Creation of a Medical Physics Training Programme in New Zealand

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ABSTRACT

A shortage of trained medical physicists in New Zealand combined with an increasing need for medical physicists was acutely realised in 2001. In response to this shortage, the University of Canterbury started in 2002 to design and organise a master's of science (MSc) degree in medical physics. The programme of study, approved an started in July 2003, comprises eight courses in one year of study and a thesis project during the second year of study. Seven of the eight courses are mandatory and cover the field of medical physics. The eighth course is open for the student to select. Students completing the MSc in medical physics have successfully worked overseas in Australia the United Kingdom and the United States. Other students have stayed in New Zealand and have become fully accredited medical physicists by the Australasian College of Physical Scientists and Engineers in Medicine.

1. INTRODUCTION

As early as 2001, a workforce development committee was established by the Ministry of Health to examine the workforce situation relative to all professions involved with the National Screening Unit (NSU) for breast cancer detection and the six cancer treatment centres in New Zealand.[1] All imaging, x-ray therapy and other equipment utilizing radiological physics is calibrated and otherwise in the care of medical physicists. Discussions at that time with the Australasian College of Physical Scientists and Engineers in Medicine (ACPSEM) revealed that there were serious concerns regarding the state of the medical physics profession in New Zealand. They noted that there was considerable pressure on an ageing workforce and no succession programme in place. The Clinical Training Agency (CTA) of the Ministry of Health determined that the profession was short of at least eight full-time equivalents (FTEs) medical physicists, and the shortfall was likely to remain. New Zealand needed to train at least five trainees per year to ensure an adequate future workforce.

The CTA was informed that no New Zealand training programme in medical physics existed and the ACPSEM Education Committee was clearly concerned regarding the deteriorating situation. From the Ministry of Health's point of view, given the well-publicized waiting lists for radiation therapy and in the knowledge that the NSU was likely to increase the eligibility age-range for breast screening, it was immediately imperative that a medical physics education and training programme needed to be established to both secure the availability and accuracy of existing equipment and to ensure quality outcomes.

These needs were brought to the attention of the University of Canterbury in Christchurch, New Zealand in April 2002 through a survey carried out by the New Zealand Branch of the ACPSEM. The survey was followed in May 2002 by a meeting of interested parties convened by the CTA in Christchurch, New Zealand. At this meeting various matters were approved, in principle, by the relevant parties. The various matters included that CTA would fund the training of medical physicists for a five year training programme, two years academic and three years clinical.[2, 3] During this time the trainees would be known as medical physics registrars, and it is expected that the CTA, and the hospitals, would treat them in the same manner as they treat surgical or medical registrars. The CTA would fund the education aspects of the programme and buy out their time while they were otherwise employed by the hospitals. Since the majority of the five-year training period is hospital based, the CTA suggests that they would fund the academic training (the MSc degree) at much the rates the Ministry of Education would, but that it would come from the health workforce training budget.

For a number of years, up until the mid 1990’s, the University of Otago in Dunedin New Zealand offered an MSc in Medical Physics through the Department of Physics. The Otago MSc in Medical Physics was in abeyance in 2002, in part because it was a general MSc specification and did not meet the requirements of the relevant professional body or the needs of many of the hospitals. The decision to create a new Medical Physics education programme in Christchurch, as opposed to resurrecting and restructuring the Otago University programme was based to several factors. These included the expertise of the Physics and Astronomy Department at the University of Canterbury, Christchurch Hospital hosts the only hospital Medical Physics and Bio-Engineering Department in New Zealand, and the National Radiation Laboratory of the Ministry of Health is based in Christchurch.

2. GOALS OF THE PROGRAMME

The goal of the medical physics programme is to educate physics graduates in the knowledge and skills required of a physicist practicing in a hospital or other relevant institution. The programme results in an MSc in medical physics and was designed to comprise two academic years. In the first year the student must pass eight taught courses, four each semester for two semesters. In the second academic year, students are expected complete a thesis on a medical physics topic. These research projects will be completed within research groups inside and outside of the University of Canterbury. All institutions hosting research projects must meet the standards and record keeping requirements of the medical physics programme at the University of Canterbury. Institutions with active research programs involved in MSc thesis research in medical physics with undergo a minimum of one site visit every five years to assure that standards are being met.

The eight courses provide a formal academic education in the physics, anatomy, physiology, biology, nuclear medicine, technical matters and professional matters that are needed by a physicist practicing in radiation oncology or medical imaging. Seven of the courses are required course with content that is specific to medical physics. The eighth course is determined by the student and approved by the Medical Physics Programme Director to assure a comprehensive and complete pathway of study. Graduates of the programme are expected to meet the Graduate Profile at outlined in Table 1.

Table 1: Graduate profile of a MSc Medical Physicist

- An adequate span of theoretical knowledge and practical experience to work under general supervision on standard medical physics tasks
- An ability to exercise individual judgement and initiative in the application of physics principles, techniques and methods to medical situations
- An ability to carry out research in medical physics
- An ability to explain problems to other specialists and to respond with appropriate vocabulary
- An ability to establish new work programmes
- A capacity for judgement, innovation and creativity
- A capacity for interpreting the state of the art to non-specialist clients, professionals in related disciplines, students, enforcing authorities or administrators
- An appreciation of professional matters relevant to the practice of medical physics such as ethics and responsibilities

The teaching of the seven courses specific to medical physics use a mix of formal lectures, tutorials, computer laboratory sessions, experimental exercises, site visits and student lectures appropriate to the material covered. Learning is enhanced by access to and hands-on training with the equipment at the hospitals, clinics, and the National Radiation Laboratory in Christchurch. Additionally, guest lectures from individuals at the outside institutions are used to emphasise the practical aspects within the courses. All seven courses are single-semester courses, and all seven are taught each year. This allows students to enter the degree at mid-year as well as at the beginning of each year.

Each course represents a total of 150 hours of learning by the student. Typically, students have about 40 to 45 contact hours of learning in the lectures, tutorials and training sessions. The remaining 105 to 110 hours are independent learning time where the students are reading, studying, or preparing assignments. Students are generally assessed with a combination of (percentages are the approximate weight of each factor to the final grade)

- Assignments (10%)
- Literature review project (15%)
- Mid-term exam or experimental exercise reports (25%)
- Final exam (50%)

The actual weighting varies, slightly, with the course and particular instructor. Some courses, such as MDPH407, do not have a final exam.

Specific details of the seven courses are:

MDPH 401: Anatomy and Physiology

The purpose of this course is to educate medical physicists in the basic physiology, anatomy and biology relevant to their profession. The textbook for this course is **Principles of Anatomy and Physiology, 10th Edition** by Gerard J. Tortora and Sandra R. Grabowski.[4] At the conclusion of this course, a student should have an understanding and knowledge of:

- Human anatomy including cross-sectional anatomy, organ systems, skeleton
- Physiology – nervous system, endocrine system
- Pathophysiology
- Cell biology including embryology
- Cancer including tumour pathology, cell proliferation, carcinogenesis
- Physiological measurement – EEG, EMG, ECG, blood pressure etc
- Medical terminology

MDPH402 Nuclear Medicine

The purpose of the course is to educate qualified graduates in the knowledge and skills in nuclear medicine and ethical and professional awareness required of a physicist practising in a hospital or other relevant institution. The textbook for this course is the **Physics in Nuclear Medicine** by Simon R. Cherry, James Sorenson and Michael Phelps.[5] The medical ethics taught in the course can be supplemented with **Ethics and Basic Law for Medical Imaging Professionals** by Bettye G. Wilson. [6] At the conclusion of this course, a student should have an understanding and knowledge of:

- Quality assurance, commissioning and acceptance testing of medical equipment
- Communication skills
- Professional awareness
- Medical ethics
- Radionuclides and generators including unsealed sources
- Imaging systems using radionuclides
- Radiation protection and nuclear probes

MDPH403 Radiation Physics

The purpose of the course is to educate medical physicists in the radiation physics relevant to their profession. The textbook for this course is **Physics of Radiology,** by Harold Elford Johns and John Robert Cunningham.[7] At the conclusion of this course, a student should have an understanding and knowledge of:

- Types of ionising radiation – alpha, beta, gamma etc
- Interactions and energy deposition, exponential absorption vs. attenuation, coefficients, HVLs, absorption and scattering cross sections, photoelectric effect, Compton effect, pair production, Auger effect, coherent and other types of scattering, energy absorption, broad vs narrow beam, Kerma, energy losses, LET
- Nuclear models, half-lives, branching ratios, binding energies, radioactive series, radioactive growth and decay
- Radiation units – fluence (m^{-1}), energy fluence ($J\ m^{-2}$), Kerma and absorbed dose (Gy), exposure ($C\ kg^{-1}$) dose equivalent (Sv)
- Radiation generation
- Isotope production

MDPH404 Radiation Biology

The purpose is to educate medical physicists in radiation biology and protection relevant to their profession. The textbook used for this course is **Radiobiology for the Radiologist** written by Eric J Hall and Amato J Giaccia.[8] Work in the course is supplement with **Radiation Oncology Physics: A Handbook for Teachers And Students** written by E. B. Podgorsak as the Technical Editor, and the International Atomic Energy Agency.[9] At the conclusion of this course, a student should have an understanding and knowledge of:

- Radiation measurement - scintillators, GM, TLD, gel, diodes, film, semiconductors ion chambers and other detectors
- Radiation biology – modes of radiation cell kill, cell survival, mutagenicity, time-dose relationships, linear quadratic approach to fractionation, hyperfractionation and accelerated radiotherapy, combined radiotherapy and chemotherapy, mathematical modelling
- Radiation and carcinogenesis – current models, risks
- ICRP system of radiation protection – principles, effective dose, dose constraints, reference doses
- Radiation safety, protection and legislation – isotope storage, transportation, handling, shielding (including room design for diagnostic radiology, teletherapy and brachytherapy), personnel protection, disposal

MDPH405 Radiation Therapy

The purpose of this course is to educate medical physicists in radiotherapy principles, practice and technology relevant to their profession. The textbook used for this course is **Radiation Oncology Physics: A Handbook for Teachers And Students** with E. B. Podgorsak as the Technical Editor, and written by the International Atomic Energy Agency.[9] The course can be supplemented with material from **The Physics of Radiation Therapy, 3rd Ed.** By Faiz M. Khan.[10] At the conclusion of this course, a student should have an understanding and knowledge of:

- Radiotherapy equipment – electron and photon production, linear accelerator
- Calibration of therapeutic X-ray machines, linear accelerators and cobalt units
- Phantoms for radiotherapy
- Radiotherapy dosimetry including calculating dose distributions, machine settings
- Beam data - % dose, peak scatter factor, tissue-air ratio, tissue phantom ratio, tissue-maximum ratio, scatter derivatives, equivalent squares and circles, beam profiles, isodose curves, beam energy, electron range
- Beam modifiers – shielding, wedges, asymmetric collimators, multileaf collimators, bolus, compensating filters
- Patient positioning, immobilization, simulators, simulation, portal imaging
- Brachytherapy physics – LDR, HDR, implants, sealed and unsealed sources, activity measurement, manual and computer dose calculation

MDPH406 Medical Imaging

The purpose of this course is to educate medical physicists in radiological imaging principles, practice and technology relevant to their profession. The textbook used for the course is the **Essential Physics of Medical Imaging (2nd Edition)** written by Jerrold T. Bushberg, J. Anthony Seibert , Edwin M. Leidholdt Jr., and John M. Boone.[11] At the conclusion of this course, a student should have an understanding and knowledge of:

- Radiographic practice and terminology
- Image perception - theory of vision, information theory, psychophysics of image perception, design of display systems, contrast, noise, resolution, MTF, image viewing, ocular response
- X-ray – theory, generation, technology, screens, contrast agents, QA
- Fluoroscopy – design, theory, QA
- CT – theory, multislice, spiral, image reconstruction (Fourier, ART, convolution, backprojection), artifacts, QA
- MRI – theory, technology, sequences, flow-sensitive measurement, contrast agents, chemical shift, spectroscopy, artifacts, QA
- Ultrasound –theory (inc. doppler), technology, contrast agents, bioeffects and limits, QA, therapy
- Digital radiographic image measurement –image specs, DICOM, image compression & storage, networking & data security
- Radiation protection for diagnostic X-rays
- Patient dosimetry (radiography, fluoro, CT, mammography)
- Occupational radiation dose factors and considerations

MDPH407 Research Tools

The purpose of this course is to educate medical physicists in the knowledge and skills necessary to carry out research, including treatment planning and research. There is no specific textbook used for this course. However, student are frequently referred to an external book to refresh their understanding of statistics.[12-14] There are several excellent sources of information on the Monte Carlo modelling.[15-17] Websites also provide help with MathLab[18] and LabView.[19] The course is taught a computer cluster and the students are introduced to various computer tools that will assist them in future research and their career. At the conclusion of this course, a student should have an understanding and knowledge of:

- Electronics, medical instrumentation, control theory & engineering, computer interfacing, sensors
- Statistics – errors, distributions, graphic representations, distribution parameters, curve fitting, predictors, hypothesis and significance tests
- Research methods
- Monte Carlo techniques
- Treatment planning – planning systems, algorithms, single beam, multiple beam, isocentric and SSD techniques, conformal radiotherapy, IMRT

Thesis research may be University-based or hospital-based as appropriate. A hospital thesis supervisor as well as University supervisors are appointed to monitor research conducted in hospitals.

The thesis, MDPH690, is a one-year full-time course of study. Students generally work in collaboration with one of the hospitals. A member of the hospital staff who provides the day-to-day supervision of the student is part of the supervisory team. Additionally, a continuing academic from the University of Canterbury is also a member of the supervisory team. Students are encouraged to select from 3 to 5 members of the supervisory team, with a minimum of two required. Formal meetings are held between the senior supervisor and the student at least once every two months. Additionally, progress reports are due every 6 months. Students first fill out their accomplishments, their problems and the goals they have for the next six months. The supervisors and the Head of Department then make comments about the progress report and the student is allowed to answer the comments. This report is then reviewed by the Dean of Science. The Dean can accept the report, call a meeting with the student and supervisory staff, request additional progress reports or move to change or terminate the thesis project.

At the end of the 12 months, a thesis must be submitted. The thesis is sent to one internal examiner, possibly the senior supervisor, and one external examiner who does not work closely with the research group. Both examiners independently read the thesis, make comments about the thesis and suggest a grade. The thesis examiners' reports are then reviewed by the Department of Physics and Astronomy and a final grade is decided.

The thesis and courses are they weighted with a 3:2 ratio to determine a final grade for the MSc. Those students earning an A- grade or higher are awarded the MSc with first class honours. Those students earning a B+ average are awarded second class, first division honours. Those students earning a B average are awarded second class, second division honours. The remaining students are awarded the MSc without honours.

3. PARTNERSHIP

It must be recognised that the provision of academic education in medical physics at the University of Canterbury is a partnership between the University of Canterbury, the clinical institutions, and the ACPSEM. Each has a unique role to play, with the University providing the academic education and the clinical institutions providing the clinical tools, setting and relevant supervision. The ACPSEM maintains a set of standards that they expect will be met. There is no hard and fast concept as to how this partnership must evolve and innovations to improve the partnerships are constantly explored.

The ACPSEM establishes the standard by setting the required medical physics breadth and depth of knowledge, accrediting the universities and clinical training institutions and by acting as the responsible professional body for the assessment of the candidates progressing through the program. The ACPSEM has reviewed and accredited the MSc medical physics degree at the University of Canterbury for five years.

4. CONCLUSIONS

The MSc in medical physics at the University of Canterbury is a growing programme. There are now four full-time continuing academic staff members participating in medical physics at the University of Canterbury. In addition, there are two fixed term, part time academic staff members who teach into the programme. There are a number of guest lectures from outside individuals, including those from the Christchurch Hospital and the National Radiation Laboratory. Several students have completed their degrees. The first of these students are currently undergoing examination for full accreditation as a medical physicist by the ACPSEM. Thus far, the candidates have all passed their accreditation examinations. Four students have gone overseas after completing their MSc. One is currently working on a PhD in the United States, one is a medical physics registrar is Australia and one is currently moving to the United Kingdom.

5. REFERENCES

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