PHYSICS AND SOCIETY: THE MEDICAL PHYSICS PROFESSION AND ITS CONTRIBUTION TO HEALTHCARE

Carmel J. Caruana, Renato Padovani and Stelios Christofides

ABSTRACT
Physicists have been actively involved in the development of healthcare for over a hundred years. However the medical physics profession as an organized profession is relatively young and less familiar than the other healthcare professions. Even among university and pre-university mainstream physics educators little is known about the precise responsibilities of the role. We describe and discuss the function of the profession based on a review of the literature and a document analysis of the policy statements of the European Federation of Organisations for Medical Physics. We hope that in this way physics educators would be in a better position to encourage more young physicists to grasp the opportunities offered by this highly challenging and rapidly expanding profession.

KEYWORDS
Medical physics, healthcare, medicine, medical devices

INTRODUCTION

Physicists have been actively involved in the development of healthcare for over a hundred years. However, the medical physics profession as an organized profession is relatively young and less familiar than the other healthcare professions. Even among university and pre-university mainstream physics educators little is known about the precise responsibilities of the role. We describe and discuss the function of the profession based on a review of the literature and a document analysis of the policy statements (PS) of the European Federation of Organisations for Medical Physics (EFOMP). All the EFOMP policy statements and other documents referenced in this article are freely available from the website of the EFOMP at http://www.efomp.org/policyst.html. EFOMP was founded in 1980. The current membership covers 35 national organisations which together represent more than 5000 physicists and engineers practicing in the field of Medical Physics in Europe.

MEDICAL PHYSICS IN HEALTHCARE - A BRIEF HISTORY

The involvement of medical physicists (and engineers) in healthcare has a long history. Books with the titles 'Medizinische Physik' and 'Essentials of Medical Physics' were published in 1856 and 1891 respectively (Fick, 1856; Brockway, 1891). This contribution to medicine registered a big jump after the discovery of x-rays by Roentgen (1895) and radioactivity by Becquerel (1896). The first two x-ray laboratories were established in Berlin in 1896. The first chairperson of the first 'Roentgen society' was W. Wolf, a physicist. The first radiological society in England was set up in 1897 and the first president was S. Thomson, a physicist. The involvement in the first 10 years was mostly in radiodiagnosis, whilst that in radiotherapy started in 1910 (Stieve, 1991). From then onwards, the involvement of physicists in medicine increased rapidly. The first comprehensive medical physics text was the 3-volume encyclopaedia 'Medical Physics' (1944 -1960) which listed 23 domains of medicine requiring collaboration between physicists and medical specialists (Glasser, 1944 - 1960). Today medical physicists play an important part in most areas of healthcare. Medical physics is one of the primary areas of the application of physics for the benefit of society - not only with respect to the improvement of the health status of the population but also in economic terms.

DEFINITION OF MEDICAL PHYSICS

Medical physics has historically been defined in various ways. The most general definition is that medical physics is “the scientific discipline which is concerned with the application of the concepts and methods of physics in medicine” (EFOMP PS7, 1997). However, a more precise definition of the role is that medical physics is the application of physics to the “prevention, diagnosis and control of illness, disease and disability” (EFOMP PS6, 1994).

TYPES OF MEDICAL PHYSICISTS

There are two categories of medical physicists. Both are involved in the application of physics to challenges within healthcare, however, they work in different (though complementary) environments. The first category work in hospitals or as consultants to hospitals, the second in academia and industry (EFOMP PS2, 1984). In the case of physicists working in hospitals the main role is to use their physics expertise to ensure the effective, safe, efficient and scientific use of medical devices (the internationally recognised legal term used for medical equipment of any sort) within the clinical areas (EFOMP PS8, 1998). There are in fact three main EU directives regarding such devices. The first one is known as the Medical Device Directive (Council Directive 93/42/EEC) and includes the legal definition of a medical device which is:

> “any instrument, apparatus, appliance, material or other article, whether used alone or in combination, including the software necessary for its proper application intended by the manufacturer to be used for human beings for the purpose of:
> - diagnosis, prevention, monitoring, treatment or alleviation of disease,
> - diagnosis, monitoring, treatment, alleviation of or compensation for an injury or handicap,
> - investigation, replacement or modification of the anatomy or of a physiological process,
> - control of conception,
>
> and which does not achieve its principal intended action in or on the human body by pharmacological, immunological or metabolic means, but which may be assisted in its function by such means” (CE, 1993)

The other two directives are the Active Implantable Medical Device Directive (Council Directive 90/385/EEC) and the In Vitro Diagnostic Device Directive (Council Directive 98/79/EC). It is important to note that any software which is required for a medical device to function properly is itself considered as a ‘medical device’.

For historical reasons described earlier in the article such physicists are often found in hospital departments which make use of devices based on x-rays or radioactive sources (commonly referred to in the healthcare field as ‘ionising radiations’ as the photons or particles involved have enough energy to ionise molecules in the body if their energy is absorbed by tissues) i.e., radiotherapy, diagnostic radiology, nuclear medicine and radiation protection. Radiotherapy is the killing of cancer cells by the use of x-ray, gamma-ray or charged particle beams directed towards the diseased parts of the patient (‘external beam radiotherapy’) or the placement of sealed radioactive sources within diseased tissues in the patient (‘brachytherapy’). Diagnostic Radiology is the imaging of the inside of the body using x-rays for the purpose of diagnosing disease or damage to the body after trauma. Nuclear Medicine involves the use of unsealed radionuclides for diagnostic purposes or cancer therapy. Radiation Protection refers to those actions aimed at guarding patients, hospital staff and other persons in the hospital from the deleterious bioeffects of ionising radiation (in particular carcinogenesis and mutagenesis). However, physicists are today increasingly found also in departments making use of other medical devices such as non-ionising radiation based imaging devices (e.g., ultrasound and magnetic resonance imaging), non-ionising radiation based therapeutic devices (laser, ultraviolet and microwave therapy), medical electronics, bioengineering, ICT applications and lately also in physiological measurement (e.g., ECG, EEG) and audiology (EFOMP PS7, 1997; Eudaldo and Olsen, 2007). The title ascribed to medical physicists working in hospitals varies from one country to another. In some countries they are known as 'medical physicists' in others 'hospital physicists', 'clinical physicists', 'radiological physicists', 'medical radiation physicists' or 'healthcare physicists'. EFOMP is urging national associations to try to use the term 'Medical Physicist' to encourage harmonisation of the name of the profession. A 'Qualified Medical Physicist' (QMP) is an individual who is competent to practice independently and be able to register as a healthcare professional with the title 'Medical Physicist' in one or more of the above subfields (EFOMP PS7, 1997). Qualified Medical Physicists who have undertaken enough continuous professional development in their subfield/s of medical physics would achieve the status of 'Specialised Medical Physicist' in that particular subfield/s (EFOMP PS10, 2000). In the case of the ionizing radiation based subfields mentioned earlier, the Specialised Medical Physicist is equivalent to the 'Medical Physics Expert' as defined in the EU Patient Radiation Protection Directive (EU Directive 97/43/Euratom) (EFOMP PS10, 2000). In this directive the Medical Physics Expert is defined as:

> "An expert in radiation physics or radiation technology applied to exposure … who, as appropriate, acts or gives advice on patient dosimetry, on the development and use of complex techniques and equipment, on optimization, on quality assurance, including quality control, and on other matters relating to radiation protection, concerning exposure within the scope of this Directive." (EC, 1997)

The second type of medical physicist is found in the academic and industrial areas. The main functions of this type of medical physicist is teaching (both to medical physics students and other medical and healthcare professions) and/or research connected directly or indirectly to healthcare. The role of this type of medical physicist can be much wider than that of the clinically based medical physicist and involving not only medical devices but other areas such as physiological modelling, biomolecular physics, cellular physics, nanomedicine and microscopy. Again mostly for historical reasons these can be found in departments with different names such as 'medical physics' and 'biophysics'. Lately the title 'biomedical physics' is increasingly being used. Owing to the increasing multi-disciplinarity of healthcare research the term 'biomedical sciences' is increasingly being used to bring together such sciences as anatomy, physiology, pathology, medical biochemistry, medical biomathematics and of course medical physics. In this article we will focus on the role of medical physicists in hospitals.

ROLES OF THE MEDICAL PHYSICIST IN THE CLINICAL ENVIRONMENT

The role of the medical physicist within the clinical hospital environment revolves around the scientific, effective, safe and efficient use of medical devices. This role includes several component sub-roles, these are:

- Introduction, adaptation and optimisation of medical devices and medical device use protocols for individual patients or groups of patients (EFOMP PS11, 2003; EFOMP Malaga Declaration, 2006),
- Leading and managing the upholding of quality standards in the use of medical devices - particularly critical examination, acceptance testing, commissioning, constancy testing, calibration and maintenance of medical devices and the accuracy of physical methods used in clinical applications (EFOMP PS2, 1984; EFOMP PS11, 2003),
- Development of new applications for medical devices within the hospital and the full utilization of the capabilities of such devices (EFOMP PS5, 1993),
- The promotion of the safety (minimisation or elimination of risk) of patients, staff and others with respect to physical agents associated with medical devices, in particular though not exclusively ionising radiation (EFOMP PS2, 1984),
- Optimisation of radiation dose delivery when physical agents are used for treatment again in particular though not exclusively ionising radiation (EFOMP Malaga Declaration, 2006),

- Supervision of medical physics technicians (EFOMP PS5, 1993) and other healthcare professionals involved in the quality and safety aspects of the use of medical devices (EFOMP PS7, 1997; EFOMP Malaga Declaration, 2006),
- Provision of advice to clinicians regarding the appropriateness of diagnostic investigations and the presentation and interpretation of non-standard or novel data (EFOMP PS7, 1997; EFOMP PS11, 2003),
- Provision of in-service education and training to both medical physics trainees and to other medical and healthcare professionals with respect to medical device use (EFOMP PS2, 1984; EFOMP PS5, 1993; EFOMP PS11, 2003),
- Participation in research, clinical trials and health technology assessments involving medical devices (EFOMP PS7, 1997; EFOMP PS11, 2003),
- Engagement in problem-oriented research and development where a critical ability, innovative approach and specialised scientific knowledge are required (EFOMP PS11, 2003).

Critical examination refers to those tests and checks that are carried out to ensure that the safety features and warning devices on a medical device are operating correctly and that the device is safe for use. Acceptance testing refers to the tests that are carried out when a new device is delivered to hospital to ensure that its specifications are the same as those in the contract of sale. Commissioning tests are those tests carried out to ensure that the device is ready for clinical use, whilst constancy tests are those routine tests carried out to ensure that the device specifications do not deteriorate with time. Optimisation refers to the process by which radiation doses delivered to tissues for purposes of diagnosis or therapy are such that unnecessary doses to those tissues are avoided and the doses to neighbouring healthy tissues are minimised.

CORE MEDICAL PHYSICS TASKS WITHIN THE VARIOUS SUB-SPECIALITIES

To ensure that tasks carried out by medical physicists across the EU are well specified in the interest of both the profession and patient, the EFOMP has specified the 'core tasks' to be carried out by medical physicists working within the specialities of radiotherapy, nuclear medicine, diagnostic radiology and radiation protection (EFOMP PS7, Appendix 1, 1997). Table 1 shows the core tasks for Radiation Protection whilst Table 2 shows those for Diagnostic Radiology. Figure 1 shows medical physicists executing some of these tasks within Diagnostic Radiology and figure 2 shows software used by medical physicists to carry out the core tasks of treatment planning in radiotherapy departments. Constancy testing of imaging devices ensures that images from the different medical imaging devices are of high quality hence ensuring accurate diagnosis for the benefit of patients (figure 3). EFOMP would in the future also be specifying core tasks for other emerging sub-specialities.

Table 1. Core Medical Physics tasks within Radiation Protection

Dose Monitoring of Entire Staff
Personal dosimeters and workplace dose monitoring.
Radiation protection advice.
Observation of conduct of medical investigations.
Supervision of incorporation measurements according to regulations and guidance.
Calibration of radiation monitoring instruments.
Structural Protection
Radiation protection plans for new installations.
Radiation protection measurements.
Organisational Radiation Protection
Monitoring of work practices in order to improve protection.
Advice to medical practitioners and the general public.
Representing the employer in relations with authorities, approval laboratories and standards institutions.
Organisation of training in compliance with legal requirements and/or good practice.

Table 2. Core Medical Physics tasks within Diagnostic Radiology

Quality Assurance
Film processors: acceptance testing and regular constancy checks according to regulations and guidance. Acceptance testing of X-ray equipment and image receptors according to regulations and guidance. Regular constancy testing of X-ray equipment according to regulations and guidance. Development of new test methods.
Data Processing in Diagnostic Radiology
Software maintenance in computerised tomography (CT), digital subtraction angiography (DSA), digital radiography systems. Software development.
Supervision of Equipment, Maintenance, Repair
Organisation of preventive and corrective maintenance. Calibration of area dosemeters, TL-dosemeters and radiation protection instruments.
Special Radiation Protection Duties Exceeding those in Table 1
Determination of organ doses to patients, fetal doses, radiation dose burden in research work. Participation in development and improvement of image quality and optimization in x-ray procedures
General Duties
Education and Training (medical physics and diagnostic radiology staff). Collaboration in procurement of equipment and systems. Administration (personnel, purchasing, etc.). Department meetings.

Figure 1. Some Medical Physics tasks within Diagnostic Radiology

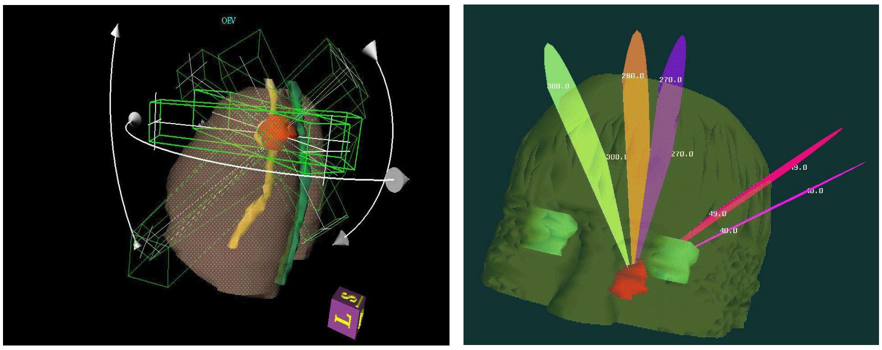

Figure 2. Software used in radiotherapy.

Figure 3. Some images from various medical imaging devices.

DISCUSSION AND CONCLUSION

This article has presented an overview of the role of the medical physicist working in hospitals in Europe. We have seen that although the possible scope of the role encompasses all medical devices, at the present time the scope is limited to radiotherapy, nuclear medicine, diagnostic radiology and radiation protection. Part of this limited scope is due to historical reasons but another factor is the low number of medical physicists in Europe. We hope that on reading this article mainstream physics educators would appreciate more the important functions exercised by medical physicists within the clinical environment and hence be in a better position to encourage more young physicists to grasp the opportunities offered by this highly challenging and rapidly expanding healthcare profession.

ACKNOWLEDGEMENTS

The authors would like to thank Dr. Slavik Tabakov of the Department of Medical Engineering and Physics, King's College London for permission to reproduce images from the EMERALD-EMIT e-Learning materials.

REFERENCES

Brockway, F. J. (1891). Essentials of Medical Physics. Saunders, London.

EC. (1993). Council Directive 93/42/EEC of 14 June 1993 concerning medical devices. Official Journal L 169, 12/07/1993 P. 0001 – 0043.

EC. (1997). Council Directive 97/43/Euratom of 30 June 1997 on health protection of individuals against the dangers of ionizing radiation in relation to medical exposure, and repealing Directive 84/466/Euratom. Official Journal L 180, 09/07/1997 P. 0022 – 0027.

EFOMP. (1984). Policy Statement 2 - The Roles, Responsibilities and Status of the Clinical Medical Physicist.

EFOMP. (1993). Policy Statement 5 - Departments of Medical Physics - Advantages, Organisation and Management.

EFOMP. (1994). Policy Statement 6 - Recommended guidelines of National Registration Schemes for Medical Physicists.

EFOMP. (1997). Policy Statement 7 - Criteria for the Staffing Levels in a Medical Physics Department.

EFOMP. (1998). Policy Statement 8 - Continuing Professional Development for the Medical Physicist.

EFOMP. (1999). Policy Statement 9 - Radiation Protection of the Patient in Europe: The Training of the Medical Physics Expert in Radiation Physics or Radiation Technology.

EFOMP. (2001). Policy Statement 10 - Recommended Guidelines on National Schemes for Continuing Professional Development of Medical Physicists.

EFOMP. (2003). Policy Statement 11- Guidelines on Professional Conduct and Procedures to Be Implemented in the Event of Alleged Misconduct.

EFOMP. (2006). Malaga Declaration - EFOMP's position on medical physics in Europe, 2006.

Eudaldo, T., and Olsen, K. (2008). The present status of Medical Physics Education and Training in Europe: An EFOMP survey. Physica Medica – European Journal of Medical Physics, 24, 3-20.

Fick, A. (1856). Medizinische Physik - Supplementband in Muller-Pouillet's Lehrbuch der Physik fur Mediziner. Vieweg, Braunschweig.

Glasser, O. (1944 -1960). Medical Physics Vol 1 - 3. Year Book Pub, Chicago.

Stieve, F.E. (1990). Medical physics, in the past, today and in the future - the development of medical physics from the point of view of a radiologist. 1990 EFOMP Federation Lecture. Phys Med Biol, 1991, 36, 687-708.