



IAEA HUMAN HEALTH SERIES

No. 25

Roles and Responsibilities, and Education and Training Requirements for Clinically Qualified Medical Physicists



IAEA

International Atomic Energy Agency

IAEA HUMAN HEALTH SERIES PUBLICATIONS

The mandate of the IAEA human health programme originates from Article II of its Statute, which states that the “Agency shall seek to accelerate and enlarge the contribution of atomic energy to peace, health and prosperity throughout the world”. The main objective of the human health programme is to enhance the capabilities of IAEA Member States in addressing issues related to the prevention, diagnosis and treatment of health problems through the development and application of nuclear techniques, within a framework of quality assurance.

Publications in the IAEA Human Health Series provide information in the areas of: radiation medicine, including diagnostic radiology, diagnostic and therapeutic nuclear medicine, and radiation therapy; dosimetry and medical radiation physics; and stable isotope techniques and other nuclear applications in nutrition. The publications have a broad readership and are aimed at medical practitioners, researchers and other professionals. International experts assist the IAEA Secretariat in drafting and reviewing these publications. Some of the publications in this series may also be endorsed or co-sponsored by international organizations and professional societies active in the relevant fields.

There are two categories of publications in this series:

IAEA HUMAN HEALTH SERIES

Publications in this category present analyses or provide information of an advisory nature, for example guidelines, codes and standards of practice, and quality assurance manuals. Monographs and high level educational material, such as graduate texts, are also published in this series.

IAEA HUMAN HEALTH REPORTS

Human Health Reports complement information published in the IAEA Human Health Series in areas of radiation medicine, dosimetry and medical radiation physics, and nutrition. These publications include reports of technical meetings, the results of IAEA coordinated research projects, interim reports on IAEA projects, and educational material compiled for IAEA training courses dealing with human health related subjects. In some cases, these reports may provide supporting material relating to publications issued in the IAEA Human Health Series.

All of these publications can be downloaded cost free from the IAEA web site:

<http://www.iaea.org/Publications/index.html>

Further information is available from:

Marketing and Sales Unit
International Atomic Energy Agency
Vienna International Centre
PO Box 100
1400 Vienna, Austria

Readers are invited to provide their impressions on these publications. Information may be provided via the IAEA web site, by mail at the address given above, or by email to:

Official.Mail@iaea.org

ROLES AND RESPONSIBILITIES,
AND EDUCATION AND
TRAINING REQUIREMENTS FOR
CLINICALLY QUALIFIED MEDICAL
PHYSICISTS

The following States are Members of the International Atomic Energy Agency:

| | | |
|-------------------------------------|-------------------------------------|--|
| AFGHANISTAN | GUATEMALA | PANAMA |
| ALBANIA | HAITI | PAPUA NEW GUINEA |
| ALGERIA | HOLY SEE | PARAGUAY |
| ANGOLA | HONDURAS | PERU |
| ARGENTINA | HUNGARY | PHILIPPINES |
| ARMENIA | ICELAND | POLAND |
| AUSTRALIA | INDIA | PORTUGAL |
| AUSTRIA | INDONESIA | QATAR |
| AZERBAIJAN | IRAN, ISLAMIC REPUBLIC OF | REPUBLIC OF MOLDOVA |
| BAHRAIN | IRAQ | ROMANIA |
| BANGLADESH | IRELAND | RUSSIAN FEDERATION |
| BELARUS | ISRAEL | RWANDA |
| BELGIUM | ITALY | SAUDI ARABIA |
| BELIZE | JAMAICA | SENEGAL |
| BENIN | JAPAN | SERBIA |
| BOLIVIA | JORDAN | SEYCHELLES |
| BOSNIA AND HERZEGOVINA | KAZAKHSTAN | SIERRA LEONE |
| BOTSWANA | KENYA | SINGAPORE |
| BRAZIL | KOREA, REPUBLIC OF | SLOVAKIA |
| BULGARIA | KUWAIT | SLOVENIA |
| BURKINA FASO | KYRGYZSTAN | SOUTH AFRICA |
| BURUNDI | LAO PEOPLE'S DEMOCRATIC REPUBLIC | SPAIN |
| CAMBODIA | LATVIA | SRI LANKA |
| CAMEROON | LEBANON | SUDAN |
| CANADA | LESOTHO | SWAZILAND |
| CENTRAL AFRICAN REPUBLIC | LIBERIA | SWEDEN |
| CHAD | LIBYA | SWITZERLAND |
| CHILE | LIECHTENSTEIN | SYRIAN ARAB REPUBLIC |
| CHINA | LITHUANIA | TAJIKISTAN |
| COLOMBIA | LUXEMBOURG | THAILAND |
| CONGO | MADAGASCAR | THE FORMER YUGOSLAV REPUBLIC OF MACEDONIA |
| COSTA RICA | MALAWI | TOGO |
| CÔTE D'IVOIRE | MALAYSIA | TRINIDAD AND TOBAGO |
| CROATIA | MALI | TUNISIA |
| CUBA | MALTA | TURKEY |
| CYPRUS | MARSHALL ISLANDS | UGANDA |
| CZECH REPUBLIC | MAURITANIA | UKRAINE |
| DEMOCRATIC REPUBLIC OF THE CONGO | MAURITIUS | UNITED ARAB EMIRATES |
| DENMARK | MEXICO | UNITED KINGDOM OF GREAT BRITAIN AND NORTHERN IRELAND |
| DOMINICA | MONACO | UNITED REPUBLIC OF TANZANIA |
| DOMINICAN REPUBLIC | MONGOLIA | UNITED STATES OF AMERICA |
| ECUADOR | MONTENEGRO | URUGUAY |
| EGYPT | MOROCCO | UZBEKISTAN |
| EL SALVADOR | MOZAMBIQUE | VENEZUELA |
| ERITREA | MYANMAR | VIETNAM |
| ESTONIA | NAMIBIA | YEMEN |
| ETHIOPIA | NEPAL | ZAMBIA |
| FIJI | NETHERLANDS | ZIMBABWE |
| FINLAND | NEW ZEALAND | |
| FRANCE | NICARAGUA | |
| GABON | NIGER | |
| GEORGIA | NIGERIA | |
| GERMANY | NORWAY | |
| GHANA | OMAN | |
| GREECE | PAKISTAN | |
| | PALAU | |

The Agency's Statute was approved on 23 October 1956 by the Conference on the Statute of the IAEA held at United Nations Headquarters, New York; it entered into force on 29 July 1957. The Headquarters of the Agency are situated in Vienna. Its principal objective is "to accelerate and enlarge the contribution of atomic energy to peace, health and prosperity throughout the world".

IAEA HUMAN HEALTH SERIES No. 25

ROLES AND RESPONSIBILITIES,
AND EDUCATION AND
TRAINING REQUIREMENTS FOR
CLINICALLY QUALIFIED MEDICAL
PHYSICISTS

INTERNATIONAL ATOMIC ENERGY AGENCY
VIENNA, 2013

COPYRIGHT NOTICE

All IAEA scientific and technical publications are protected by the terms of the Universal Copyright Convention as adopted in 1952 (Berne) and as revised in 1972 (Paris). The copyright has since been extended by the World Intellectual Property Organization (Geneva) to include electronic and virtual intellectual property. Permission to use whole or parts of texts contained in IAEA publications in printed or electronic form must be obtained and is usually subject to royalty agreements. Proposals for non-commercial reproductions and translations are welcomed and considered on a case-by-case basis. Enquiries should be addressed to the IAEA Publishing Section at:

Marketing and Sales Unit, Publishing Section
International Atomic Energy Agency
Vienna International Centre
PO Box 100
1400 Vienna, Austria
fax: +43 1 2600 29302
tel.: +43 1 2600 22417
email: sales.publications@iaea.org
<http://www.iaea.org/books>

© IAEA, 2013

Printed by the IAEA in Austria

August 2013

STI/PUB/1610

IAEA Library Cataloguing in Publication Data

Roles and responsibilities, and education and training requirements for clinically qualified medical physicists. — Vienna : International Atomic Energy Agency, 2013.

p. ; 24 cm. — (IAEA human health series, ISSN 2075-3772 ; no. 25)

STI/PUB/1610

ISBN 978-92-0-142010-7

Includes bibliographical references.

1. Medical physics — Study and teaching. 2. Nuclear medicine — Quality control.
I. International Atomic Energy Agency. II. Series.

IAEAL

13-00829

FOREWORD

The IAEA technical cooperation project Strengthening Medical Physics in Radiation Medicine was approved by the IAEA Board of Governors for the period 2009–2013 with the aim of ensuring the safe and effective diagnosis and treatment of patients. The IAEA, together with the World Health Organization and stakeholders from numerous medical physics professional societies worldwide, including the International Organization for Medical Physics (IOMP), the European Federation of Organisations for Medical Physics, the American Association of Physicists in Medicine (AAPM), the Latin American Medical Physics Association, the Asia–Oceania Federation of Organizations for Medical Physics, the European Society for Radiotherapy and Oncology, the European Commission and the International Radiation Protection Association, as well as regional counterparts from Africa, Asia, Europe and Latin America, met in Vienna in May 2009 to plan and coordinate the new project. A shortage of clinically qualified medical physicists (CQMPs), insufficient education and training (especially properly organized and coordinated clinical training), and lack of professional recognition were identified as the main problems to be addressed under this project. This publication was developed under the project framework in response to these findings. It aims, first, at defining appropriately and unequivocally the roles and responsibilities of a CQMP in specialties of medical physics related to the use of ionizing radiation, such as radiation therapy, nuclear medicine, and diagnostic and interventional radiology. Important, non-ionizing radiation imaging specialties, such as magnetic resonance and ultrasound, are also considered for completeness. On the basis of these tasks, this book provides recommended minimum requirements for the academic education and clinical training of CQMPs, including recommendations for their accreditation, certification and registration, along with continuing professional development. The goal is to establish criteria that support the harmonization of education and clinical training worldwide, as well as to promote the recognition of medical physics as a profession.

This publication has been endorsed by the AAPM and IOMP.

The IAEA acknowledges the major contributions of C. Constantinou (Cyprus) and K.Y. Cheung (China), Chairs of the working groups that drafted the recommendations, on the role and responsibilities of CQMPs and on education, and on clinical training requirements and certification, respectively. The IAEA also acknowledges the special contribution of P. Andreo (Sweden) for the compilation of the final report.

The IAEA officers responsible for this publication were A. Meghziene and D. van der Merwe from the Division of Human Health.

EDITORIAL NOTE

Although great care has been taken to maintain the accuracy of information contained in this publication, neither the IAEA nor its Member States assume any responsibility for consequences which may arise from its use.

The use of particular designations of countries or territories does not imply any judgement by the publisher, the IAEA, as to the legal status of such countries or territories, of their authorities and institutions or of the delimitation of their boundaries.

The mention of names of specific companies or products (whether or not indicated as registered) does not imply any intention to infringe proprietary rights, nor should it be construed as an endorsement or recommendation on the part of the IAEA.

The IAEA has no responsibility for the persistence or accuracy of URLs for external or third party Internet web sites referred to in this book and does not guarantee that any content on such web sites is, or will remain, accurate or appropriate.

CONTENTS

| | | |
|--------|--|----|
| 1. | INTRODUCTION..... | 1 |
| 2. | ROLES AND RESPONSIBILITIES OF CLINICALLY QUALIFIED MEDICAL PHYSICISTS..... | 3 |
| 3. | ROLES AND RESPONSIBILITIES OF CLINICALLY QUALIFIED MEDICAL PHYSICISTS COMMON TO ALL MEDICAL PHYSICS SPECIALTIES..... | 5 |
| 4. | ROLES AND RESPONSIBILITIES SPECIFIC TO EACH MEDICAL PHYSICS SPECIALTY..... | 9 |
| 4.1. | Radiation therapy..... | 9 |
| 4.2. | Medical imaging..... | 20 |
| 4.2.1. | Nuclear medicine..... | 21 |
| 4.2.2. | Diagnostic and interventional radiology..... | 26 |
| 4.2.3. | Other imaging areas..... | 30 |
| 4.3. | Occupational and public radiation protection..... | 36 |
| 4.3.1. | Safety of the staff and the public..... | 36 |
| 4.3.2. | Safety of radioactive sources..... | 39 |
| 5. | STAFFING AND ORGANIZATION OF A MEDICAL PHYSICS SERVICE..... | 39 |
| 5.1. | Staffing requirements..... | 41 |
| 6. | RECOMMENDATIONS FOR THE ACADEMIC AND CLINICAL TRAINING OF CLINICALLY QUALIFIED MEDICAL PHYSICISTS..... | 44 |
| 6.1. | Current status..... | 44 |
| 6.2. | Qualification requirements for academic and clinical training..... | 45 |
| 6.3. | Accreditation, certification and registration..... | 47 |
| 6.4. | Continuing professional development programme..... | 48 |
| 6.5. | Summary of qualification requirements..... | 49 |

APPENDIX I: CODE OF ETHICS FOR MEDICAL PHYSICISTS
WORKING IN THE CLINICAL ENVIRONMENT. 51

APPENDIX II: MEDICAL DOSIMETRISTS — DUTIES AND
SKILLS 62

REFERENCES 65

LIST OF ABBREVIATIONS AND ACRONYMS. 69

CONTRIBUTORS TO DRAFTING AND REVIEW. 71

1. INTRODUCTION

Medical physics is a branch of applied physics, pursued by medical physicists, who use physics principles, methods and techniques in practice, in the clinical environment and in research, for the prevention, diagnosis and treatment of human diseases with the specific goal of improving human health and well-being. Medical physics encompasses a wide range of applications in multiple areas and has recently been classified internationally as a profession [1]. The general roles and responsibilities of medical physicists have been summarized by the International Organization for Medical Physics (IOMP) [2]. Providing a detailed description of these roles in a clinical environment, mainly in fields related to the use of ionizing radiation, is one of the goals of the present publication as well as providing the basis for justifying harmonized international requirements for the academic education and clinical training of medical physicists.

According to the definition of the International Basic Safety Standards (BSS) [3], a medical physicist working in a clinical environment is:

“a health professional, with specialist education and training in the concepts and techniques of applying physics in medicine, and competent to practise independently in one or more of the subfields (specialties) of medical physics.”

A similar definition, although restricted to applications dealing with medical radiation exposures, was given by Council Directive 97/43/Euratom for the term ‘medical physics expert’ [4], recently amended during the process of the revision of the Euratom Basic Safety Standards [5]. The term ‘practise independently’ means that a medical physicist works without the direct supervision of a more experienced medical physicist and is capable of ensuring the safe and effective delivery of radiation to achieve a diagnostic or therapeutic result as prescribed in patient care. The specialties involving the use of ionizing radiation in medical exposure comprise medical imaging physics, which includes diagnostic and interventional radiology (DIR) procedures (radiology physics) and radionuclide procedures (nuclear medicine physics), radiation therapy physics and medical health physics (radiation protection in medicine). These medical physics specialties are an essential component of radiation medicine.

The goal of the publication is to establish criteria that support the harmonization of education and clinical training worldwide, as well as to promote the recognition and professionalism of medical physics as a profession internationally.

Medical physicists must have received appropriate undergraduate education in physical or engineering sciences, followed by a professional competency training that includes an additional period of 1–3 years of academic education in medical physics at the postgraduate level. In order to become a clinically qualified medical physicist (CQMP), the academic training at the postgraduate level must be followed by at least two additional years of structured practical training in a clinical environment, in one or more specialties of medical physics. Overall, the academic education and clinical training should extend over a minimum period of, typically, seven years. Medical physicists that have completed an academic programme and work or do research in a non-clinical environment will require additional appropriate training to become CQMPs. The education and training of medical physicists should be recognized by a national or international accreditation body. In order to maintain and enhance their professional competence, and their ability to work independently, practising medical physicists should undertake a continuing professional development (CPD) programme which should include attendance at national and/or international conferences and courses on topics related to their field of specialization. They should also regularly consult relevant scientific journals and literature.

The competence of medical physicists should be assessed by an appropriate authority, which results in a formal mechanism for their registration and/or accreditation or certification. The professional certification body should represent medical physicists duly elected by the national CQMP community for the purpose. Where no formal mechanism exists, medical physicists should be certified by a national or international professional certification body, after proving by means of written and oral examinations that they have the level of expertise needed to practise independently in one or more subfields of medical physics. A certified medical physicist is, therefore, a CQMP who has been certified to have the level of expertise needed to practise independently in one or more subfields of medical physics, based on passing written and oral examinations conducted by a national or international professional certification body, duly appointed for this purpose.

This publication aims to provide recommendations on the minimum requirements for the academic education and clinical training necessary for a physicist to become a CQMP. It includes recommendations for accreditation, certification and registration, along with CPD. With the purpose of establishing the grounds for justifying the recommendations, it first details the roles and responsibilities of a CQMP in the various specialties, including advice on the organization of a clinical medical physics service.

As CQMPs are health professionals and, as a result, have access to patient data, have direct contact with patients in the clinical environment and participate in patient management, they are subject to the same ethical principles that

determine professional behaviour. A sample code of ethics that must be adhered to by CQMPs in a clinical environment is summarized in Appendix I.

In some countries, particularly in North America, a separate group of professionals, known as medical dosimetrists, has emerged. In most countries, the roles and responsibilities of medical dosimetrists are performed by CQMPs. Appendix II provides information on the typical duties and skills of medical dosimetrists according to the American Association of Medical Dosimetrists (AAMD).

2. ROLES AND RESPONSIBILITIES OF CLINICALLY QUALIFIED MEDICAL PHYSICISTS

The medical physicist is a member of the multidisciplinary team involved in diagnosing and treating patients with ionizing and non-ionizing radiation, and contributes to ensuring a high standard of quality of service in hospitals and clinics (cf. Refs [6–8]). As a professional in physics, a CQMP is able to identify problems and formulate strategies for their solution, interpret new or non-standard information, evaluate unusual situations in a scientific way, communicate scientific opinions clearly and accurately, recognize erroneous situations and take appropriate corrective actions, and recognize their own limitations in knowledge and skills. The primary role of the CQMP in clinical practice is to optimize, or advise other health care professionals to optimize, the use of radiation to ensure the safety and quality of diagnostic or therapeutic procedures, establish policies, guidelines and measurement techniques for the determination of patient dose, and to collect and analyse clinical physics data for diagnosis or treatment of diseases.

CQMPs are responsible for developing and implementing the physical and technical aspects of the quality assurance (QA) programmes in diagnostic and therapeutic procedures. They are also responsible for advising or assisting other health care professionals in optimizing the balance between the beneficial and deleterious effects of radiation, and play a key role in the installation of new equipment with regard to the radiation protection of patients, workers and the public, including the design of radiation shielding. Medical physicists perform research and development of new equipment, methods, procedures and technologies for improving diagnostic and therapeutic clinical care. They also provide education and training of applied physics and radiation safety to medical practitioners [9], nurses, technical staff, students and other personnel. In most hospitals, CQMPs have responsibilities in ensuring that diagnostic imaging and radiation treatment facilities comply with the national rules and regulations, and follow the recommendations of competent international bodies [3]. They

support the hospital management in defining specifications for the purchase of equipment, and provide technical, scientific and administrative advice.

This section describes the specific roles and responsibilities of CQMPs in radiation therapy and medical imaging with ionizing and non-ionizing radiation. Although not fully described in this publication, CQMPs are sometimes also competent to provide professional support in other areas of medicine (photodynamic therapy, optical imaging, use of lasers, therapeutic use of ultrasound and physiological measurement, etc.). Some of these modalities are intrinsically included in this section.

The principal roles and responsibilities of CQMPs in a hospital environment are based on their professional development in one or more of the specialties of medical physics and on their clinical knowledge of the principles, and the anatomical and physiological basis for related clinical studies, techniques for clinical procedures, etc. The roles and responsibilities can be divided into two major groups: one considers aspects which are common across all medical physics specialties and the other is related to specific areas of specialization. These can be summarized as:

- (a) Roles and responsibilities common to all specialties:
 - (i) Calibration and verification of measurement instruments;
 - (ii) Technical supervision of equipment operation and maintenance;
 - (iii) Records and documentation;
 - (iv) Clinical computing and networking;
 - (v) Research and development;
 - (vi) Education and training.
- (b) Roles and responsibilities specific to the specialties of radiation therapy, nuclear medicine and DIR:
 - (i) Installation design, technical specification, acceptance and commissioning of equipment, including the establishment of criteria for acceptable performance;
 - (ii) Radiation safety and protection of patients, staff and the general public;
 - (iii) Radiation dosimetry of radiation sources and patients;
 - (iv) Optimization of the physical aspects of diagnostic and therapeutic procedures;
 - (v) Quality management of the physical and technical aspects of radiation medicine, such as:
 - Development of institutional policies and procedures for the safe and effective use of radiation;
 - Supervision of QA and quality control (QC) procedures;
 - Risk assessment and management.

- (vi) Collaboration with other clinical professionals in patient care, such as:
 - Consultation with medical practitioners and other clinical team members during diagnostic or therapeutic procedures;
 - Commissioning and supervision of the implementation of new or complex clinical procedures, and assisting the training of clinical staff.

The roles and responsibilities common to all medical physics specialties are covered below, followed by a section where the functions and responsibilities specific to the different ionizing radiation based specialties, namely radiation therapy, nuclear medicine and DIR, are given. The roles and responsibilities in some imaging specialties dealing with non-ionizing radiation, such as magnetic resonance imaging (MRI) and ultrasound imaging (USI), are also delineated. A summary of functions and responsibilities is presented, together with the responsibilities of CQMPs in radiation protection of patients, staff and the public. The radiation protection aspects relating to the use of radioactive sources and radiation generators in the clinic are discussed within each area of specialization, while those related to radiation protection of workers and the public are discussed separately.

3. ROLES AND RESPONSIBILITIES OF CLINICALLY QUALIFIED MEDICAL PHYSICISTS COMMON TO ALL MEDICAL PHYSICS SPECIALTIES

The main functions and responsibilities of CQMPs which are common to all medical physics specialties are described below (summarized in Table 1):

- (a) *Calibration and verification of measurement instruments:* CQMPs are responsible for the calibration of the instruments they use or are responsible for following recommended standards or codes of practice and keeping appropriate calibration records. They are responsible for developing procedures to determine the stability of the instruments for clinical use.
- (b) *Technical supervision of equipment operation and maintenance:* CQMPs supervise the preventive and corrective maintenance, repair and calibration of the diagnostic, therapeutic and measuring equipment, and are responsible for documenting the relevant information. They collaborate with service engineers in developing and maintaining a quality management programme for all of the equipment, so as to make it possible for the equipment to operate optimally. CQMPs are responsible for authorizing the clinical use

TABLE 1. SUMMARY OF THE ROLES AND RESPONSIBILITIES OF CLINICALLY QUALIFIED MEDICAL PHYSICISTS COMMON TO ALL MEDICAL PHYSICS SPECIALTIES

| | |
|--|---|
| (a) Calibration and verification of measurement instruments | CQMPs are responsible for the suitability and periodic calibration of the instruments they use or are responsible for. |
| (b) Technical supervision of equipment operation and maintenance | CQMPs are responsible for establishing acceptance and commissioning procedures for diagnostic, therapeutic and measurement equipment. They collaborate with service engineers for the coordination of preventive and maintenance programmes and supervise their implementation, performing quality control and calibration measurements to ensure the safe and optimal performance of the equipment, and authorizing clinical use after each procedure. |
| (c) Records and documentation | CQMPs are responsible for the documentation and records on maintenance, calibrations and performance of the equipment in their area of work, providing evidence of compliance with regulatory and accreditation authorities' rules and recommendations of equipment and procedures. |
| (d) Clinical computing and networking | CQMPs assist in the clinical use of reviewing/processing computer workstations, perform basic computer system management and first line troubleshooting. They collaborate with computer engineers for the verification of network integration and data transfer to ensure that all systems are functional. |
| (e) Research and development | CQMPs evaluate new technologies and investigate the adoption of new procedures, assisting in the training of clinical staff for their implementation. They support technical aspects of clinical research and often have a leading role in the medical research team, particularly in centres of high technological complexity. They carry out research and development in medical physics and instrumentation. |

TABLE 1. SUMMARY OF THE ROLES AND RESPONSIBILITIES OF CLINICALLY QUALIFIED MEDICAL PHYSICISTS COMMON TO ALL MEDICAL PHYSICS SPECIALTIES (cont.)

(f) Education and training

CQMPs provide lectures and training in medical physics to medical practitioners, technologists, junior medical physicists, nurses, students, residents and technical maintenance staff. They also provide mentoring and supervision to other professionals, based on the requirements for their professional education and development.

Note: CQMP: clinically qualified medical physicist.

of radiation equipment after a maintenance procedure. For this purpose, they perform QC measurements of particular complexity after preventive or corrective maintenance, to ensure that the function of the equipment has not been affected by any alteration made during maintenance or repair. By verifying the proper function of the equipment, they aim to ensure optimal performance as well as patient and staff safety.

- (c) *Records and documentation*: CQMPs provide the documentation needed and maintain the records of their area of work, providing evidence of the compliance of equipment and procedures with the appropriate regulatory and accreditation authorities' rules and recommendations. They review the records in patient clinical histories regarding the correct interpretation of a dose prescription or request for a radiation medicine imaging procedure, optimization of radiation therapy treatment plan parameters, therapeutic or imaging radiation beam parameters, patient dosimetry and/or radiopharmaceutical dosimetry. In addition, CQMPs are responsible for the documentation of QA, equipment calibration, independent dosimetry audits and any other medical physics policies and procedures.
- (d) *Clinical computing and networking*: CQMPs have the knowledge and skills to assist in the clinical use of Intranets, e.g. reviewing/processing computer workstations or record and verify systems, and to perform basic computer system management and administrative tasks, apply image data processing techniques, e.g. image reconstruction, registration and fusion, and perform first line system troubleshooting to eliminate common computer problems. They are familiar with the core concepts and use of record and verify systems, picture archiving and communication systems, radiology information systems and hospital information systems. They are also knowledgeable on how to store, handle or distribute patient images and data between different workstations. They collaborate with computer engineers for the verification of network integration and data transfer to ensure that all systems are functional, and patient data are protected against unauthorized access and breach of privacy.
- (e) *Research and development*: CQMPs evaluate new technologies and investigate the adoption of new procedures, assisting in the training of clinical staff for their implementation. They support the physical and technical aspects of clinical research and often have a leading role in the medical research team, particularly in centres of high technological complexity. CQMPs play an important role in clinical protocols used in applied research. They carry out research and development in medical physics and instrumentation, monitor current advances in specific areas of research, and design project plans with milestones, experimental methodology and estimated time frames.

- (f) *Education and training*: CQMPs play a key role in the academic education and clinical training of medical physicists. They also lecture and develop educational material for medical practitioners, technologists, dosimetrists and nurses, as well as for students, residents and technical maintenance staff. In addition, they may also provide ongoing mentoring or clinical supervision of professionals, based on the requirements for their continued professional education and development.

4. ROLES AND RESPONSIBILITIES SPECIFIC TO EACH MEDICAL PHYSICS SPECIALTY

4.1. RADIATION THERAPY

Radiation therapy is the medical discipline which uses generators of ionizing radiation or radioactive sources to deliver a high radiation dose to a target volume containing a malignant or benign lesion, while sparing the surrounding healthy tissues. When external sources of X rays, gamma rays, electrons, protons and heavier ions, neutrons, etc. are used, the modality is called teletherapy. Another approach, known as brachytherapy, employs sealed radioactive sources emitting gamma rays, electrons or other possible particles to treat cancerous tissues in almost every anatomical site of the body; depending on the source geometry distribution, the technique is referred to as contact (intracavitary, intraluminal, endovascular or surface) or interstitial brachytherapy. Both modalities rely comprehensively on medical imaging techniques to localize the tumours and clinical volumes to be treated or spared. The medical specialty is often termed ‘radiation oncology’, although strictly this includes other aspects of cancer management in addition to the therapeutic use of radiation. Medical physicists are only involved with the patient once the clinical decision to include radiation therapy in the management of the patient has been decided and, for this reason, the term ‘radiation therapy physicist’ appears to be more consistent than ‘radiation oncology physicist’; there is, however, a substantial lack of harmonization of the terminology worldwide.

CQMPs in radiation therapy develop and implement procedures for dosimetry and treatment planning, for QA of processes and equipment, for treatment delivery and verification, and for the radiation safety and protection of patients, staff members and the public. Their knowledge is also applied to the development and optimization of new treatment techniques and they play an important role in the adoption, implementation, development, safe use and optimization of advanced techniques and technologies. The performance of the

medical physicists in radiation therapy is fundamental to providing a safe and qualified service. Hence, their scientific and practical training should include an in depth understanding of the clinical aspects of radiobiology. This includes the use of fractionation schemes accounting for gaps between radiation therapy fractions, biological treatment parameters for different tumour types, rationale for using X rays and electrons versus protons or heavier ions, distributions of energy deposition and linear energy transfer, and dose optimization. The main responsibilities and functions of CQMPs in radiation therapy are described below (summarized in Table 2):

- (a) *Installation design, technical specification, and acceptance and commissioning of equipment, including the establishment of criteria for acceptable performance:* Within the technical specification, acceptance, commissioning and supervision of the proper operation of the installation and its equipment, and the establishment of criteria for its acceptable performance, the following roles and duties must be considered:
 - (i) CQMPs are an essential part of the team for the installation, design and shielding of new or modified radiation therapy rooms, ensuring that all safety requirements are complied with. They calculate and provide the thickness, material composition and placement of the shielding needed to protect patients, staff and the general public, thus ensuring that all requirements of safety and functionality are met. They also verify the adequacy of the shielding after installation.
 - (ii) CQMPs have a leading role in preparing equipment specifications according to the needs of the radiation therapy facility, and they participate in the tender evaluation and purchase recommendation of the equipment. They analyse the functional requirements for clinical use, and specify the necessary conditions for integration, compatibility and connectivity to existing equipment of the equipment to be purchased.
 - (iii) Following the installation of new equipment, CQMPs are responsible for specifying the basic standards to be applied for its acceptance and subsequent commissioning. They ensure that all units and systems function according to their technical specification and provide advice on any deviation of equipment performance from acceptable criteria, including guidance on decommissioning when appropriate. CQMPs also have, often in collaboration with computer engineers, responsibility for the verification of the computer systems and algorithms associated with the new equipment, and for ensuring that they are adequate for safe and effective clinical use.

TABLE 2. SUMMARY OF THE ROLES AND RESPONSIBILITIES OF CLINICALLY QUALIFIED MEDICAL PHYSICISTS SPECIFIC TO THE SPECIALTIES OF RADIATION THERAPY, NUCLEAR MEDICINE, AND DIAGNOSTIC AND INTERVENTIONAL RADIOLOGY

| Area of responsibility | Radiation therapy | Nuclear medicine | Diagnostic and interventional radiology |
|---|--|---|--|
| (a) <i>Installation design, technical specification, acceptance, commissioning and maintenance of equipment</i> | <p>(i) Be an essential part of the team for shielding and installation design of new or modified radiation therapy rooms, ensuring that safety requirements are complied with;</p> <p>(ii) Lead the development of equipment specifications;</p> <p>(iii) Have responsibility for the acceptance and commissioning of equipment, including radiation therapy treatment and imaging units, brachytherapy sources and treatment planning systems;</p> <p>(iv) Provide advice on equipment decommissioning.</p> | <p>(i) Be an essential part of the team for the shielding and design of new or modified facilities, ensuring that safety requirements are complied with;</p> <p>(ii) Lead the development of equipment specifications;</p> <p>(iii) Have responsibility for the acceptance and commissioning of equipment;</p> <p>(iv) Provide advice on equipment decommissioning.</p> | <p>(i) Be an essential part of the team for the shielding and installation design of new or modified facilities, ensuring that safety requirements are complied with;</p> <p>(ii) Lead the development of equipment specifications;</p> <p>(iii) Have responsibility for the acceptance and commissioning of equipment;</p> <p>(iv) Provide advice on equipment decommissioning.</p> |

TABLE 2. SUMMARY OF THE ROLES AND RESPONSIBILITIES OF CLINICALLY QUALIFIED MEDICAL PHYSICISTS SPECIFIC TO THE SPECIALTIES OF RADIATION THERAPY, NUCLEAR MEDICINE, AND DIAGNOSTIC AND INTERVENTIONAL RADIOLOGY (cont.)

| Area of responsibility | Radiation therapy | Nuclear medicine | Diagnostic and interventional radiology |
|--|--|---|--|
| (b) <i>Radiation safety and protection of patients, staff and the general public</i> | <ul style="list-style-type: none"> (i) Develop the clinical radiation safety programme for radiation protection of patients, staff and the public; (ii) Participate in the investigation of radiation incidents and accidents; (iii) Develop procedures for verifying the integrity, safe operation and use of radiation therapy equipment and accessories. | <ul style="list-style-type: none"> (i) Develop the clinical radiation safety programme for radiation protection of patients, staff and the public; (ii) Participate in the investigation of radiation incidents and accidents; (iii) Develop procedures for verifying the integrity, safe operation and use of nuclear medicine equipment and radioactive sources. | <ul style="list-style-type: none"> (i) Develop the clinical radiation safety programme for radiation protection of patients, staff and the public; (ii) Participate in the investigation of radiation incidents and accidents; (iii) Develop procedures for verifying the integrity, safe operation and use of diagnostic and interventional radiology equipment and accessories. |

TABLE 2. SUMMARY OF THE ROLES AND RESPONSIBILITIES OF CLINICALLY QUALIFIED MEDICAL PHYSICISTS SPECIFIC TO THE SPECIALTIES OF RADIATION THERAPY, NUCLEAR MEDICINE, AND DIAGNOSTIC AND INTERVENTIONAL RADIOLOGY (cont.)

| Area of responsibility | Radiation therapy | Nuclear medicine | Diagnostic and interventional radiology |
|--|--|--|--|
| (c) <i>Patient radiation dosimetry</i> | <ul style="list-style-type: none"> (i) Acquire the data needed for the clinical use of treatment units (part of the acceptance and commissioning process for entry into service); (ii) Develop tables of data for clinical use; (iii) Establish and perform procedures for patient dose calculation and verification; (iv) Have overall responsibility for the treatment planning calculations; (v) Perform patient dose verifications including in vivo dosimetry. | <ul style="list-style-type: none"> (i) Perform activity measurements and calculation of the dose received by different organs following the administration of radiopharmaceuticals in the various clinical procedures; (ii) Perform patient specific dose calculations, establishing tolerances. | <ul style="list-style-type: none"> (i) Establish procedures for estimating the absorbed dose in patients during different clinical procedures; (ii) Perform patient specific dose calculations, establishing tolerances; (iii) Perform patient dose estimations to establish diagnostic reference levels, or to verify conformity with recommended diagnostic reference levels. |

TABLE 2. SUMMARY OF THE ROLES AND RESPONSIBILITIES OF CLINICALLY QUALIFIED MEDICAL PHYSICISTS SPECIFIC TO THE SPECIALTIES OF RADIATION THERAPY, NUCLEAR MEDICINE, AND DIAGNOSTIC AND INTERVENTIONAL RADIOLOGY (cont.)

| Area of responsibility | Radiation therapy | Nuclear medicine | Diagnostic and interventional radiology |
|---|---|--|--|
| (d) <i>Optimization of physical aspects of medical procedures</i> | (i) Optimize the treatment planning process, including image acquisition and treatment delivery; (ii) Develop a quality management programme for radiation therapy imaging, dose calculation and treatment delivery systems. | (i) Optimize data acquisition processes and procedures to improve image quality while minimizing radiation dose to patients; (ii) Assist nuclear medicine medical practitioners in evaluating examination efficacy and in image quality and perception studies. | (i) Optimize data acquisition techniques and procedures to improve image quality while minimizing radiation dose to patients; (ii) Assist diagnostic and interventional radiology medical specialists in evaluating examination efficacy and in image quality and perception studies. |

TABLE 2. SUMMARY OF THE ROLES AND RESPONSIBILITIES OF CLINICALLY QUALIFIED MEDICAL PHYSICISTS SPECIFIC TO THE SPECIALTIES OF RADIATION THERAPY, NUCLEAR MEDICINE, AND DIAGNOSTIC AND INTERVENTIONAL RADIOLOGY (cont.)

| Area of responsibility | Radiation therapy | Nuclear medicine | Diagnostic and interventional radiology |
|---|--|--|--|
| (e) <i>Quality management of the physical and technical aspects</i> | <p>Participate as a team member in designing and implementing a quality management programme, being responsible for:</p> <ul style="list-style-type: none"> (i) Developing institutional policies and procedures related to the use of radiation; (ii) Establishing and implementing a quality assurance programme for treatment units, treatment planning systems, dosimetry equipment and radiation therapy imaging equipment; (iii) Calibrating radiation generators and brachytherapy sources according to a well established code of practice; (iv) Performing risk assessment, identifying potential radiation exposures, and developing action procedures for such events. (v) Investigating unintended or accidental medical exposures. | <p>Participate as a team member in designing and implementing a quality management programme, being responsible for:</p> <ul style="list-style-type: none"> (i) Developing institutional policies and procedures for the continuous optimization of radiation use; (ii) Establishing and implementing a quality assurance programme with appropriate elements for the handling and measurement of radioactive sources and regulatory compliance of imaging and dosimetry equipment; (iii) Performing risk assessment, identifying potential radiation exposures and developing action procedures for such events; (iv) Investigating unintended or accidental medical exposures. | <p>Participate as a team member in designing and implementing a quality management programme, being responsible for:</p> <ul style="list-style-type: none"> (i) Developing institutional policies and procedures for the continuous optimization of radiation use; (ii) Developing and implementing procedures for the initial and continuing evaluation of the imaging and associated equipment, as well as calibration of patient dosimetry equipment; (iii) Calibrating X ray units according to a well established code of practice; (iv) Ensuring compliance of imaging radiation equipment with government and accreditation agency regulations and recommendations. |

TABLE 2. SUMMARY OF THE ROLES AND RESPONSIBILITIES OF CLINICALLY QUALIFIED MEDICAL PHYSICISTS SPECIFIC TO THE SPECIALTIES OF RADIATION THERAPY, NUCLEAR MEDICINE, AND DIAGNOSTIC AND INTERVENTIONAL RADIOLOGY (cont.)

| Area of responsibility | Radiation therapy | Nuclear medicine | Diagnostic and interventional radiology |
|--|--|---|--|
| (f) <i>Collaboration with other clinical professionals as key team members</i> | <p>(i) Provide consultation to radiation oncology medical practitioners to establish optimal treatment technique;</p> <p>(ii) Supervise technologists in the implementation of new clinical procedures, including assistance in set-up and correct treatment delivery.</p> | <p>(i) Provide consultation to nuclear medicine medical practitioners on special cases of diagnostic exploration or treatment and assist to establish the optimized approach for each case;</p> <p>(ii) Assist to introduce new clinical procedures, develop methods for their quality assurance and control, and supervise their implementation.</p> | <p>(i) Provide consultation to diagnostic and interventional radiology medical practitioners on special cases of diagnostic or interventional procedures and assist to establish the optimized approach for each case;</p> <p>(ii) Assist to introduce new clinical procedures, develop methods for their quality assurance and control, and supervise their implementation.</p> |

- (b) *Radiation safety and protection of patients, staff and the general public:* CQMPs have responsibilities in the development and implementation of a clinical radiation safety programme for the radiation protection of the patient in radiation therapy. In the majority of cases, however, they also have responsibilities with respect to radiation safety of the staff and the public, as it pertains to the radiation therapy service and infrastructure. CQMPs are responsible for developing the procedures needed for testing the integrity of the equipment and accessories, for the proper operation of interlocks and other safety aspects.
- (c) *Patient radiation dosimetry:* CQMPs are responsible for establishing procedures for the calculation and verification of the radiation dose to the patient. Their duties include dosimetry measurements using ionization chambers and other detectors for the reference and relative determination of absorbed dose from external beam radiation therapy and brachytherapy sources, development of methods to analyse the results of dose measurements, and verification of the accuracy of dose distributions delivered to patients. Tasks related to patient dosimetry include:
- (i) Acceptance testing and commissioning of radiation generators, radioactive sources and treatment planning systems (TPSs): CQMPs are responsible for the acceptance testing, commissioning and acquisition of all of the data needed for the clinical use of the imaging and treatment units (part of the commissioning process for entry into service):
 - For all the energies, modalities and sources needed for the delivery of external beam radiation therapy and brachytherapy, the process includes measurements to establish the parameters characterizing the radiation sources, including additional measurements for commissioning accessories, which serve as reference values for future QC measurements, as well as for dose calculations at a reference point and for 2-D, 3-D and 4-D dose distributions.
 - Development of tables of data for clinical use: CQMPs are responsible for ensuring that data from the institution's external beams and radioactive sources have been properly modelled and inserted into the TPSs during their commissioning; they record and tabulate the data in a way that is useful and intelligible to those who need to perform or verify dosimetry calculations.
 - (ii) Treatment planning and dose calculations: Medical physicists perform or supervise the calculations and measurements necessary for optimizing the dose distribution in the patient and ensure their proper application for the different types of treatment. These can either be manual or computer calculations and/or in-phantom measurements.

CQMPs are also responsible for the validation of image and data transfer to and from the TPS. Often, they also perform administrator duties for the TPS, applying system security policies, enabling data protection, import and export of data, backups, data storage and archival, system upgrades/updates, etc.

- (iii) Patient dose verification: CQMPs are responsible for patient specific dose verification measurements. They establish tolerances and action levels. This includes relevant in vivo dosimetry measurements using appropriate detectors.
- (iv) Additional tasks in brachytherapy: Subsequent to the calibration of the radioactive sources used for brachytherapy, but still as a component of the commissioning process, CQMPs are responsible for the comparison with the manufacturer's calibration certificates, resolving any discrepancy that may arise. To initiate treatments with manual after-loading implants, they are responsible for the transfer of the sources from the shielded safe to the patient's room, and for the necessary radiation survey after the sources have been inserted into the applicators. They make periodic QC measurements to ensure that the computer controlled movements of the source are accurate. CQMPs are responsible for producing policies and procedures to ensure the safety and protection of patients, staff and members of the public for this type of source. They develop an emergency action plan, indicating the steps to be followed in the case that a source is lost or the computerized brachytherapy treatment system fails. When decommissioning a brachytherapy unit or sources, medical physicists are responsible for their radioactive waste disposal after removal of the source from the equipment.
- (d) *Optimization of physical aspects of therapeutic procedures*: CQMPs have responsibilities for optimizing the physical and technical aspects of the therapeutic procedures used in their radiation therapy facility. This includes assisting in the selection of the appropriate positioning and immobilization aids for optimization of patient treatment plans according to the delivery techniques envisaged, overseeing the manufacture, QC and verification of beam shaping devices, performing the QA of the intensity modulation used for each treatment, defining the imaging protocols used for treatment planning and image guided radiation therapy (IGRT), and developing the methodologies used in the determination of set-up margins.
- (e) *Quality management of the physical and technical aspects of radiation therapy*: CQMPs participate as team members in establishing a quality management programme and have responsibility for the physical and technical aspects. Related tasks are:

- (i) Developing institutional policies and procedures related to the use of radiation, which includes responsibility for documenting and implementing new policies and procedures, or updating existing ones:
 - Procedures related to health and safety, e.g. procedures related to radiation protection, personnel monitoring, reporting of incidents and near accidents, QA, safety during work in mould room workshops, patient and personnel radiation dose and associated risks;
 - Procedures related to equipment, e.g. procedures for the immediate notification of equipment failure to technical staff;
 - Procedures related to patient treatments, e.g. for the care of patients with special needs and review of dosimetry information noted in patient records;
 - Protocols and procedures related to improvement of quality of service, workflow, productivity of personnel, safe operation of new equipment and information systems, and training of personnel.
- (ii) Establishing QA programmes and performing QC of all of the radiation generators (all radiation therapy imaging and treatment units), TPSs, radiation therapy networks, e.g. record and verify systems, and dosimetry equipment (ionization chambers and other detectors, electrometers, phantoms, scanners, etc.): One of the major tasks of QA in radiation therapy is the calibration of radiation sources. CQMPs are responsible for performing the calibration of radiation units and brachytherapy sources according to well established dosimetry protocols or codes of practice, and for ensuring compliance of radiation therapy equipment with national and international regulations and recommendations. They also verify the accuracy of the TPS and perform QC of individual treatment plans using independent dose calculation methods or systems.
- (iii) Performing risk assessments and identifying potential radiation emergencies, such as incidents resulting from equipment malfunction, human error or loss of radioactive sources: CQMPs develop plans of action to be followed in the event of such occurrences and carry out drills to verify that they can be implemented correctly. In general, CQMPs try to find ways to minimize the risk in each case, adopt mandatory peer review processes, follow continuous quality improvement methods and participate in external audits whenever possible.

- (iv) Investigating unintended or accidental medical exposures: CQMPs have responsibilities in analysing all incidents related to equipment failure, accident, error or other unsolicited event which could result in patients receiving an exposure that was significantly different, higher or lower, from that prescribed. CQMPs provide consultation on the doses received by patients or personnel and on their associated risks, and recommend measures to minimize the likelihood of accidents happening again.
- (f) *Collaboration with other clinical professionals:* CQMPs are key members of the team of clinical professionals, including medical practitioners, technologists and nursing staff, that work together in the treatment of malignant diseases. The contribution of CQMPs in this respect includes:
 - (i) Consultation with radiation oncology medical practitioners on patient cases, in order to establish the optimal treatment technique including patient positioning and immobilization aids and accessories, and beam modifiers that may be needed and manufactured for the best outcome: CQMPs provide treatment plan assessments and proposals on how to optimize them.
 - (ii) Collaboration with the technology staff in the set-up, correct treatment delivery and dosimetry of patients: Advanced treatment modalities, especially during initial implementation, may require more intensive collaboration, e.g. intensity modulated radiation therapy (IMRT) and IGRT. Some modalities, e.g. stereotactic radiosurgery and permanent prostate seed implant brachytherapy, require the physical presence of the CQMP during the procedure.
 - (iii) Comprehensive quality management systems require the input of the CQMP in regular peer review meetings, e.g. film review and new patient planning conferences.

4.2. MEDICAL IMAGING

Advances in medical imaging enable the acquisition of very accurate and precise information about the anatomy, physiology and functionality of different organs in the patient's body. Patient images can be acquired using conventional or digital X ray imaging techniques, USI or MRI units and nuclear medicine imaging equipment.

CQMPs are an important component of the team working in DIR and nuclear medicine. They have responsibilities in the optimization of the dose and image quality in medical imaging, including both diagnostic and interventional procedures. CQMPs work with medical practitioners and technologists to interpret and optimize the technical aspects of the different methods of image

acquisition and display. In the current digital era, CQMPs have a significant role in complicated imaging tasks, assisting medical practitioners and technologists in the selection of the optimal post-processing protocol and the optimization of digital image presentation and display. They also deal with patient safety and perform research and teaching tasks.

Owing to the technological differences between medical imaging with radioactive materials and X rays, the roles and responsibilities of CQMPs in nuclear medicine and DIR, respectively, are discussed separately in this section.

4.2.1. Nuclear medicine

Nuclear medicine is the medical discipline which uses unsealed radioactive sources for a variety of diagnostic and therapeutic applications. Nuclear medicine procedures employ pure radioisotopes, or radioisotopes tagged to a specific molecule (e.g. monoclonal antibodies and peptides) to form a radiopharmaceutical, which is administered to patients intravenously or orally. The body metabolizes the radiopharmaceutical as if it were a 'normal' substance, the radionuclide distribution within the body is measured with an external detector and the acquired data are converted into images and analysed. The process allows visualization or tracking of organ function (even at a molecular level) in order to diagnose disease, which can lead to the early detection of abnormalities. At present, nuclear medicine deals mostly with diagnosis, and for this reason is often classified within diagnostic imaging.

The main fields of application of nuclear medicine are oncology, cardiology and neurosciences. Therapeutic applications are mainly related to cancer treatment and laboratory procedures, such as tumour marker determination, molecular biology applications and new emerging techniques for the evaluation of gene expression in several diseases.

CQMPs in nuclear medicine contribute to the implementation and optimization of clinical procedures for diagnosis and treatment utilizing radionuclides. They have responsibilities in the management and dosimetry of all of the radioactive sources and for the planning of therapeutic applications, for the QA of processes and measuring equipment, and for the radiation safety and protection of patients, staff members and the public. They also analyse data to determine physiological variables, such as metabolic rates and blood flow. Their knowledge is applied to the development and optimization of new imaging techniques and they play an important role in the adoption, implementation, development, safe use and optimization of advanced technologies. The performance of medical physicists in nuclear medicine is fundamental to providing a safe and qualified service. Hence, their scientific and practical

training should include an in depth understanding of physiology, radiobiology and mathematical methods for imaging.

The main responsibilities and functions of CQMPs in nuclear medicine are listed below (summarized in Table 2):

- (a) *Installation design, technical specification, acceptance and commissioning of equipment, including the establishment of criteria for acceptable performance:* Within the technical specification, acceptance, commissioning and supervision of the proper operation of the installation and its equipment, and the establishment of criteria for its acceptable performance, the following roles and duties must be considered:
 - (i) CQMPs are an essential part of the design team for new installations. They are responsible for shielding and installation designs of new or modified nuclear medicine facilities, ensuring that all safety requirements are complied with. They calculate and provide the thickness, material composition and placement of shielding needed to protect patients, staff and the general public, and design the system for the management of isotopes and radioactive wastes, thus ensuring that all requirements of safety and functionality are met. They also verify the adequacy of the shielding after installation.
 - (ii) CQMPs have a leading role in preparing equipment specifications according to the needs of the nuclear medicine facility, and they participate in the tender evaluation and purchase recommendation of the equipment. They analyse the functional requirements for clinical use, and specify the necessary conditions for integration, compatibility and connectivity to existing equipment of the equipment to be purchased.
 - (iii) Following the installation of new equipment, CQMPs are responsible for specifying the basic standards to be applied for its acceptance and subsequent commissioning. They ensure that all units and systems function according to their technical specification and provide advice on any deviation of equipment performance from acceptable criteria, including guidance on decommissioning when appropriate. CQMPs also have, often in collaboration with computer engineers, responsibility for the verification of the computer systems; they assist medical practitioners in evaluating imaging or diagnostic algorithms for their safe and effective clinical use. They are responsible for authorizing the clinical use of the imaging equipment and instrumentation after a maintenance procedure.

- (b) *Radiation safety and protection of patients, staff and the general public:* CQMPs have responsibilities in the development and implementation of a clinical radiation safety programme for the radiation protection of the patient in nuclear medicine. In the majority of cases, however, they also have responsibilities with respect to the radiation safety of the staff and the public, as it pertains to the nuclear medicine service and infrastructure. CQMPs are responsible for developing the procedures needed for testing the integrity of equipment and radioactive sources and for the proper operation of the equipment. They establish policies and procedures for the safe transport of these radionuclides, for precautions in the case of contamination or spillage of unsealed radionuclides, and for the management of radioactive waste as required by regulations. CQMPs have responsibilities with respect to discharging the patient after radionuclide therapy, based on the potential exposure of the public. They have responsibilities for communicating with the patients to provide instructions that can further minimize the exposure of relatives and the public after discharge.
- (c) *Patient internal dosimetry:* CQMPs are responsible for establishing procedures for the calculation and verification of the radiation dose received by different internal organs, as well as the total effective dose to the patient, resulting from the administration of radionuclide activity. They are also responsible for verifying the accuracy of such calculations. Tasks related to patient dosimetry include:
- (i) Activity measurements and calculation of absorbed doses: CQMPs use activity distribution data and internal dosimetry methodology to estimate the dose absorbed by patients during different clinical procedures. This requires the use of manual or computerized models and/or in-phantom measurements. Judgement with respect to the applicability of the models used and the ability to synthesize new models is necessary, as well as knowledge to estimate dosimetry uncertainties.
 - (ii) Specific patient dose calculations: CQMPs are responsible for the measurement and/or calculation of individual patient dose, as well as foetal doses in cases where patients are found to be pregnant; this is particularly important in therapeutic applications where dosimetry needs to be done for each patient. They also establish tolerances and make judgements on the appropriateness of the measured data, including advice to the medical practitioner and the patient on any associated risks, especially those related to the induction of cancer.

- (d) *Optimization of the physical aspects of diagnostic procedures:* CQMPs have responsibilities for the optimization of the physical aspects of the imaging systems (gamma cameras, single photon emission computed tomography (SPECT), positron emission tomography (PET), the latter two often combined with computed tomography (CT), etc.). They are responsible for the development and maintenance of a quality management programme for all imaging equipment, so as to produce images of optimal quality while minimizing the radiation dose delivered to patients. CQMPs are also responsible for the equipment and instrumentation needed to ensure proper QC, optimal image quality, monitoring of patient exposure, and determination of dose to individual organs from different nuclear medicine imaging procedures, as well as for the use of the appropriate guidelines and techniques. They can also assist medical practitioners in the evaluation of examination efficacy and participate in image quality and perception studies.
- (e) *Quality management of the physical and technical aspects of nuclear medicine:* CQMPs participate as team members in establishing a quality management programme and have responsibility for physical and technical aspects. Related tasks comprise:
- (i) Developing institutional policies and procedures for the continuous optimization of radiation use, which includes responsibility for writing new policies and procedures, or updating existing ones:
 - Institutional policies and procedures related to improvement of quality of service, productivity of personnel, handling of new equipment and information systems, and training of personnel;
 - Patient imaging and treatment, e.g. for children or patients that require special attention, and review of clinical records, immediately reporting any anomalous finding to the responsible medical practitioner;
 - Radiation safety, e.g. procedures related to radiation protection, personnel monitoring, reporting of incidents and accidents, QA, safe handling of radioactive sources, radioactive wastes and personnel radiation dose and associated risks;
 - Radiation incidents and emergency notifications.
 - (ii) Establishing QA programmes ensuring that policies and procedures are in place, with appropriate elements of good practice for handling of radioactive material, for radiation protection of patients, and for QC and regulatory compliance of equipment, for example:

- Establishing and conducting regular QC procedures to verify that the technical parameters of imaging equipment performance remain within an acceptable range of variation with respect to the reference values.
 - Calibrating the radiation detectors and equipment used for measuring the activity of radioactive sources and radionuclides before they are used clinically: CQMPs are responsible for the QA of the equipment, in accordance with recommended guidelines.
 - Establishing procedures for the preparation of radiopharmaceuticals administered to patients for diagnostic or therapeutic purposes: CQMPs design QC processes to ensure the absence of traces of contaminants that may cause harm to patients. They also perform calculations to determine the necessary activity for therapeutic procedures and are responsible for patient dosimetry.
- (iii) Performing risk assessments and identifying potential radiation emergencies, such as incidents resulting from equipment malfunction, human error, radioactive spill or losses of radioactive sources: CQMPs develop action procedures to be followed in the event of such occurrences and carry out drills to verify that procedures can be implemented correctly. In general, CQMPs try to find ways to minimize the risk in each case, adopt mandatory peer review processes, follow continuous quality improvement methods and participate in voluntary external audits whenever possible.
- (iv) Investigating unintended or accidental medical exposures: CQMPs have responsibilities in analysing all incidents related to equipment failure, accidents, errors or other unsolicited events which could result in patients receiving an exposure significantly different from that intended. CQMPs provide consultation on the doses received by patients or personnel and on the associated risks, and recommend measures to minimize the chances for accidents to happen again.
- (f) *Collaboration with other clinical professionals:* CQMPs are key members of the team of clinical professionals, including medical practitioners, technologists, radiopharmacists or radiochemists and nursing staff, that work together for the diagnosis and/or treatment of patients. The contribution of medical physicists in this respect includes:
- (i) Consultations with nuclear medicine medical practitioners on special cases where diagnostic tests or treatment require additional actions to those routinely established: The collaboration between the medical practitioners and the medical physicists helps in establishing the optimal approach for each case.

- (ii) Supervision of technologists in the implementation of new clinical procedures, being key members of the team responsible for the introduction of new imaging or therapeutic procedures in the institution: CQMPs are also responsible for developing methods for QA of the new procedures.

4.2.2. Diagnostic and interventional radiology

The fields of DIR involve the use of X rays to produce morphological or functional images of the human body, based on the attenuation properties of X rays in the various tissues. Contrast media are frequently used in such procedures to enhance the image contrast between vascular structures and the surrounding tissues, or between different organs or histologies. In interventional procedures, the X ray images typically assist in guiding the operator during the positioning of catheters, coils, stents, etc., placed with the intention of obtaining diagnostic information or a therapeutic effect from the procedure. X rays are used to diagnose a vast spectrum of pathological conditions in the body. Owing to the different attenuation of diagnostic X rays in organs or tissues, and as X ray imaging allows for very high spatial resolution, X ray imaging is the preferred technique to image density and composition differences. The presentation of X ray images can be a 2-D projection, tomographic slice images or 3-D reconstructed volumes (tomographic techniques). Fluoroscopy images are presented in (close to) real time. Such systems are used mostly in surgical, angiographic and interventional procedures. X ray imaging is by far the most frequently used imaging method in medical applications, and as such also accounts for the bulk of radiation dose delivered to patients in medical exposure.

CQMPs in DIR contribute to the implementation and optimization of clinical X ray imaging procedures; the optimization of image quality versus radiation dose is a key task for medical physicists in this area. They are responsible for the dosimetry of the patient undergoing any of the X ray imaging modalities and for the QA procedures of such systems. This includes all of the hardware and software components used to obtain the X ray images that radiological medical practitioners use for the diagnostic evaluation of patient examinations. CQMPs also have responsibilities for the radiation safety and protection of patients, staff members and the public, related to the use of X rays in DIR procedures. Their knowledge is applied to the development and optimization of new imaging techniques, and they play an important role in the adoption, development, implementation, safe use and optimization of advanced techniques. The performance of medical physicists in diagnostic and interventional X ray imaging is fundamental in providing a safe and qualified service. Hence, their training should include a comprehensive understanding of

anatomy and physiology, image processing and mathematical methods used for image reconstruction.

The main responsibilities and functions of CQMPs in DIR are listed below (summarized in Table 2):

- (a) *Installation design, technical specification, acceptance and commissioning of equipment, including the establishment of criteria for acceptable performance:* Within the technical specification, acceptance, commissioning and supervision of the proper operation of equipment, and the establishment of criteria for its acceptable performance, the following roles and duties must be considered:
 - (i) CQMPs are an essential part of the design team for new installations. They are responsible for shielding and installation design of new or modified radiology rooms, ensuring that all safety requirements are complied with. They calculate and provide the thickness, material composition and placement of shielding needed to protect patients, staff and the general public, and supervise the construction, thus guaranteeing that all requirements of safety and functionality are met. They also verify the adequacy of the shielding after installation.
 - (ii) CQMPs have a leading role in preparing equipment specifications and they participate in the tender evaluation and purchase recommendation of equipment. They perform analysis of the functional requirements for clinical use, and specify conditions for integration, compatibility and connectivity of the equipment to be purchased.
 - (iii) Following the installation of new equipment, or after any significant change or service, CQMPs are responsible for specifying the basic standards to be applied for its acceptance and subsequent commissioning. They ensure that all units and systems function according to their technical specifications and provide advice on any deviation of equipment performance from acceptable criteria, including guidance on decommissioning when appropriate. CQMPs also have, often in collaboration with computer engineers, responsibility for the verification of the computer systems; they assist medical practitioners in evaluating imaging or diagnostic algorithms for their safe and effective clinical use.
- (b) *Radiation safety and protection of patients, staff and the general public:* CQMPs have responsibilities in the development and implementation of a clinical radiation safety programme for the radiation protection of patients in areas where DIR equipment is used. In the majority of cases, however, the CQMP also has responsibilities with respect to the radiation safety of the staff and the public, as it pertains to the radiology service

and infrastructure. CQMPs are responsible for developing procedures for testing the integrity of the equipment and accessories, for the proper operation of dosimetry equipment and other safety features. They also participate in the investigation of incidents involving radiation and they provide the appropriate report and documentation.

- (c) *Patient dosimetry*: CQMPs are responsible for establishing procedures for the calculation and verification of the radiation dose received by the patient. Their duties include dosimetry measurements as well as the development of methods to analyse the results of the measurements and verify the accuracy of doses delivered to patients. In special cases, duties also involve individual patient dose calculations. Tasks related to patient dosimetry include:
- (i) Measurements and calculation of absorbed doses: CQMPs use data acquired during commissioning and information from dosimetry measurements to estimate the absorbed dose by patients during different clinical procedures. This requires the use of analytical calculations, computerized models or in-phantom measurements. Judgement with respect to the applicability of the models used and the ability to synthesize new models is necessary, as well as knowledge to estimate dosimetry uncertainties.
 - (ii) Specific patient dose calculations: CQMPs are responsible for the measurement and/or calculation of individual patient doses and foetal doses in cases where a patient is found to be pregnant. This may include detailed measurements. They establish tolerances and make judgements on the appropriateness of the measured data, including advice to the medical practitioner and the patient on any associated risks, especially those related to the induction of cancer.
 - (iii) Patient dose estimations to establish diagnostic reference levels (DRLs), or to verify conformity with recommended DRLs by national or international regulations: CQMPs have responsibilities in reviewing procedures and equipment when DRLs are consistently exceeded in standard procedures
- (d) *Optimization of physical aspects of diagnostic and interventional procedures*: CQMPs have responsibilities in the optimization of the physical and technical aspects of the different processes used to produce medical images and the necessary imaging equipment (analogue and digital X ray units, CT, angiography units, etc.). They also assist medical practitioners in the evaluation of examination efficacy and participate in image quality and perception studies.

- (e) *Quality management of the physical and technical aspects:* CQMPs participate as team members in establishing a quality management programme and have responsibility for the physical and technical aspects. They are primarily responsible for developing and implementing procedures for the initial and continuing evaluation of the DIR equipment as well as for the calibration of dosimetry equipment. Related tasks comprise:
- (i) Developing institutional policies and procedures for the continuous optimization of radiation use, which includes responsibility for writing new policies and procedures, or updating existing ones, related to:
 - Policies and procedures related to objectives, such as improvement of quality of service, productivity of personnel, handling of new equipment and information systems, and training of personnel;
 - Procedures related to patient investigations, e.g. for patients with special needs, and review of patient dosimetry information, immediately reporting any anomalous finding to the responsible medical practitioner;
 - Procedures related to safety, e.g. procedures related to radiation protection, personnel monitoring, reporting of incidents and accidents, QA, and patient and personnel radiation dose and associated risks;
 - Procedures related to equipment, for the immediate notification of equipment failure to technical staff.
 - (ii) Establishing a QA programme for verifying, setting and accepting the initial reference values of parameters for optimal image quality and the initial reference state of the imaging equipment: This includes developing and implementing QC, ensuring that periodic QC measurements are carried out for the X ray units and associated equipment for image visualization, processing, storage and printing. CQMPs are also responsible for ensuring compliance of the imaging equipment with government and accreditation agency regulations and recommendations.
 - (iii) Performing risk assessments and identifying possible radiation emergencies, such as incidents resulting from equipment malfunction or human error: CQMPs develop action procedures to be followed in the event of such occurrences and carry out drills to verify that procedures can be carried out correctly.
 - (iv) Investigating unintended or accidental medical exposures, such as sentinel events in interventional radiology: CQMPs provide consultation on the doses received by patients or personnel and on the associated risks, and recommend measures to minimize the chances for accidents to happen again.

- (f) *Collaboration with other clinical professionals*: CQMPs are key members of the team of clinical professionals, including radiological medical practitioners and other clinical specialists, technologists and nursing staff, that work together for the diagnosis and treatment of patients. The contribution of medical physicists in this respect includes:
- (i) Consultations to medical practitioners on special patient cases that may be encountered during diagnostic or interventional procedures that require additional actions to those routinely established: The collaboration between the medical practitioners and the CQMPs helps in establishing the optimal approach for each case.
 - (ii) Supervision of the technologists in the implementation of new clinical procedures, being key members of the team responsible for the introduction of new clinical procedures in the institution: CQMPs are also responsible for developing methods for QA of the new procedures.

4.2.3. Other imaging areas

This section deals with the medical physicist's role and responsibilities in the medical specialties of MRI and USI. Unlike the ionizing radiation produced by generators and radioactive sources discussed so far in this publication, MRI and USI do not ionize patient tissues when radiofrequency electromagnetic radiation or ultrasonic waves, respectively, deposit energy in a human body. Therefore, patient radiation dosimetry is not required in these imaging modalities although other physical and technical measurements need to be performed. The responsibilities of the CQMPs for the education and training of other clinical professionals do not differ from those described for ionizing radiation. However, the physical parameters, quantities and methodology used for the production of images with MRI and USI units are different from those discussed for ionizing radiation. Consequently, the roles and responsibilities of CQMPs in patient imaging, research and development of MRI and USI applications are specific to these imaging modalities. The most relevant aspects are delineated in the following.

4.2.3.1. Magnetic resonance imaging

- (a) *Research, development and education*: CQMPs apply their knowledge of the magnetic resonance process to research in clinical imaging based on the use of magnetic fields and radiofrequency power. They support the technical aspects of clinical research and often have a leading role in the medical research team. In specialized centres of high technical complexity, they carry out research and development in MRI and related instrumentation

(e.g. development of new pulse sequences, and coils for optimal imaging). CQMPs play an important role both in developing clinical protocols for applied research, as well as in the education of clinical staff on magnetic resonance, and safety issues and requirements for MRI equipment.

- (b) *Safety and protection of patients, staff and the general public:* CQMPs are responsible for the development and implementation of a clinical safety programme and for testing the integrity of the MRI equipment and accessories, for protection of patients. They are responsible for evaluating the biophysical risks of the MRI equipment, for measuring the fringe fields and establishing procedures for screening patients and staff for ferrous materials, for advising patients on safety issues related to magnetic fields (particularly patients with implants and pacemakers), for collaborating in drawing up fire protection measures and other emergency procedures, for setting safety procedures for varying magnetic field intensities, and for identifying controlled areas and putting in place the administrative controls required for MRI to comply with safety standards. In the majority of cases, CQMPs are also responsible for the safety of staff and the public. They also participate in the investigation of incidents involving MRI and they provide the appropriate report and documentation.
- (c) *Installation design, technical specification, acceptance and commissioning of equipment, including the establishment of criteria for acceptable performance:* Within the technical specification, acceptance, commissioning and supervision of the proper operation of equipment, and the establishment of criteria for its acceptable performance, the following roles and duties must be considered:
 - (i) CQMPs are an essential part of the design team for new MRI installations. They are responsible for ensuring that the requirements for integration and compatibility with other equipment and units are met, and that all safety and magnetic field uniformity requirements are complied with. They also verify that the quench pipe needed for the transfer of the inert helium gas to the open atmosphere in case of a quench accident has the correct diameter and length according to the facility construction plans.
 - (ii) CQMPs have a leading role in preparing equipment specifications and they participate in the tender evaluation and purchase recommendation of equipment. They analyse the functional requirements for clinical use, and specify conditions for integration, compatibility and connectivity of the equipment to be purchased.

- (iii) CQMPs are responsible for supervising the installation of new equipment and for specifying the basic standards to be applied for its acceptance and subsequent commissioning. They develop acceptance and commissioning procedures to ensure that the systems are functioning properly. They ensure that all units and systems function in accordance with their technical specifications and provide advice on any deviation of equipment performance from acceptable criteria, including guidance on decommissioning when appropriate. CQMPs also have, often in collaboration with computer engineers, responsibility for the verification of the computer systems; they assist medical practitioners in evaluating imaging or diagnostic algorithms for their safe and effective clinical use. They establish procedures for the application of special techniques (e.g. spectroscopy and functional magnetic resonance) before they are implemented in the clinic.
- (iv) CQMPs are responsible for the technical supervision of equipment maintenance and for the subsequent verification of its operation, for recording the results of the tests realized, and for authorizing the clinical use of the equipment when the results are within acceptable limits or match the reference values obtained during the acceptance process.
- (d) *Optimization of the physical and technical aspects of imaging procedures:* CQMPs are responsible for the optimization of the physical and technical aspects of the MRI process and equipment used to produce medical images. This includes the optimization of pulse sequences, and the selection of coils when necessary, needed for improving imaging of different tissues and organs of the human body. CQMPs also assist medical practitioners in the evaluation of the examination and participate in image quality and perception studies.
- (e) *Quality management of the physical and technical aspects of MRI:* CQMPs participate as team members in establishing a quality management programme and have responsibility for the physical and technical aspects. They are primarily responsible for developing and implementing procedures for the initial and continuing evaluation of the MRI equipment. Related tasks comprise:
 - (i) Developing institutional policies and procedures for the optimal use of MRI, which includes responsibility for writing new policies and procedures, or updating existing ones:
 - Policies and procedures related to objectives, such as the improvement of the quality of the service, productivity of personnel, handling of new equipment and information systems, and training of personnel;

- Procedures related to patient investigations, e.g. for care of patients that require special attention, and review of clinical records, immediately reporting any anomalous finding to the responsible medical practitioner;
 - Procedures related to safety, e.g. procedures related to patients with pacemakers, reporting of incidents and accidents, QA, intensity of magnetic fields around the magnet and associated risks;
 - Procedures related to equipment, e.g. for the immediate notification of equipment failure to technical staff.
- (ii) Establishing a QA programme and the necessary QC processes, both for the MRI equipment and for the associated systems used for image visualization, including image storage and transfer systems: CQMPs are responsible for establishing and accepting the initial reference values of parameters related to the image quality and initial reference state of the imaging equipment, and for ensuring that periodic QC measurements are carried out to verify that the performance of the equipment is maintained. They are also responsible for ensuring compliance of the MRI equipment with government and accreditation agency regulations and recommendations.
- (f) *Collaboration with other clinical professionals*: CQMPs are key members of the team of professionals, including magnetic resonance practitioners, technologists and nursing staff, working together for the diagnosis of patients. The contribution of medical physicists in this respect includes:
- (i) Consultation with medical practitioners on special cases: Medical physicists consult with medical practitioners on special cases that may be encountered during MRI diagnostic imaging procedures. In patients where the exploration requires more than the routine established methods of diagnosis, the collaboration between medical practitioners and CQMPs helps to establish the optimal approach for each case, and provides advice on safety for the best outcome from such special cases.
 - (ii) Supervision of technologists in the implementation of new clinical procedures: CQMPs are key members of the team responsible for the introduction of new clinical imaging procedures in their institution. They are also responsible for developing methods for QC of the new procedures.

4.2.3.2. *Ultrasound imaging*

- (a) *Research, development and education*: CQMPs apply their knowledge of the propagation of ultrasound waves in human tissues to conduct research

in clinical imaging based on the use of ultrasound equipment and probes. They play an important role in developing clinical protocols for applied research, as well as in the education of clinical staff on the principles and use of ultrasound equipment for medical imaging.

- (b) *Safety and protection of patients, staff and the general public*: CQMPs are responsible for the development and implementation of a clinical safety programme and for testing the integrity of the ultrasound equipment, probes and other accessories. They are also responsible for analysing and preventing possible biological effects or electrical accidents that may be associated with the use of ultrasound in the clinical procedures, thus ensuring the protection of patients and staff.
- (c) *Installation design, technical specification, acceptance and commissioning of equipment, including the establishment of criteria for acceptable performance*: Within the technical specification, acceptance, commissioning and supervision of the proper operation of equipment, and the establishment of criteria for its acceptable performance, the following roles and duties must be considered:
 - (i) CQMPs play an important role in preparing equipment specifications and requirements for integration and compatibility of new ultrasound units with other equipment, and they participate in the tender evaluation and purchase recommendation of equipment. They analyse the functional requirements for clinical use, and ensure that the technical specifications are in compliance with regulatory safety requirements.
 - (ii) CQMPs are responsible for the acceptance and commissioning of new ultrasound equipment. They ensure that new ultrasound units perform in accordance with their technical specifications, obtain reference values of imaging parameters for comparison with future QC measurements, and provide advice on any deviation of performance from acceptable criteria, including advice on decommissioning when appropriate. CQMPs also have, often in collaboration with computer engineers, responsibility for the verification of the computer systems; they assist medical practitioners in evaluating imaging or diagnostic algorithms for their safe and effective clinical use.
 - (iii) CQMPs are responsible for the technical supervision of ultrasound equipment maintenance, and for the subsequent verification of its operation, for recording the results of the tests realized, and for authorizing the clinical use of the equipment after preventive or corrective maintenance. They also have responsibility for record keeping in compliance with existing regulations.

- (d) *Optimization of the physical and technical aspects of ultrasound imaging procedures*: CQMPs are responsible for the optimization of the physical and technical aspects of the ultrasound processes and equipment used to produce medical images. They also assist medical practitioners in the evaluation of the examination and participate in image quality and perception studies.
- (e) *Quality management of the physical and technical aspects of ultrasound imaging*: CQMPs participate as team members in establishing a quality management programme and have responsibility for its physical and technical aspects. They are primarily responsible for developing and implementing procedures for the initial and continuing evaluation of the USI equipment. Related tasks comprise:
 - (i) Developing institutional policies and procedures for the optimal use of ultrasound in clinical imaging, which includes responsibility for writing new policies and procedures, or updating existing ones:
 - Policies and procedures related to objectives, such as the improvement of the quality of the service, productivity of personnel, handling of new equipment and information systems, and training of personnel;
 - Procedures related to equipment, e.g. for the immediate notification of equipment failure to technical staff.
 - (ii) Establishing a QA programme and the necessary QC processes, both for the ultrasound equipment and for the associated systems used for image visualization, including image storage and transfer systems: CQMPs are responsible for establishing and accepting the initial reference values of parameters related to image quality and initial reference state of the imaging equipment, and for ensuring that periodic QC measurements are carried out to verify that the performance of the equipment is maintained. They are also responsible for ensuring compliance of the ultrasound equipment with government and accreditation agency regulations and recommendations.
- (f) *Collaboration with other clinical professionals*: CQMPs are key members of the team of professionals, including ultrasound practitioners, technologists and nursing staff, working together for the diagnosis of patients. The contribution of CQMPs in this respect includes:
 - (i) Consultation with medical practitioners on special cases: CQMPs consult with medical practitioners on special cases that may be encountered during ultrasound diagnostic imaging procedures. In patients where the exploration requires more than the routine established methods of diagnosis, the collaboration between medical practitioners and CQMPs helps to establish the optimal approach for each case.

- (ii) Supervision of technologists in the implementation of new clinical procedures: Medical physicists are responsible for supervising the introduction of new clinical imaging procedures in their institution. They are also responsible for developing methods for QC for the new procedures.

4.3. OCCUPATIONAL AND PUBLIC RADIATION PROTECTION

The BSS [3] assign specific responsibilities to the medical physicist for medical exposures and the patient's radiation protection, both intrinsically related to therapeutic and diagnostic procedures using ionizing radiation discussed in previous sections. The BSS [3] also introduce the term 'radiation protection officer' (RPO) for:

“A person technically competent in radiation protection matters relevant for a given type of practice who is designated by the registrant, licensee or employer to oversee the application of relevant requirements.”

In many clinical environments, medical physicists have responsibilities not only for the safety of the patient, but also for the protection of the staff and the public, as well as for the safety of radioactive sources. As stated jointly by the IOMP and the International Radiation Protection Association [10], all medical physicists receive adequate training in radiation protection and, as part of their assigned duties, many act as RPOs in health facilities and/or participate as members of the radiation safety committee. One of the specialties of medical physics is medical health physics (radiation protection in medicine). Medical physicists trained in this specialty and working mostly in large teaching hospitals undertake the role of RPOs, which may require a higher level of training and more experience in radiation protection.

The main roles and responsibilities of CQMPs in radiation protection in the workplace and for the public are described in this section. They are classified into two major areas, namely safety of the staff and the public, and safety of radioactive sources.

4.3.1. Safety of the staff and the public

- (a) *Installation design, technical specification, acceptance and commissioning of equipment, including the establishment of criteria for acceptable performance:* CQMPs collaborate in the shielding design of installations and ensure compliance with safety requirements, classify work areas into supervised and controlled areas, help to develop and define the technical

specifications for the purchase of new equipment for radiation protection and safety inspections, and develop procedures for the initial and continued evaluation of such equipment. They advise on practical methods to reduce the dose to the staff and the public who work or are in areas adjacent to rooms where radiation equipment is installed or radioactive sources used. In addition, they are responsible for designating the areas in which pregnant, occupationally-exposed women may not work. They also perform calculations and surveys to verify the adequacy of the existing shielding in these rooms using their relevant dimensions, occupancy factors and workload, and establish criteria for the access to rooms that are controlled, with limited access to members of the public, supervising their implementation. CQMPs are also responsible for supervising the installation of new radiation protection equipment and for performing acceptance testing and commissioning of such equipment, including related computer systems, their algorithms, data and results.

- (b) *Radiation safety programme for the protection of staff and the general public:* CQMPs have responsibilities in the development and implementation of a clinical radiation safety programme for the hospital, including policies and procedures for the radiological protection and safety of the workers and the public. CQMPs carry out hazard assessment of the facilities and procedures, and establish whether the existing procedures are adequate (taking into account the type of radiation sources), the dose rates to which staff members may be exposed, the results of personnel dosimetry obtained for similar activities, control measures in place, and the need for personal protection devices, such as lead aprons, thyroid shields, goggles and other devices. They ensure that the latter are correctly used and tested periodically for integrity. CQMPs have responsibilities in establishing policies and procedures for the safe transport of radioactive material, for precautions in cases of contamination or spillage of unsealed radionuclides, for the management of radioactive waste and for the integrity and proper operation of survey meters and other measuring equipment, as required by the regulations
- (c) *Radiation dosimetry:* CQMPs organize and provide personnel dosimetry and monitoring systems at a local level, following the local legislative procedures. Records of personnel dosimetry and of estimated doses received by members of the public are maintained for the period of time specified in national regulations. They also have responsibilities in investigating anomalous exposures and determine whether any radiological hazard is present, and if so to what extent, particularly when hazards result from gamma rays emitted by radioactive sources or from ionizing radiation emitted by equipment used for diagnosis or treatment. They develop

procedures and contingency plans to deal with unintended or accidental exposures, and make recommendations on actions required to minimize the likelihood of such unintended exposures happening again. In addition, they provide the required surveys, interpret their results and evaluate compliance with the appropriate regulatory bodies.

(d) *Optimization of the physical and technical aspects of radiation safety procedures*: CQMPs carry out radiation protection and safety audits, and identify whether appropriate licences exist. They ensure that radiation areas are properly designated and warning signs are in place, and that radiological checks of the working areas provide evidence for compliance with the existing radiation protection policies and procedures, as well as with regulatory and accreditation agency rules and recommendations.

(e) *Quality management of the physical and technical aspects of radiation safety equipment*: CQMPs have responsibilities in developing, implementing and supervising the physical aspects of the quality management programme for the equipment used for radiation protection of the staff and the public. Related tasks include:

(i) Developing institutional policies and procedures for the safe and optimal use of equipment used for radiation detection and measurement.

(ii) Establishing QA programmes and performing QC for all of the radiation protection equipment: CQMPs are responsible for the selection, periodic calibration and QC processes used to establish the correct operation of equipment used for radiation surveys, as well as for the associated systems used for environmental monitoring, as required by the regulations.

(iii) Carrying out risk assessment and management: CQMPs are responsible for the integrity of the survey meters and other equipment used to measure the radiation levels to which staff and/or the public is exposed, and for establishing methods to minimize the radiation dose to the staff and the public, thus reducing the associated risks.

(f) *Collaboration with other clinical professionals*: CQMPs work with other clinical professionals, including medical practitioners, technologists and nursing staff, on special cases that may be encountered in the clinical environment and may compromise the safety of the staff and the public, e.g. an accident during the transport of radioactive materials. In such cases, the members of the public and/or the driver that may be involved, injured or contaminated are brought to the hospital for observation and possible treatment. The role of the CQMP, acting in most cases as RPO, is essential in providing instructions on the actions to be taken for triage and decontamination of such victims without spreading the contamination,

and to prevent unnecessary radiation exposure of staff members and other patients during treatment. Collaboration between medical practitioners and medical physicists helps to establish the optimal approach for each case, and the CQMP provides advice on safety for the best and safest outcome of such special situations.

- (g) *Education and training*: CQMPs provide education and continuous training to clinical staff on radiation safety and radiological protection. They ensure that training programmes are in place and deliver lectures and practical training to staff on the basic principles of radiation safety, including the classification of controlled and supervised areas, the expected exposure resulting from different diagnostic or therapeutic procedures using radiation sources, and establish and promote a safety culture and the concept of defence in depth.

4.3.2. Safety of radioactive sources

- (a) CQMPs establish procedures for the safe transport of radioactive sources and equipment that emit or use radiation within the hospital complex, taking into account all regulatory requirements and safety considerations. This includes transfer of ownership of sources during delivery or disposal.
- (b) CQMPs develop a programme of physical security for radioactive sources, including procedures for receiving, storing securely, stock-taking and controlling their fixed or temporary location at the hospital. They plan and supervise regular inventories of all of the radioactive sources, ensuring their safe disposal as radioactive waste when relevant, according to national and international safety regulations and recommendations.
- (c) CQMPs perform risk assessments and identify possible accidents or losses of radioactive sources, develop action procedures to be followed in the event of such occurrences and carry out exercises to verify that they can be implemented correctly.

5. STAFFING AND ORGANIZATION OF A MEDICAL PHYSICS SERVICE

Staffing requirements for providing medical physics services supporting the efficient and safe care of patients need to be defined using criteria consistent with current medical practice. The impact of the continuous development of medical technology and its applications, as well as changes in the regulatory requirements worldwide, make most previous recommendations on staffing outdated. Although

the scope of this publication does not include providing details on this topic, it seems advisable to reflect the current status of recommendations for staffing levels.

Few organizations have considered staffing requirements in detail, including the impact of academic and clinical training activities (to be discussed in the next section) and the criteria, therefore, vary considerably worldwide. Radiation therapy physics is probably the specialty that has received the most attention, the most recent being from the Institute of Physics and Engineering in Medicine (IPEM) [11] and the American Association of Physicists in Medicine (AAPM) [12]. The European Federation of Organisations for Medical Physics (EFOMP) [13] and the IAEA (for Latin America) [14] have provided criteria for all of the specialties. Whereas old recommendations were mostly based on the amount of equipment available at an institution (e.g. those from the AAPM for diagnostic radiology dated 1991 [7]), it has become more common to consider the amount and complexity of equipment, the number of patients, the complexity of the procedures, and the departmental organization. For the latter, it should be noted that some countries allow for certain medical physicists' tasks to be delegated to technologists, dosimetrists or other personnel, working under the supervision of a CQMP (see Appendix II).

Detailed examples of staffing levels based on their specific requirements have been provided in most publications. The IPEM [11], for instance, considers a large radiation therapy facility including four multi-modality and four single-modality accelerators (half of them equipped with IGRT systems), and two CT simulators. The workload is 4800 patients per year of whom half are treated palliatively and 400 are treated with special techniques such as IMRT and total body irradiation. In addition, 350 patients are treated with high dose rate brachytherapy and 100 with low dose brachytherapy seeds. The calculations yield estimates of 16 CQMPs, 19 technologists or dosimetrists, and 8 engineers. The IAEA's estimates [14] are not too dissimilar for an advanced facility with the same characteristics. However, a basic radiation therapy department, comprising three ^{60}Co units, one conventional simulator, a 2-D TPS and 1600 treatments per year, requires 2 CQMPs and 2.5 dosimetrists according to the IAEA [14]; these are substantially different from the estimates resulting from the requirements of the EFOMP. Similar evaluations for nuclear medicine and diagnostic radiology facilities, as well as for radiation protection, based on publications of the AAPM, EFOMP and IAEA, also yield considerable differences. The need for harmonized criteria is, therefore, recognized.

The organization of the medical physics services is frequently governed by the size and type of medical facility, though it varies considerably. Medical physicists in large general hospitals are often organized into an autonomous medical physics department which provides services to the various clinical

departments. Alternatively, they are staff members of independent DIR, cardiology, neurosurgery, nuclear medicine or radiation therapy departments. In small facilities, there may be only one full time CQMP available, supported by an external CQMP, as a consultant, to provide backup [13].

CQMPs with complementary specializations should collaborate to meet the necessary requirements for optimal patient care. Depending on the size and needs of the facility, CQMPs with different qualifications (and possibly pertaining to different departments) may work jointly to provide medical physics support, thus fulfilling the needs of the organization. For example, the QA programme and necessary QC procedures of CT or MRI scanners located in a radiation therapy department, or SPECT/CT and PET/CT imaging units located in a nuclear medicine department, in both cases operated by local, trained clinical staff, may be developed and implemented by CQMPs working in the DIR or MRI departments, suitably trained in the techniques necessary for CT or MRI units. In such cases, the CQMPs from different departments should consult to ensure that all of the medical physics roles are fulfilled. If collaboration or support is not possible, the radiation therapy or nuclear medicine medical physicists must undergo appropriate training to be able to undertake the QA and QC of relevant equipment in their departments. Another possible situation often found in some large departments arises from the sub-specialization that some CQMPs may have, e.g. for external beam and brachytherapy treatments; in such situations, the facility management should ensure that adequate coverage is available for all sub-specialties at all times.

In all cases, CQMPs should be aware of the limitations of their own specialization. If roles for which they are not qualified or competent need to be fulfilled, they should seek the support of appropriate CQMPs or obtain the necessary qualifications by being mentored by a suitable CQMP, or by taking CPD courses for further education. In exceptional cases, they could undertake a self-directed educational programme.

5.1. STAFFING REQUIREMENTS

Medical physics is part of an interdisciplinary team composed of other health care professionals, such as radiological medical practitioners, radiopharmacists, biomedical engineers, technicians, radiographers, dosimetrists and nurses; it is necessary to define overall staffing requirements for providing appropriate health care services to support the efficient and safe care of patients, which are consistent with current best medical practice. A patient centred approach will help ensure that all overlapping activities in radiation medicine are accounted for, irrespective of the profession.

Staffing levels in the clinical environment are not only important for planning and budgetary purposes, and fundamental to patient safety, but they are often also specified for practice accreditation purposes and professional certification. The estimation of reasonable staffing levels to support radiation medicine services has often been loosely based on population size, equipment availability, disease incidence, etc. Retrospective subjective estimates based on existing practice are often the benchmark for predicting future staffing needs locally. Detailed measurements of how long each procedure and activity take to perform are probably the most objective basic evidence required to estimate full time equivalent staffing levels. Such measurements are logically more useful and valid if they are performed in a variety of clinics, services and on staff with a wide range of experience. Median values obtained from national surveys have been used extensively to support medical physics staffing levels.

It is unlikely that accurate estimations of every possible professional activity can be obtained as this is clearly an onerous task. Furthermore, new procedures are developed all the time and new technology is introduced, so this is recognized as a dynamic process. This is another reason why workload staffing surveys will always lag behind technological developments by a considerable number of years. In these cases, benchmarking or professional expert consensus is the next best option.

Activities often need to be grouped because some activities can only be performed safely if they are attended to by more than one person, e.g. treatment delivery in radiation therapy. In some cases, more than one type of professional may need to be in attendance during a single procedure. On the other hand, not all procedures involve professional activities that are directly linked to equipment utilization, e.g. the activity of reporting images does not always require that the radiologist or nuclear medicine medical practitioner be present during the actual image acquisition procedure.

There is very little documentation based on evidence that precisely quantifies the number and type of professional(s) needed to support a service and that is also directly related to patient workload, technology, technique, procedures and infrastructure. It is recognized that a tool is required which provides hospital managers with staffing guidelines that are transparent, flexible and allow for an expansion of existing services, a broader range of modalities, emerging technologies, and in so doing, maintain safe, effective and quality patient care. In this context, the IAEA has assembled a team of experts and representatives from professional societies to develop a 'universal' guide and a set of models for estimating staffing levels for the three radiation medicine specialties (DIR, nuclear medicine and radiation oncology). Although the models being developed for the three specialties are different, they are all based on:

- (a) An analysis of the tasks which need to be performed by the relevant staff;
- (b) Their duration;
- (c) The clinical workload (number of patients, examinations, procedures, etc.).

The three algorithms require the user to define the local working conditions and to estimate the workload, the number of pieces of equipment and modalities, the number of procedures and/or the techniques to be employed within each specialty. The specific user inputs required for each discipline, e.g. number of procedures in radiology and nuclear medicine, or the number of patients treated per year in radiation oncology, are based on statistics that were considered to be readily available to users of the tool, or alternatively can be estimated from other indicators such as the patient population and case mix. The models are currently in the process of being validated in a wide range of departments.

For example, in radiation oncology, services are provided primarily by three professional groups: radiation oncologists, CQMPs and medical radiation technologists, with additional support services provided by radiation oncology nurses, mechanical and electrical engineers, and information technology (IT) experts. In some countries, medical dosimetrists are recognized as an additional professional group in radiation therapy (see Appendix II). Optimal radiation therapy is only achieved when these professionals work together as a team and the process is, therefore, seamless. The radiation oncology model represents an activity based approach to defining required staffing levels and reflects all activities over the entire radiation therapy pathway: patient related activities, equipment maintenance and QC, special procedures, management, administration, education and research. It relates only to the professionals specifically dedicated to the radiation oncology service — medical oncology is not included, for instance. It is based on a defined number of working hours per day/week accounting for annual leave. These parameters can be adjusted to the local situation.

The individual identified tasks relate to the prescription, preparation, imaging, treatment planning, treatment delivery and follow-up of patients receiving external beam radiation therapy and brachytherapy. The personnel carrying out the tasks have been defined under services rather than a profession as it is acknowledged that different professionals may carry out the same task in different resource settings. In this way, the tool has been designed to offer maximum flexibility. The services defined are: radiation oncology service, medical physics service, radiation therapy technology service, treatment planning service, radiation oncology nurse service, mechanical engineering and electrical engineering services, and IT support. Each task has been defined in terms of an estimated time frame within which it can be realistically completed based on best evidence or consensus based practice. The time frame was then subsequently

related to each of the services typically performing these tasks. In other words, for each task, in addition to an estimated overall time, the time spent by each type of professional to accomplish the task is also estimated.

The number of patients and fractions treated within a department are entered such that they reflect the complexity level of the department practice and, thereby, enable individual departments to calculate the number of full time equivalent staff necessary to support a range of technology. The guideline and tool have, therefore, been designed to be flexible and facilitate each department to calculate the requirement based on the resources available to them and the knowledge and skill sets of their staff.

6. RECOMMENDATIONS FOR THE ACADEMIC AND CLINICAL TRAINING OF CLINICALLY QUALIFIED MEDICAL PHYSICISTS

6.1. CURRENT STATUS

Medical physicists working as health professionals shall demonstrate competency in their discipline by obtaining the appropriate educational qualification and clinical competency training in one or more subfields of medical physics. The current requirements for the qualification of medical physicists vary largely throughout the world (cf. Refs [15–18]). This variation has recently been confirmed by the results of two large scale surveys undertaken by the EFOMP in 2006 [19] and the IAEA in 2010–2011, which together included responses from 77 countries on five continents.

Acknowledging that different interpretations may have occurred with some questions, and that even within a country the requirements may vary among different institutions, the overall analysis is shown in Fig. 1. The left panel indicates that the minimum ‘academic education and clinical training’ time frame for employment as a medical physicist at a hospital varies between three and nine years, the average being about six years. The requirements for the time fraction spent in basic, postgraduate and clinical training varies enormously, as shown in the right panel, ranging from a basic three year degree without any clinical training to nine years including all three components. Basic physics studies of approximately four years are the most common modality for over 90% of the respondents, and for countries with a postgraduate system, one or two year programmes are most frequent. The largest discrepancy found in the analysis corresponds to the clinical training programmes across different countries. Their duration varies from non-existent to a four year requirement. They also have

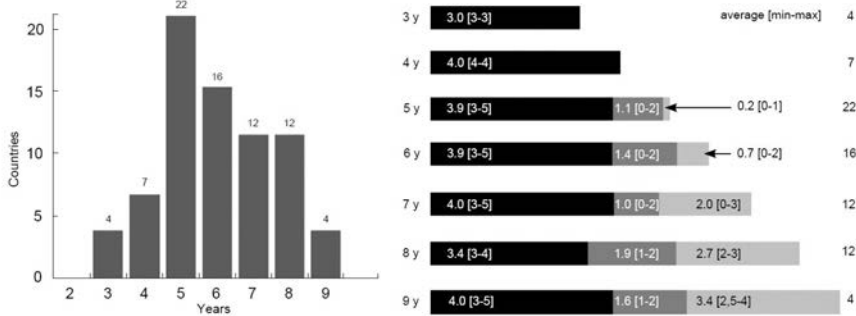


FIG. 1. Results of two comprehensive surveys on the requirements for the qualification of medical physicists made by the EFOMP in 2006 [19] and the IAEA in 2010–2011 which include responses from 77 countries. The left panel shows the minimum ‘academic education and clinical training’ time frame for employment as a medical physicist. The right panel illustrates the time fraction spent in basic, postgraduate and clinical training for each group. The figures on top of the bar chart in the left panel and on the right hand column in the right panel indicate the number of countries.

rather different formats; for example, among the formally structured programmes, 20% have a residency system or on the job training for the first years, 29% have it as a component of the postgraduate programme and 51% do not have structured clinical training. The assessment of the skills acquired during the clinical training also shows rather different patterns, ranging from a formal examination (57%) to continuous assessment (9%) or a combination of the two (23%); 11% of the responses were unspecified. It is worth noting that a significant number of countries having formal clinical training have their trainees remunerated as staff members, and that some countries have their trainees employed automatically upon completion of the training programme, whereas others do not guarantee employment.

6.2. QUALIFICATION REQUIREMENTS FOR ACADEMIC AND CLINICAL TRAINING

The analysis points to the need for establishing harmonized criteria on the minimum recommendations for academic and clinical training of medical physicists. This could be used to achieve common standards of competence worldwide. Based on the findings of the surveys and the guidelines issued by a number of international organizations, such as the EFOMP [17], the IOMP [18] and the European Commission [20], the following recommendations on academic and clinical training leading to the status of CQMP are made.

The recommended standard route is to fulfil studies at the level of a basic university degree in physics, engineering or equivalent (i.e. a 3–4 year degree including advanced mathematics and physics), followed by:

- (a) A postgraduate degree in medical physics: This could be an MSc or equivalent degree of 1–3 years including courses covering all of the specialties of medical physics, which is completed with a research report in one of them. Examples of course syllabuses have been published by the IAEA in the form of handbooks on radiation oncology physics [21], diagnostic radiology physics [22] and nuclear medicine physics [23], and by scientific and professional organizations such as the AAPM [24, 25] and IPEM [26].
- (b) Clinical training for a period of not less than two years in one of the specialties of medical physics in the form of a structured residency programme, supervised by a senior CQMP: Examples of medical physics clinical training programmes can be found in the IAEA's Training Course Series Nos 37¹, 47² and 50³ [27–29]. Clinical training for each additional specialty should be accomplished by a period of not less than one year. The clinical training programmes developed for each specialty should emphasize the roles and responsibilities of the CQMP in the respective discipline, as described in Sections 2–4.

The following conditions should be observed during the clinical residency programme:

- (i) The training is to be carried out in a hospital.
- (ii) It shall consist of full time equivalent years, meaning that if the clinical training programme includes academic courses, the allocated time for the clinical training must be extended accordingly.
- (iii) The trainees entering the programme and any academic courses included in it shall be formally assessed to ensure their knowledge and competencies. Even when continuous assessment is conducted, it should be complemented with oral and/or written examinations.
- (iv) The centres where clinical training will be performed shall offer a broad range of relevant clinical procedures, and shall be equipped with a complete range of dosimetry and QC equipment, so that the resident will be appropriately trained in a wide spectrum of techniques. Additional resources such as a library, computers and Internet access should also be available.

¹ This publication is also available in French, Russian and Spanish.

² This publication is also available in French and Spanish.

³ This publication is also available in French. A Spanish version is in preparation.

- (v) It is advisable that the number of trainees per supervisor not exceed two or three at any given time, depending on the clinical duties of the supervisor. Should the supervision be shared by a group of trainers, the amount of supervision shall be added, so that the total corresponds to one full time equivalent supervisor.

An alternative route is to enter the training process having a postgraduate degree (MSc or PhD) in physics, engineering or equivalent, in which case the incumbent shall take appropriate academic courses covering all of the relevant specialties of medical physics (cf. Refs [30, 31]). This can be taken prior to or during the period of clinical training. In this case, point (b)(ii) above applies.

The three steps above complete the minimum qualification requirements for the CQMP. It is emphasized that the indicated year intervals are intended to provide minimum periods for each component. Thus, for the academic component, they correspond to possible different lengths of the basic and postgraduate academic periods, which in total should be 4–7 years, depending on national university cycles. Similarly, the effective duration of the clinical training should be no shorter than two years and if it includes other activities (e.g. courses and academic project work), its length needs to be extended accordingly to three years or even more. Clinical training should be competency based. Overall, the academic education and clinical training should extend over a minimum period of, typically, seven years, which is similar to that of medical specialists in most countries.

6.3. ACCREDITATION, CERTIFICATION AND REGISTRATION

The formal process by which an independent recognized body (professional and/or governmental) evaluates and recognizes that a programme or a clinical site meets pre-determined requirements or criteria is called accreditation. It is highly desirable that both the postgraduate academic programme and the clinical residency be formally accredited by a national or international professional body authorized by the government or by a relevant government office. It is emphasized that accreditation does not constitute a permanent status, and should be renewed periodically.

Certification (or ‘credentialing’) is the formal process by which an authorized body (governmental or non-governmental) evaluates and recognizes the knowledge and proficiency of an individual, which must satisfy pre-determined requirements or criteria. Certification of CQMPs should be mandatory, as it is with most other health professionals. It helps to achieve a homogeneous professional standard at the national (and international) level which ensures quality and safety in radiation medicine. As with accreditation,

certification does not provide a permanent standing, and a regular re-certification system should be implemented in order to demonstrate that the CQMP maintains current knowledge of modern technologies, methods and practice standards. This is usually achieved via a CPD programme (see below).

Professional certification of CQMPs, as for other health professionals, should ideally be conducted by national boards. International boards could provide guidelines on the standards, requirements and format of certification, and perform accreditation of certification systems. International boards may grant and issue certificates to applicants who have been found qualified, maintain a registry of holders of such certificates, and serve the public by preparing and furnishing lists of CQMPs who have been certified by the international body. National medical physics organizations should share expertise, experience and resources on setting up and running certification systems. Countries that do not have professional certification systems in place may consider starting with a voluntary system and transit to a mandatory one when the system matures. They could seek consultation and support from established national and international certification boards. Countries which have difficulties in forming certification boards for reasons such as a small number of medical physicists and/or a shortage of trainers could consider having their medical physicists obtain certification from countries where board certification systems exist. Countries that are already running voluntary certification systems should consider transforming them into mandatory systems.

The process of certification should lead to that of registration, where records of certified professionals are maintained and organized in the form of databases or rosters. The registry should ideally be a legal system which can be operated by a governmental office or by a professional body authorized by the government, but it should be at the national level. A government operated CQMP registry has the advantage that professional requirements can be implemented in a harmonized way across the country, in a similar manner to requirements for regulating other professionals, e.g. architects and medical practitioners. In some countries, registration is a requirement to obtain a professional licence to practise, which is an effective QC mechanism to measure professional competence.

6.4. CONTINUING PROFESSIONAL DEVELOPMENT PROGRAMME

CPD is one of the essential measures in maintaining professional competency, particularly for certified CQMPs. Its goal is to keep professional knowledge and skills up to date. The concept of CPD varies from country to country, but, in general, includes participation in educational and scientific activities such as conferences, symposia, courses and workshops, and education

and training duties of medical physicists and other clinical professionals. Research and development oriented activities also pertain to CPD, including individual contributions to journals or books, publications and refereeing. Highly developed CPD systems often require professionals to participate in a range of activities, including ongoing education in ethics. Formal CPD programmes should include an evaluation mechanism, such as a credit based system, where CQMPs are awarded a number of points for each activity they participate in. These should form part of the criteria for re-certification. An appropriate CPD system should be implemented in every country. National professional societies can play a major role in organizing and accrediting CPD events. For countries that do not have a certification system in place, a voluntary CPD programme is highly recommended.

6.5. SUMMARY OF QUALIFICATION REQUIREMENTS

The recommended minimum academic education and clinical training requirements, and the steps involved in establishing the level of a CQMP are summarized in the flow chart in Fig. 2.

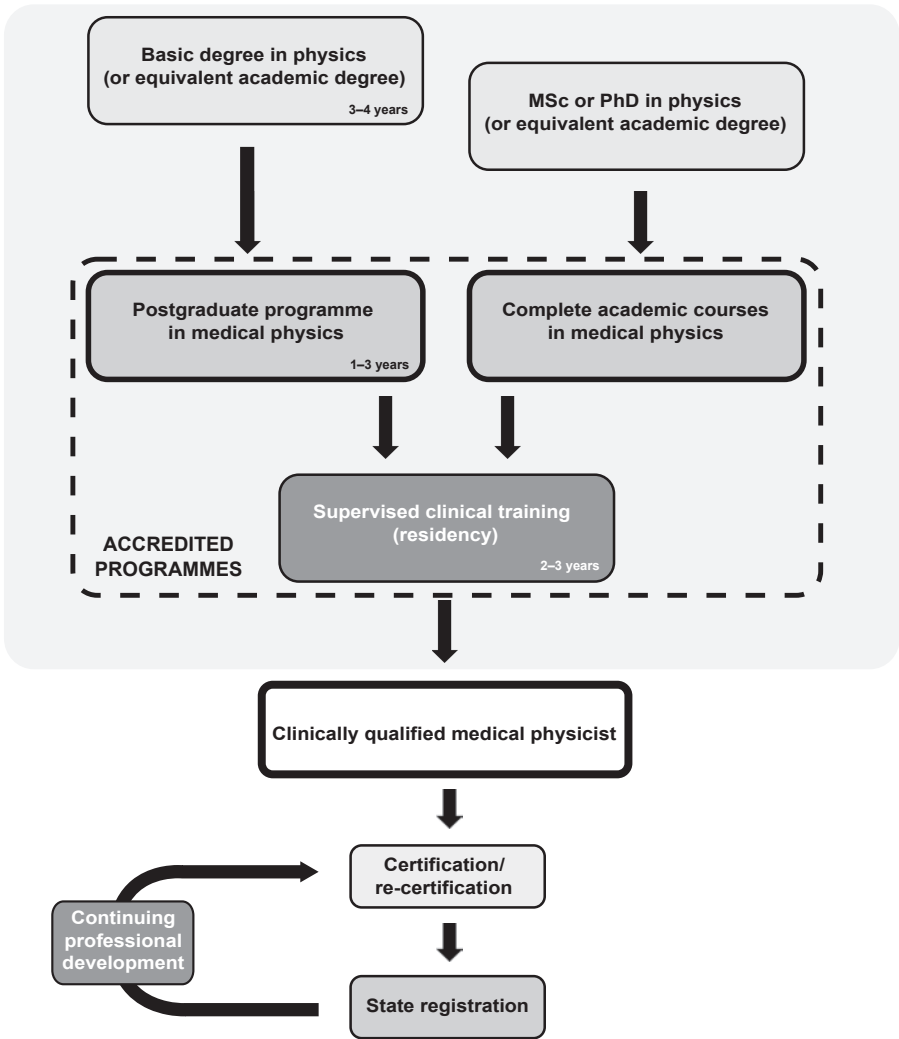


FIG. 2. Recommendations on minimum requirements for the academic education and clinical training of a clinically qualified medical physicist. Two possible academic based routes lead to the mandatory clinical training component. The intervals in years for the academic component correspond to the possible different lengths of the basic and postgraduate academic periods, which in total should be 4–7 years depending on national university cycles. Similarly, the clinical training period may include academic courses in medical physics, but should be no shorter than two years. Overall, academic education and clinical training should extend over a minimum period of, typically, seven years.

Appendix I

CODE OF ETHICS FOR MEDICAL PHYSICISTS WORKING IN THE CLINICAL ENVIRONMENT

This code of ethics and professional conduct is based on publications and information from the AAPM [32, 33] and the Health and Care Professions Council [34]. It includes two major sections, namely principles and guidelines. The principles are standards of ethical conduct intended to help medical physicists perform their duties and conduct themselves in a professional way, showing respect to patients, their colleagues and the public. The guidelines are instructions to help medical physicists interpret and implement the principles, and although they may not specifically address all situations, they include guidelines for professional conduct, research ethics and education/teaching ethics. In some countries, postgraduate students participating in clinical research or residents undergoing clinical training in medical physics may also have to register with the national authority that regulates the professional conduct of health workers. In addition, ethical guidelines pertaining to business, government, employment, complaints, hearings and malpractice may be applicable.

I.1. PRINCIPLES OF PROFESSIONAL CONDUCT

Medical physicists shall abide by the following principles:

- (a) Strive to provide the best quality patient care with competent and professional service. Ensure that the well-being, interests and dignity of patients are promoted and safeguarded at all times.
- (b) Safeguard patient and professional confidences and privacy. Respect confidential information obtained on patients in the course of professional practice.
- (c) Respect the rights of patients, colleagues, health professionals and those in training.
- (d) Recognize one's own limitations of knowledge, skill or time and seek consultations and assistance when indicated. Do not undertake any assignments or responsibilities that are beyond one's abilities or competencies.
- (e) Respect the law and regulatory requirements for the safe and effective practice of the profession. Do not undertake employment or consultation which is contrary to the law or the public's welfare.

- (f) Be honest in all professional interactions and in one's own work. Avoid conduct that may be derogatory to the dignity of the profession. All relations with employers, co-workers, governmental agencies and the general public shall be based upon and shall reflect the highest standard of integrity and fairness.
- (g) The relationship among medical physicists and other health professionals shall be open, collegial and based on mutual respect. Work in a collaborative and cooperative manner with other health care professionals, recognizing and respecting their particular contributions to health care.
- (h) Disclose conflicts of interest when financial or other personal considerations may compromise or appear to affect one's own professional judgement. Inform one's employer or client in writing of any conflict between service to them and one's own personal interests.
- (i) Strive to improve one's professional knowledge and skills, and share them with colleagues and those in training. Take all reasonable steps to maintain and develop one's competence and help colleagues working with or under one's supervision to do the same.
- (j) One's own work as a medical physicist, including research, shall be truthful, based on accepted scientific principles, and shall cite prior work when applicable. Maintain proper professional standards in research and development and prevent the dissemination of fraudulent or intentionally biased results.
- (k) Maintain a record of evidence of one's own CPD and advise one's colleagues to do likewise.
- (l) Strive to protect the safety and welfare of patients.
- (m) Report any incident or errors that may occur in the line of work that might affect or has affected the treatment process of any patient.

1.2 GUIDELINES OF ETHICS

The general guideline is to conform to high standards of ethical, legal and professional conduct. Any activity that fails to conform to these standards compromises personal integrity.

1.2.1. Guidelines for professional conduct

- (a) *Academic freedom*: Strive to pursue scientific enquiry, and to promote a scientific and clinical environment free of political, ideological, or religious pressures or constraints.

- (b) *Honesty*: Be honest in all professional interactions and in your work. Document and report your professional credentials, such as academic degrees, training, continuing education, and scholarly and research contributions, truthfully and accurately. Present your activities, services and products delivered, honestly. Fraudulent documentation of work not done, backdating reports, signing reports of work done by others, data fabrication and data falsification are unethical.
- (c) *Maintenance of knowledge and skills*: Strive to improve your knowledge and skills relevant to your professional work. Participate in appropriate continuing medical physics education activities. Sharing such knowledge and skills with colleagues is essential. Strive to make your experience available to the medical physics community.
- (d) *Competence*: Be aware of the limitations of your knowledge, skills, competencies and experience. Undertake only work that you are qualified to perform and seek additional education and training or consultation when indicated.
- (e) *Professional relationships*: Strive to have mutually beneficial relationships with other colleagues. All such interactions should be open, honest and respectful. Where appropriate, share your skills and experience and assist the professional development of colleagues. Those who are in a supervisory position have an obligation to guide their associates.
- (f) *Responsibility to the public, the patient and the institution*: Strive to improve the public's welfare through the dissemination of scientific knowledge and pertinent education. Place primary importance on the welfare of patients and only participate in patient care activities that are in the best interest of the patient. If affiliated with or employed by a health care facility, consider the interests of the institution. Promote a mutually respectful atmosphere with health care providers, administrators and ancillary staff. Support other staff within the institution in order to achieve quality patient care. Respect institutional policies and procedures, and contribute to their continuous improvement.
- (g) *Patient confidentiality*: Respect the confidential nature of all patient information and protect the confidentiality of such information.
- (h) *Conflict of interest*: Conflicts may exist with an institution, within an educational setting, with industry or with clinical practice activities. Be aware when personal interests conflict with other interests. Put the needs of the patient above your own personal interests. Conflicts of interest are not inherently unethical or to be avoided, but they must be disclosed to any involved party and managed appropriately.

- (i) *Discrimination*: Treat fairly, equally and with respect all those with whom you have professional relationships. Judge others on the basis of knowledge, training, skill and quality of service rendered. Prejudicial, biased discrimination not based on merit is reprehensible and unethical.
- (j) *Harassment*: Contribute to a work environment where people can do their best and most productive work. Use positive, supportive language. Verbal abuse, demeaning comments, uncontrolled angry exchanges, or any conduct that directly or indirectly creates a hostile work environment is not acceptable. You shall not sexually harass anyone. Sexual harassment is an unwelcome sexual advance, a request for sexual favours, or other verbal or physical conduct of a sexual nature.
- (k) *Exploitative relationships*: You shall not exploit any person with whom you have a professional relationship. Exploitation can be, but is not limited to, coercing a person to perform work without equitable compensation, forcing a person to act against their will or consent, or creating working conditions where one or more persons is treated unfairly for the benefit of others.
- (l) *Response to impaired or incompetent colleagues*: The safety and welfare of patients are primary concerns of medical physicists. If, due to some impairment, a colleague is perceived to jeopardize the patient's welfare, you should attempt to respond on the patient's behalf. The particular circumstances may be ambiguous and you should proceed judiciously. If a legal, contractual or regulatory obligation to report the concerns exists, the member shall comply with that obligation. Incidents, defined as unwanted or unexpected changes from normal that cause or have the potential to cause an adverse effect on a person or equipment, shall be reported by medical physicists in accordance with local institutional policy and applicable governmental regulations. Learning from incidents is a critically important tool to help minimize the risk of future similar events. Members should also encourage other health care professionals to report incidents.
- (m) *Relationship with regulators*: You have an obligation to assist and cooperate with regulators in the performance of their duties in an honest and respectful manner.
- (n) *Whistle-blower protection*: You shall respect and not participate in taking punitive or retaliatory action against other medical physicists (whistle-blowers) who report those deficient in competence or engaging in unethical, fraudulent or deceptive behaviour.
- (o) *Reviewing the work of another medical physicist (incumbent)*: At least two categories of review may occur: those initiated by the incumbent physicist as part of an ongoing QA process and those initiated by someone else. Procedures and guidelines regarding reviews initiated by the incumbent are published in the literature [31]. In the case of reviews not initiated by

the incumbent physicist, the IAEA (as the AAPM and other professional associations) does not affirm or reject the process of review. In the interest of protecting the rights of the incumbents in such cases, the following are the expectations that the incumbent should rightfully enjoy:

- (i) The review should be performed by a qualified medical physicist peer, i.e. a CQMP who has similar or senior credentials and is familiar with the type of practice setting. The medical physicist being reviewed should receive a courtesy call from the reviewer to establish mutually agreeable times and to communicate processes and goals for the review.
- (ii) Whenever possible, the reviewer should have no present or past professional relationship with the entity requesting the review, e.g. no close personal, professional or training relationship.
- (iii) The medical physicist being reviewed should receive a copy of the final report, both orally and in written form.
- (iv) Confidentiality should be maintained throughout the review process.
- (v) All care must be exercised when reviewing an incumbent not to jeopardize the incumbent's position unnecessarily (e.g. by the expression of personal opinions or judgements beyond those based on the data presented). The process should be used to create the opportunity for improvement (and/or enhancement of the working environment, equipment, personnel, etc.) for all concerned, as well as the community at large.

1.2.2. Guidelines for research ethics

Biomedical research, including that conducted by or involving medical physicists, has its own set of ethical obligations that should be closely adhered to by investigators and others engaged in research. Ethical obligations arise in the design and conduct of the research, collection and interpretation of data resulting from the research, publication of reports and scientific monographs describing the research, management of intellectual property emanating from the research, and relationships of the research team to the financial sponsors of the research. Lapses in ethical standards can compromise the acceptance of the research findings and seriously damage the careers of researchers responsible for the findings.

- (a) *Acquisition, management, sharing and ownership of research data*: Medical physicists should ensure that all data collected during a study are real, and that fabrication, falsification of data or plagiarism has not occurred. All medical physicists of the team should respect the confidentiality of research

data and should not disclose data to other scientists or the public without the consent of all team members. Members of the research team should fully understand who owns research data.

- (b) *Conflict of interest*: The most commonly discussed conflict of interest is a financial one, where one or more members of the research team or their immediate family members stand to gain financially if the results or reports of the research turn out in a particular way. If significant, such a conflict should be reported. As an example, the US National Institutes of Health (NIH) have established a financial gain of \$10 000 as a limit above which researchers supported by the NIH must report a conflict of interest to their employing institution. It is possible to have a conflict of interest with regard to proposed or actual research even if there is no potential financial gain. For example, researchers gain prestige among their peers and within their institution or organization if their research results are positive and progressive. There is nothing inherently wrong with a conflict of interest, but it should be acknowledged to eliminate the perception of possible impropriety. The best protection against conflict of interest accusations is full disclosure and the acquisition, interpretation and publication of research findings in a manner that is transparent and above suspicion.
- (c) *Human participants*: Research involving human participants should adhere to Principle 15 of the Belmont Report [35], namely “respect of persons, beneficence and justice”. Respect for persons recognizes the autonomy of individuals and the right of each research volunteer to be treated with respect, to be fully informed about the research and its potential benefits and risks, and to be granted the ability to decide for themselves whether to participate in the research. Beneficence ensures that some potential benefit will accrue from the research, to the participants themselves, to others with similar conditions who may benefit in the future or to society at large. Justice means that potential participants in a study are not excluded without a valid reason for exclusion. Most institutions subscribe to the “general rule” which says that all research involving human participants is subject to the same degree of oversight and follows the guidance of the Belmont principles [35].
- (d) *Research misconduct*: Specific examples of research misconduct are data fabrication, data falsification and plagiarism. Fabrication is the artificial manufacturing of research data rather than obtaining data by experiment. Falsification is manipulation of data by selectively choosing only those data that support a research hypothesis. Plagiarism is the misrepresentation of data from another researcher as one’s own. These ethical breaches are intentional wrongdoings that are considered abhorrent and intolerable by the research community.

- (e) *Animal welfare*: Animals should be used as research subjects only when alternatives are not available. Researchers have a moral obligation to handle animals used for experimental investigation humanely and with respect. Researchers shall adhere to the pertaining laws and standards relevant to their research, their laboratory rules and their funding agencies.
- (f) *Collaborative science*: Research is often collaborative and interdisciplinary by its very nature; the concept of the sole investigator working independently in the laboratory is rare today. Invariably, a research effort is a partnership involving several individuals from different disciplines and, frequently, different institutions. Research collaborators shall treat all team members with respect and trust. All collaborators must sustain the confidential nature of the research and its findings until their agreed upon presentation and publication.
- (g) *Authorship*: Authorship of a scientific publication should be reserved only for those individuals who have contributed substantially to the conception and design of a research investigation and/or to the collection, analysis and interpretation of data resulting from the investigation. Authorship also implies that the individual was directly involved in the drafting and revising of the publication. Authors are discouraged from awarding authorship to an individual if the individual did not contribute substantially to the publication.
- (h) *Editorship and peer review*: The editor is responsible for ensuring that the peer review process of the journal is objective and fair, and that reviews do not contain derogatory critiques or disparaging remarks. Editors should recuse themselves if they have a conflict of interest related to the reported research that could compromise their objectivity. The editor and reviewers are ethically bound to ensure the confidential nature of reviews and to protect the identity of authors and/or reviewers when reviews are single or doubly blinded. The integrity of research relies heavily on the process of peer review, which means that one's work is transparent and subject to review by scientific peers. Peer review should always be conducted with total objectivity, honesty, thoroughness and confidentiality, and with respect for those doing the review and those whose work is being reviewed. Reviewers must remember that the work they are reviewing is confidential and should not be disclosed to anyone outside the review team. They must not appropriate the work or any of the results into their own research, even though they may be working in a similar field.
- (i) *Author or reviewer conflict of interest*: Authors should report any conflict of interest they may have regarding research reported in a scientific publication. Individuals asked to review papers should decline the journal's invitation to review if they have a conflict of interest related to the reported

research or if they have a personal relationship with the authors that could compromise their objectivity.

- (j) *Privacy and confidentiality*: Authors shall respect the confidentiality of patients by not revealing their identities in publications or otherwise. This protection of privacy extends to individuals serving as volunteers in research involving humans.
- (k) *Overlapping publications*: It is unethical for an author to simultaneously or sequentially submit for publication substantially the same material to two or more journals, unless permission is granted by the editors of all affected journals, except in the case of rejected manuscripts.

I.2.3. Guidelines for education ethics

Formal educational settings present an environment within which the student will have the opportunity to absorb the intellectual and ethical atmosphere of the institution and its educators. Thus, it is of paramount importance that teachers/educators exhibit the highest ethical standards, and students begin the practice of ethical behaviour that will guide them for the remainder of their careers. In this education ethics section, the following definitions apply: ‘teacher’ refers to any person responsible for the education or supervision of a student engaged in any educational or training programme; ‘student’ refers to a person engaged in any educational or training programme. All activities performed in the clinical environment by a student are assumed to be carried out under the direct supervision of the teacher, and the student should be aware of this medico-legal responsibility at all times.

- (a) Guidelines for the teacher:
 - (i) *Student programme completion*: Teachers shall endeavour to contribute to the intellectual development of their students and to support students in achieving their educational goals. Teachers shall guide students towards an efficient path to reaching these goals. Students entrust their educational outcome to their teachers, advisers and mentors. As such, teachers shall act as advocates for their students. For example, work on institutional grants or research projects that primarily benefit the teacher or institution may be a component of a student’s education, but should not unduly delay his or her overall progress.
 - (ii) *Safe environment*: Teachers shall promote a safe environment for learning and shall educate students regarding the hazards and methods to control and minimize potential risks.

- (iii) *Respect for students*: Teachers shall interact with students in a respectful manner. Teachers are in a position of power and authority. They have the responsibility to relate with students in a positive manner. Their verbal, non-verbal and written communication with students should be constructive and reasoned with the intent to enhance the educational experience.
- (iv) *Non-discrimination*: Teachers shall treat all students fairly and equally irrespective of age, race, colour, creed, sex, national origin, marital status, political or religious beliefs, family, social or cultural background, or sexual orientation.
- (v) *Equal opportunity*: Teachers shall fairly consider all students for participation in any programme or for any benefits that may aid the student, including, but not limited to, attendance at scientific meetings or training programmes, research projects, internships and scholarships.
- (vi) *Student confidentiality*: The trust inherent in a good teacher–student relationship will be irrevocably damaged if a teacher casually divulges confidential information. Teachers shall maintain the confidentiality of non-public student information. Evaluations of the student’s work along with verbal and electronic communications between the teacher and student shall be confidential unless required to document the student’s work.
- (vii) *Consensual student relationship*: A consensual or romantic relationship between a teacher and a student should be avoided. The teacher bears the primary burden of accountability to ensure proper relationships are maintained.
- (viii) *Sexual harassment*: Sexual harassment of a student by a teacher is unacceptable. Sexual harassment is an unwelcome sexual advance, a request for sexual favours, or other verbal or physical conduct of a sexual nature, and any conduct that directly or indirectly creates a hostile environment.
- (ix) *Acknowledgement of a student’s or others’ work*: Teachers shall acknowledge and cite prior work by others if used in their teaching media presentations or within their course material. Teachers shall acknowledge significant academic or scholarly assistance from students. This acknowledgement may be as recognition of the student as a co-author of a publication. The mentor–trainee or researcher–student relationship and issues related to authorship are further described in the research ethics section.

- (x) *Fair evaluation*: Teachers shall make fair evaluations of student efforts and document those evaluations in the student's record when appropriate.
 - (xi) *Intellectual and academic freedom*: Teachers shall encourage an open atmosphere of scientific enquiry and promote an environment free of political, ideological or religious pressures and constraints.
- (b) Guidelines for the student:
- (i) *Review and inspection of personal records*: Students have a right to review and inspect their personal records. They may request amendments to their records if they can show evidence that the record is not correct.
 - (ii) *Whistle-blower protection*: Students shall be free to report or provide information regarding violations of this code without fear of retaliation and/or reprisal.
 - (iii) *Work requirements of the educational programme*: Students have a right to expect that completion of the educational programme will not be contingent on performing work for a teacher or institution that is not a formal, documented part of the educational programme.
 - (iv) *Programme requirements*: Students have the right to be informed and to have clearly defined requirements for the completion of their educational programme.
 - (v) *Adherence to institutional policies and procedures*: Students shall adhere to the policies and procedures of their institution.
 - (vi) *Academic honesty and integrity*: Students shall uphold and maintain academic honesty and integrity. Examples of academic dishonesty include cheating, plagiarism, falsifying or fabricating information or data, and unauthorized collaboration.
 - (vii) *Acknowledgement of work of others*: Students must fully acknowledge the prior work of others when including it in their own work.
 - (viii) *Freedom of expression*: Students shall respect the freedom of expression of others.
 - (ix) *Patient and institutional confidentiality*: Students shall respect the confidentiality of institutional and patient information.
 - (x) *Respect for students, teachers, staff and patients*: Students shall interact with other students, teachers, staff and patients in a respectful manner. They will respect and support other students' classroom participation.

- (xi) *Respect for institutional property*: Students shall not use professional information, data or property belonging to a teacher or institution that is not part of their educational materials for their own professional practice without express permission. This could be either intellectual or physical property. Some examples are institutional procedures, policies, worksheets, checklists, QA programmes, teaching aids, presentations and research protocols. While a teacher or institution may permit or release such information or data, it is the student's responsibility to obtain permission to use it.

Appendix II

MEDICAL DOSIMETRISTS — DUTIES AND SKILLS

The medical dosimetrist is a member of the radiation therapy team who has knowledge of the overall characteristics of radiation therapy treatment machines and equipment, is cognizant of procedures normally used in external beam therapy and brachytherapy, and has the education and expertise necessary to generate radiation dose distributions and dose calculations in collaboration with the medical physicist and radiation oncologist. Medical dosimetrists are educated to perform duties under the supervision of CQMPs and radiation oncologists. All references in this publication to decisions, actions taken and communications assume that appropriate supervision is present and utilized by the medical dosimetrist. In addition, many tasks performed by medical dosimetrists include participation by additional members of the radiation therapy team, such as radiation therapists and nurses. At different institutions, the relative levels of responsibility vary among the different members of the team to accomplish a given task.

The information on the duties and skills of medical dosimetrists in this appendix was obtained from the AAMD [36] and is presented with minor changes in the wording and format. It presents a job description as recommended by the AAMD, addressing the major duties, skills and qualifications of medical dosimetrists in North America. Institutions utilizing it as a template are encouraged to modify it to local conditions if relevant or applicable.

II.1. MAJOR DUTIES OF MEDICAL DOSIMETRISTS

- (a) Design a treatment plan by means of computer and/or manual computation that will deliver a prescribed radiation dose and field placement technique in accordance with the radiation oncologist's prescription to a defined tumour volume.
- (b) Consider dose-limiting structures in the design of treatment plans and document dose in accordance with the radiation oncologist's prescription.
- (c) Coordinate treatment simulations and tumour localization on dedicated devices, including CT, MRI and PET when indicated, for radiation therapy treatment planning according to institutional guidelines.
- (d) Supervise, perform or assist in the planning of the fabrication and QC of compensation filters, custom shields, wedges and other beam modifying devices.
- (e) Supervise, perform or assist in the planning of the production and QC of moulds, casts and other immobilization devices.

- (f) Supervise the therapist staff in the implementation of the treatment plan, including the correct use of immobilization devices, compensators, wedges, field arrangement and other treatment variables.
- (g) Perform calculations for the accurate delivery of the radiation oncologist's prescribed dose, document all pertinent information in the patient record and verify the mathematical accuracy of all calculations using a system established by the medical physicist.
- (h) Provide physics and technical support to the medical physicist, in radiation protection, qualitative machine calibrations and QA of the radiation oncology equipment.
- (i) Supervise, perform or assist in the application of specific methods of dosimetry, including ion chamber, thermoluminescence dosimetry or film measurement, as directed by the medical physicist.
- (j) Assist in intracavitary and interstitial brachytherapy procedures, and in the subsequent manual and/or computer calculation of the dose distributions of these treatments under the supervision of the CQMP.
- (k) Teach applied aspects of medical dosimetry to students and residents, as assigned.
- (l) Participate in clinical research for the development and implementation of new techniques.
- (m) Participate in continuing education in the area of current treatment planning techniques and advances in medical dosimetry.

II.2. SKILLS REQUIRED OF MEDICAL DOSIMETRISTS

- (a) Must be able to understand the technical aspects of radiation therapy and medical physics to derive computerized treatment plans, and communicate these aspects to the radiation oncologist for plan approval, and to the radiation therapist for plan implementation.
- (b) Performs routine duties independent of supervision, but consults with the radiation oncologist and medical physicist as required.
- (c) Operates and performs QA, under the direction of the medical physicist, on the treatment planning computer.
- (d) Has working knowledge of radiation safety and current rules and regulations of the local or national regulatory authority (e.g. the United States Nuclear Regulatory Commission).
- (e) Has the ability to interpret and execute treatment plans as defined in relevant treatment guidelines.
- (f) Must possess mathematical skills including algebra, trigonometry and introductory calculus, and be able to visualize objects in 3-D concepts to facilitate the treatment planning process.

REFERENCES

- [1] SMITH, P.H.S., NUSSLIN, F., Benefits to medical physics from the recent inclusion of medical physicists in the international classification of standard occupations (ICSO-08), *Med. Phys. Int. J.* **1** (2013) 10–14.
- [2] INTERNATIONAL ORGANIZATION FOR MEDICAL PHYSICS, The Medical Physicist: Role and Responsibilities, Working Group on Policy Statement No. 1, IOMP, York, UK (2010).
- [3] INTERNATIONAL ATOMIC ENERGY AGENCY, Radiation Protection and Safety of Radiation Sources: International Basic Safety Standards — Interim Edition, IAEA Safety Standards Series No. GSR Part 3 (Interim), IAEA, Vienna (2011).
- [4] COUNCIL OF THE EUROPEAN UNION, Council Directive 97/43 Euratom on Health Protection of Individuals Against the Dangers of Ionizing Radiation in Relation to Medical Exposure, Official Journal of the European Union 1997/L 180/22 (1997).
- [5] EUROPEAN COMMISSION, Draft Proposal for a Council Directive Laying Down Basic Safety Standards for Protection Against the Dangers Arising from Exposure to Ionising Radiation (COM/2011/0593 final — 2011/0254 (NLE)) (2011).
- [6] AMERICAN ASSOCIATION OF PHYSICISTS IN MEDICINE, The Role of a Physicist in Radiation Oncology, Rep. No. 38, AAPM, College Park, MD (1993).
- [7] AMERICAN ASSOCIATION OF PHYSICISTS IN MEDICINE, Staffing Levels and Responsibilities of Physicists in Diagnostic Radiology, Rep. No. 33, AAPM, College Park, MD (1991).
- [8] AMERICAN ASSOCIATION OF PHYSICISTS IN MEDICINE, The Role of the Clinical Medical Physicist in Diagnostic Radiology, Rep. No. 42, AAPM, College Park, MD (1994).
- [9] AMERICAN ASSOCIATION OF PHYSICISTS IN MEDICINE, A Guide to the Teaching of Clinical Radiological Physics to Residents in Diagnostic and Therapeutic Radiology, Rep. No. 64, AAPM, College Park, MD (1999).
- [10] INTERNATIONAL ORGANIZATION FOR MEDICAL PHYSICS, Statement of Collaboration between IOMP and IRPA on the Use of Ionizing Radiation in Health Care, *eMPW* **3** 2 (2012) 10–12, http://www.iomp.org/sites/default/files/empw-32_0.pdf
- [11] INSTITUTE OF PHYSICS AND ENGINEERING IN MEDICINE, Recommendations for the Provision of a Physics Service to Radiotherapy, IPEM, York, UK (2009).
- [12] AMERICAN ASSOCIATION OF PHYSICISTS IN MEDICINE, The Solo Practice of Medical Physics in Radiation Oncology, Rep. No. 80, AAPM, College Park, MD (2003).
- [13] EUROPEAN FEDERATION OF ORGANISATIONS FOR MEDICAL PHYSICS, Criteria for the staffing levels in a medical physics department, EFOMP Policy Statement No. 7, *Phys. Medica* **XIII** (1997) 187–194.
- [14] INTERNATIONAL ATOMIC ENERGY AGENCY, El físico médico: Criterios y recomendaciones para su formación académica, entrenamiento clínico y certificación en América Latina, IAEA Human Health Reports No. 1, IAEA, Vienna (2010).

- [15] TABAKOV, S., SPRAWLS, P., KRISANACHINDA, A., LEWIS, C. (Eds), *Medical Physics and Engineering Education and Training (Part I)*, ICTP Press, Trieste, Italy (2011).
- [16] ROBERTS, C., TABAKOV, S., LEWIS, C. (Eds), *Medical Radiation Physics: A European Perspective (CEC Project CIPA 3510 CT 92 2623)*, King's College School of Medicine and Dentistry, London (1995).
- [17] EUDALDO, T., OLSEN, K., *The European Federation of Organisations for Medical Physics, Policy Statement No. 12: The present status of Medical Physics Education and Training in Europe, New perspectives and EFOMP recommendations*, *Phys. Medica* **26** (2010) 1–5.
- [18] INTERNATIONAL ORGANIZATION FOR MEDICAL PHYSICS, *Basic Requirements for Education and Training of Medical Physicists, Working Group on Policy Statement No. 2*, IOMP, York, UK (2010).
- [19] EUDALDO, T., OLSEN, K., *The present status of Medical Physics Education and Training in Europe: an EFOMP survey*, *Phys. Medica* **24** (2008) 3–20.
- [20] EUROPEAN COMMISSION, *Project on Medical Physics Expert (TREN/09/NUCL/SI2.549828) — Draft Qualification and Curriculum Frameworks for the Medical Physics Expert in Europe (2010–2012)*,
<http://portal.ucm.es/web/medical-physics-expert-project>
- [21] INTERNATIONAL ATOMIC ENERGY AGENCY, *Radiation Oncology Physics: A Handbook for Teachers and Students*, IAEA, Vienna (2005).
- [22] INTERNATIONAL ATOMIC ENERGY AGENCY, *Diagnostic Radiology Physics: A Handbook for Teachers and Students*, IAEA, Vienna (2013).
- [23] INTERNATIONAL ATOMIC ENERGY AGENCY, *Nuclear Medicine Physics: A Handbook for Teachers and Students*, IAEA, Vienna (in preparation).
- [24] AMERICAN ASSOCIATION OF PHYSICISTS IN MEDICINE, *Academic Program Recommendations for Graduate Degrees in Medical Physics*, Rep. No. 197, AAPM, College Park, MD (2009).
- [25] AMERICAN ASSOCIATION OF PHYSICISTS IN MEDICINE, *Essentials and Guidelines for Hospital-based Medical Physics Residency Training Programs*, Rep. No. 90, AAPM, College Park, MD (2006).
- [26] INSTITUTE OF PHYSICS AND ENGINEERING IN MEDICINE, *Training Prospectus for Medical Physicists and Clinical Engineers in Health Care*, IPEM, London (2010).
- [27] INTERNATIONAL ATOMIC ENERGY AGENCY, *Clinical Training of Medical Physicists Specializing in Radiation Oncology*, Training Course Series No. 37, IAEA, Vienna (2010).
- [28] INTERNATIONAL ATOMIC ENERGY AGENCY, *Clinical Training of Medical Physicists Specializing in Diagnostic Radiology*, Training Course Series No. 47, IAEA, Vienna (2011).
- [29] INTERNATIONAL ATOMIC ENERGY AGENCY, *Clinical Training of Medical Physicists Specializing in Nuclear Medicine*, Training Course Series No. 50, IAEA, Vienna (2011).

- [30] AMERICAN ASSOCIATION OF PHYSICISTS IN MEDICINE, Alternative Clinical Training Pathways for Medical Physicists, Rep. No. 133, AAPM, College Park, MD (2008).
- [31] AMERICAN ASSOCIATION OF PHYSICISTS IN MEDICINE, The Essential Medical Physics Didactic Elements for Physicists Entering the Profession through an Alternative Pathway (Suppl. to Report 197), Rep. No. 197S, AAPM, College Park, MD (2011).
- [32] AMERICAN ASSOCIATION OF PHYSICISTS IN MEDICINE, Code of Ethics for the American Association of Physicists in Medicine, Rep. No. 109, AAPM, College Park, MD (2009).
- [33] AMERICAN ASSOCIATION OF PHYSICISTS IN MEDICINE, Recommended Ethics Curriculum for Medical Physics Graduate and Residency Programs, Rep. No. 159, AAPM, College Park, MD (2010).
- [34] HEALTH AND CARE PROFESSIONS COUNCIL, Standards of Conduct, Performance and Ethics (2012),
<http://www.hpc-uk.org/aboutregistration/standards/standardsofconductperformanceandethics/>
- [35] THE NATIONAL COMMISSION FOR THE PROTECTION OF HUMAN SUBJECTS OF BIOMEDICAL AND BEHAVIORAL RESEARCH, The Belmont Report, Ethical Principles and Guidelines for the Protection of Human Subjects of Research (1979),
<http://www.hhs.gov/ohrp/humansubjects/guidance/belmont.html>
- [36] AMERICAN ASSOCIATION OF MEDICAL DOSIMETRISTS,
<http://www.medicaldosimetry.org/generalinformation/description.cfm>

LIST OF ABBREVIATIONS AND ACRONYMS

| | |
|-------|--|
| AAMD | American Association of Medical Dosimetrists |
| AAPM | American Association of Physicists in Medicine |
| BSS | Basic Safety Standards |
| CPD | continuing professional development |
| CQMP | clinically qualified medical physicist |
| CT | computed tomography |
| DIR | diagnostic and interventional radiology |
| DRL | diagnostic reference level |
| EFOMP | European Federation of Organisations for Medical Physics |
| IGRT | image guided radiation therapy |
| IMRT | intensity modulated radiation therapy |
| IOMP | International Organization for Medical Physics |
| IPEM | Institute of Physics and Engineering in Medicine |
| IT | information technology |
| MRI | magnetic resonance imaging |
| NIH | National Institutes of Health |
| PET | positron emission tomography |
| QA | quality assurance |
| QC | quality control |
| RPO | radiation protection officer |
| SPECT | single photon emission computed tomography |
| TPS | treatment planning system |
| USI | ultrasound imaging |

CONTRIBUTORS TO DRAFTING AND REVIEW

| | |
|--------------------|---|
| Andreo, P. | Stockholm University, Sweden |
| Brandan, M.E.* | Universidad Nacional Autónoma de México, Mexico |
| Castellanos, M.E.* | Pontificia Universidad Javeriana, Colombia |
| Cheung, K.Y.** | Hong Kong Sanatorium & Hospital, China |
| Constantinou, C. | Bank of Cyprus Oncology Centre, Cyprus |
| Frey, G.H.*** | Medical University of South Carolina, United States of America |
| Ige, T.A.+ | National Hospital, Nigeria |
| Le Heron, J.C. | International Atomic Energy Agency |
| Lopes, M.C.** | Instituto Portugues de Oncologia de Coimbra, Portugal |
| Meghzifene, A. | International Atomic Energy Agency |
| Ramahi, S. | King Hussein Cancer Center, Jordan |
| Van der Merwe, D. | International Atomic Energy Agency |
| Van der Putten, W. | International Atomic Energy Agency |

* Also representing the Latin American Medical Physics Association.

** Also representing the International Organization for Medical Physics.

*** Also representing the American Association of Physicists in Medicine.

+ Also representing the Federation of African Medical Physics Organisations.



Where to order IAEA publications

In the following countries IAEA publications may be purchased from the sources listed below, or from major local booksellers. Payment may be made in local currency or with UNESCO coupons.

AUSTRALIA

DA Information Services, 648 Whitehorse Road, MITCHAM 3132
Telephone: +61 3 9210 7777 • Fax: +61 3 9210 7788
Email: service@dadirect.com.au • Web site: <http://www.dadirect.com.au>

BELGIUM

Jean de Lannoy, avenue du Roi 202, B-1190 Brussels
Telephone: +32 2 538 43 08 • Fax: +32 2 538 08 41
Email: jean.de.lannoy@infoboard.be • Web site: <http://www.jean-de-lannoy.be>

CANADA

Bernan Associates, 4501 Forbes Blvd, Suite 200, Lanham, MD 20706-4346, USA
Telephone: 1-800-865-3457 • Fax: 1-800-865-3450
Email: customercare@bernan.com • Web site: <http://www.bernan.com>

Renouf Publishing Company Ltd., 1-5369 Canotek Rd., Ottawa, Ontario, K1J 9J3
Telephone: +613 745 2665 • Fax: +613 745 7660
Email: order.dept@renoufbooks.com • Web site: <http://www.renoufbooks.com>

CHINA

IAEA Publications in Chinese: China Nuclear Energy Industry Corporation, Translation Section, P.O. Box 2103, Beijing

CZECH REPUBLIC

Suweco CZ, S.R.O., Klecakova 347, 180 21 Praha 9
Telephone: +420 26603 5364 • Fax: +420 28482 1646
Email: nakup@suweco.cz • Web site: <http://www.suweco.cz>

FINLAND

Akateeminen Kirjakauppa, PO BOX 128 (Keskuskatu 1), FIN-00101 Helsinki
Telephone: +358 9 121 41 • Fax: +358 9 121 4450
Email: akatilaus@akateeminen.com • Web site: <http://www.akateeminen.com>

FRANCE

Form-Edit, 5, rue Janssen, P.O. Box 25, F-75921 Paris Cedex 19
Telephone: +33 1 42 01 49 49 • Fax: +33 1 42 01 90 90
Email: formedit@formedit.fr • Web site: <http://www.formedit.fr>

Lavoisier SAS, 145 rue de Provigny, 94236 Cachan Cedex
Telephone: + 33 1 47 40 67 02 • Fax +33 1 47 40 67 02
Email: romuald.verrier@lavoisier.fr • Web site: <http://www.lavoisier.fr>

GERMANY

UNO-Verlag, Vertriebs- und Verlags GmbH, Am Hofgarten 10, D-53113 Bonn
Telephone: + 49 228 94 90 20 • Fax: +49 228 94 90 20 or +49 228 94 90 222
Email: bestellung@uno-verlag.de • Web site: <http://www.uno-verlag.de>

HUNGARY

Librotrade Ltd., Book Import, P.O. Box 126, H-1656 Budapest
Telephone: +36 1 257 7777 • Fax: +36 1 257 7472 • Email: books@librotrade.hu

INDIA

Allied Publishers Group, 1st Floor, Dubash House, 15, J. N. Heredia Marg, Ballard Estate, Mumbai 400 001,
Telephone: +91 22 22617926/27 • Fax: +91 22 22617928
Email: alliedpl@vsnl.com • Web site: <http://www.alliedpublishers.com>

Bookwell, 2/72, Nirankari Colony, Delhi 110009
Telephone: +91 11 23268786, +91 11 23257264 • Fax: +91 11 23281315
Email: bookwell@vsnl.net

ITALY

Libreria Scientifica Dott. Lucio di Biasio "AEIOU", Via Coronelli 6, I-20146 Milan
Telephone: +39 02 48 95 45 52 or 48 95 45 62 • Fax: +39 02 48 95 45 48
Email: info@libreriaaeiou.eu • Website: www.libreriaaeiou.eu

JAPAN

Maruzen Company Ltd, 1-9-18, Kaigan, Minato-ku, Tokyo, 105-0022
Telephone: +81 3 6367 6079 • Fax: +81 3 6367 6207
Email: journal@maruzen.co.jp • Web site: <http://www.maruzen.co.jp>

REPUBLIC OF KOREA

KINS Inc., Information Business Dept. Samho Bldg. 2nd Floor, 275-1 Yang Jae-dong SeoCho-G, Seoul 137-130
Telephone: +02 589 1740 • Fax: +02 589 1746 • Web site: <http://www.kins.re.kr>

NETHERLANDS

De Lindeboom Internationale Publicaties B.V., M.A. de Ruyterstraat 20A, NL-7482 BZ Haaksbergen
Telephone: +31 (0) 53 5740004 • Fax: +31 (0) 53 5729296
Email: books@delindeboom.com • Web site: <http://www.delindeboom.com>

Martinus Nijhoff International, Koraalrood 50, P.O. Box 1853, 2700 CZ Zoetermeer
Telephone: +31 793 684 400 • Fax: +31 793 615 698
Email: info@nijhoff.nl • Web site: <http://www.nijhoff.nl>

Swets and Zeitlinger b.v., P.O. Box 830, 2160 SZ Lisse
Telephone: +31 252 435 111 • Fax: +31 252 415 888
Email: infoho@swets.nl • Web site: <http://www.swets.nl>

NEW ZEALAND

DA Information Services, 648 Whitehorse Road, MITCHAM 3132, Australia
Telephone: +61 3 9210 7777 • Fax: +61 3 9210 7788
Email: service@dadirect.com.au • Web site: <http://www.dadirect.com.au>

SLOVENIA

Cankarjeva Zalozba d.d., Kopitarjeva 2, SI-1512 Ljubljana
Telephone: +386 1 432 31 44 • Fax: +386 1 230 14 35
Email: import.books@cankarjeva-z.si • Web site: <http://www.cankarjeva-z.si/uvoz>

SPAIN

Díaz de Santos, S.A., c/ Juan Bravo, 3A, E-28006 Madrid
Telephone: +34 91 781 94 80 • Fax: +34 91 575 55 63
Email: compras@diazdesantos.es, carmela@diazdesantos.es, barcelona@diazdesantos.es, julio@diazdesantos.es
Web site: <http://www.diazdesantos.es>

UNITED KINGDOM

The Stationery Office Ltd, International Sales Agency, PO Box 29, Norwich, NR3 1 GN
Telephone (orders): +44 870 600 5552 • (enquiries): +44 207 873 8372 • Fax: +44 207 873 8203
Email (orders): book.orders@tso.co.uk • (enquiries): book.enquiries@tso.co.uk • Web site: <http://www.tso.co.uk>

On-line orders

DELTA Int. Book Wholesalers Ltd., 39 Alexandra Road, Addlestone, Surrey, KT15 2PQ
Email: info@profbooks.com • Web site: <http://www.profbooks.com>

Books on the Environment

Earthprint Ltd., P.O. Box 119, Stevenage SG1 4TP
Telephone: +44 1438748111 • Fax: +44 1438748844
Email: orders@earthprint.com • Web site: <http://www.earthprint.com>

UNITED NATIONS

Dept. I004, Room DC2-0853, First Avenue at 46th Street, New York, N.Y. 10017, USA
(UN) Telephone: +800 253-9646 or +212 963-8302 • Fax: +212 963-3489
Email: publications@un.org • Web site: <http://www.un.org>

UNITED STATES OF AMERICA

Bernan Associates, 4501 Forbes Blvd., Suite 200, Lanham, MD 20706-4346
Telephone: 1-800-865-3457 • Fax: 1-800-865-3450
Email: customercare@bernan.com • Web site: <http://www.bernan.com>

Renouf Publishing Company Ltd., 812 Proctor Ave., Ogdensburg, NY, 13669
Telephone: +888 551 7470 (toll-free) • Fax: +888 568 8546 (toll-free)
Email: order.dept@renoufbooks.com • Web site: <http://www.renoufbooks.com>

Orders and requests for information may also be addressed directly to:

Marketing and Sales Unit, International Atomic Energy Agency

Vienna International Centre, PO Box 100, 1400 Vienna, Austria
Telephone: +43 1 2600 22529 (or 22530) • Fax: +43 1 2600 29302
Email: sales.publications@iaea.org • Web site: <http://www.iaea.org/books>



**RADIATION ONCOLOGY PHYSICS:
A HANDBOOK FOR TEACHERS AND STUDENTS**

STI/PUB/1196 (657 pp.; 2005)
ISBN 92-0-107304-6

Price: €65.00

**CLINICAL TRAINING OF MEDICAL PHYSICISTS SPECIALIZING
IN RADIATION ONCOLOGY**

Training Course Series No. 37
IAEA-TCS-37 (2010)

**CLINICAL TRAINING OF MEDICAL PHYSICISTS SPECIALIZING
IN DIAGNOSTIC RADIOLOGY**

Training Course Series No. 47
IAEA-TCS-47 (2011)

**CLINICAL TRAINING OF MEDICAL PHYSICISTS SPECIALIZING
IN NUCLEAR MEDICINE**

Training Course Series No. 50
IAEA-TCS-50 (2011)

**EL FÍSICO MÉDICO: CRITERIOS Y RECOMENDACIONES PARA
SU FORMACIÓN ACADÉMICA, ENTRENAMIENTO CLÍNICO Y
CERTIFICACIÓN EN AMÉRICA LATINA**

IAEA Human Health Reports No. 1
STI/PUB/1424 (77 pp.; 2010)
ISBN 978-92-0-311209-3

Price: €16.00

**SETTING UP A RADIOTHERAPY PROGRAMME: CLINICAL,
MEDICAL PHYSICS, RADIATION PROTECTION AND SAFETY ASPECTS**

STI/PUB/1296 (255 pp.; 2008)
ISBN 92-0-101807-X

Price: €55.00

**STANDARDS, APPLICATIONS AND QUALITY ASSURANCE
IN MEDICAL RADIATION DOSIMETRY (IDOS)**

Proceedings Series
STI/PUB/1514 (925 pp.; 2011)
ISBN 978-92-0-116210-6

Price: €120.00

**PLANNING NATIONAL RADIOTHERAPY SERVICES:
A PRACTICAL TOOL**

IAEA Human Health Series No. 14
STI/PUB/1462 (83 pp.; 2011)
ISBN 978-92-0-105910-9

Price: €34.00

PLANNING A CLINICAL PET CENTRE
IAEA Human Health Series No. 11

STI/PUB/1457 (146 pp.; 2010)
ISBN 978-92-0-104610-9

Price: €42.00

This publication provides internationally harmonized recommendations on the roles and responsibilities of clinically qualified medical physicists working in one or more of the specialties of radiation therapy, nuclear medicine or diagnostic and interventional radiology. It also includes recommendations on the minimum requirements for the academic education and clinical training required for a physicist to become clinically qualified in one of these specialties. This book will be particularly useful for professionals involved in the education and training of medical physicists, both at universities and hospitals, and for professionals working in medical radiation physics. It will also be of importance for national professional societies, ministries of health and regulatory authorities for regulating the profession. Implementation of these recommendations, which have been endorsed by professional societies, will ensure consistency as well as the harmonization of medical physics practice worldwide for the benefit of patients.

IAEA HUMAN HEALTH SERIES

INTERNATIONAL ATOMIC ENERGY AGENCY
VIENNA
ISBN 978-92-0-142010-7
ISSN 2075-3772