and (3) cone imaging with paired orthogonal planar imagers used in conjunction with the CyberKnife.

The next step in the full implementation of the IGRT technique is the on-board imaging (ART) to correct for: (1) the interfraction changes in target volume; (2) changes in patient’s anatomy due to patient’s loss of weight or increased hypoxia occurring during the course...
of fractionated treatment, as well as (2) the irradiation motion of the target to compensate for the patient’s respira-
tory motion during the treatment. To account for organ motion during treatment, the patient’s coordi-
nation is required, allowing the viewing of volu-
metric CT images changing over the fourth dimension.

With your own example, you pre-
sented the education and training re-
quired for entering the medical phys-
ics profession, and also alluded to the shortage of medical physicists.

What would be of general interest in this regard from the Canadian and American experience?

Today’s sophistication of modern med-
ical physics and the complexity of the treatment of human disease by radia-
tion demand a stringent approach to-
ning a member of the medical physics profession.

Currently, the most common path to a career in medical physics is an academic progression through a BSc degree in one of the physical sciences, such as biology, chemistry, physics, to a MSc degree in medical physics, and then to a PhD degree that requires the completion of an ac-
tributed program in medical physics. The minimum academic requirement for a practit-
ioner of these programs is growing, how-
ever, with medical physicists entering the medical physics profession.

The professional life of medical physi-
cists is intimately related to the vagaries of healthcare management by gov-
ernment and non-governmental organiza-
tions. Two countries with similar social and cultural systems, standards and similar healthcare stan-
dards, but which differ significantly in the organization and funding of health-
care. Both countries use a mixture of private and public funding, but the price of healthcare in the United States is about 40% of the price in Canada, and the ability of physicians to be paid is much higher in Canada than in the United States. As such, it is a very important role in the nascent healthcare systems to introduce healthcare training to all medical physicists.

Your mention of the medical physics profession’s role in translating medical physics into patient care is an important point. In the United States, the American Association of Medical Physics (AAPM) has a comprehensive program in medical physics that is accredited by the American Society for Quality (ASQ). The program is designed to prepare physicists for careers in medical physics, and it is recognized by the American Board of Medical Physics (ABMP) as a pathway to board certification. The program consists of coursework, clinical rotations, and a research project. Graduates of the program are prepared to practice in medical physics, and they are eligible to sit for the ABMP certification examination.

In the context of healthcare systems of economic powerhouses such as the United States and Canada, the Slovenian healthcare system is in reasonably good shape. On several healthcare indicators, Slovenia is above the OECD average in the fields of obesity, smoking, and diabetes. However, in the field of healthcare costs, Slovenia is below the OECD average. Similarly to Canada, Slovenia is a universal healthcare system, and the ability of the healthcare system to pay for healthcare is a key indicator of the sustainability of the healthcare system. In Slovenia, with its small and socially conscious population, there is an opportu-

ity to develop its healthcare system and to introduce new technologies. Health should not be treated as an ordinary commodity, like education, social security, and universal and timely access to good quality healthcare, regardless of the ability to pay. Slovenia should play a basic role in the healthcare systems of European and American countries.

In connection to your question about the OECD’s role in healthcare, I would like to draw your attention to a recent report published by the Organisation for Economic Co-operation and Development (OECD). The report highlights the role of healthcare systems in the overall economic performance of countries, and it underscores the importance of efficient healthcare systems in promoting economic growth.

The healthcare system in Slovenia is one of the most developed in the world, and it is considered as a best practice model for other countries. However, the healthcare system in Slovenia is facing several challenges, including the aging population, the increase in chronic diseases, and the rising costs of healthcare. Therefore, it is crucial to implement effective policies and strategies to ensure the sustainability and efficiency of the healthcare system.

In conclusion, the role of the OECD in medical physics is significant. The OECD’s expertise in healthcare systems and its ability to provide guidance on best practices can help countries like Slovenia improve their healthcare systems. By working together with healthcare stakeholders, the OECD can help make healthcare more accessible, affordable, and efficient for all citizens.