

AAPM REPORT NO. 249
(Revision of AAPM Report No. 90)



Essentials and Guidelines for Clinical Medical Physics Residency Training Programs

**Report from the Work Group on Periodic Review
of Medical Physics Residency Training**

October 2013

DISCLAIMER: This publication is based on sources and information believed to be reliable, but the AAPM and the editors disclaim any warranty or liability based on or relating to the contents of this publication.

The AAPM does not endorse any products, manufacturers, or suppliers. Nothing in this publication should be interpreted as implying such endorsement.

DISCLAIMER: This publication is based on sources and information believed to be reliable, but the AAPM, the editors, and the publisher disclaim any warranty or liability based on or relating to the contents of this publication.

The AAPM does not endorse any products, manufacturers, or suppliers. Nothing in this publication should be interpreted as implying such endorsement.

ISBN-13: 978-1-936366-25-5

© 2013 by American Association of Physicists in Medicine

All rights reserved. No part of this publication may be reproduced, stored in a retrieval system, or transmitted in any form or by any means (electronic, mechanical, photocopying, recording, or otherwise) without the prior written permission of the publisher.

Published by
American Association of Physicists in Medicine
One Physics Ellipse
College Park, MD 20740-3846

ESSENTIALS AND GUIDELINES FOR CLINICAL MEDICAL PHYSICS RESIDENCY TRAINING PROGRAMS

Report from the Work Group on Periodic Review of Medical Physics Residency Training

Members:

Joann I. Prisciandaro, Ph.D. (Work Group Chair)

University of Michigan, Ann Arbor, Michigan

Charles E. Willis, Ph.D. (Work Group Vice Chair)

The University of Texas MD Anderson Cancer Center, Houston, Texas

Jay W. Burmeister, Ph.D.

Wayne State University, Detroit, Michigan

Geoffrey D. Clarke, Ph.D.

UT Health Sciences Center, San Antonio, Texas

Rupak K. Das, Ph.D.

University of Wisconsin, Madison, Wisconsin

Jacqueline Esthappan, Ph.D.

Washington University, St. Louis, Missouri

Bruce J. Gerbi, Ph.D.

University of Minnesota, Minneapolis, Minnesota

Beth A. Harkness, M.S.

Henry Ford Hospital System, Detroit, Michigan

James A. Patton, Ph.D.

Vanderbilt University, Nashville, Tennessee

Donald J. Peck, Ph.D.

Henry Ford Health Systems, Detroit, Michigan

Robert J. Pizzutiello Jr., M.S.

Upstate Medical Physics, Victor, New York

George A. Sandison, Ph.D.

University of Washington, Seattle, Washington

Sharon L. White, Ph.D.

University of Alabama, Birmingham, Alabama

Brian D. Wichman, M.S.

Texas Oncology, Round Rock, Texas

Consultants:

Geoffrey S. Ibbott, Ph.D.

The University of Texas MD Anderson Cancer Center, Houston, Texas

Stefan Both, Ph.D.

University of Pennsylvania, Philadelphia, Pennsylvania

This page intentionally left blank.

CONTENTS

Foreword	ix
-----------------------	----

CHAPTER 1

Essentials and Guidelines for Medical Physics Residency Training Programs

1.1	Introduction	1
1.2	Objectives of a Medical Physics Residency Training Program	1
1.3	Structure and Conduct of Medical Physics Residency Programs	1
1.3.1	Length of Training	1
1.3.2	Program Director	2
1.3.3	Program Steering Committee	3
1.3.4	Other Program Staff and Personnel	3
1.3.5	Institutional Support	4
1.3.6	Educational Environment	4
1.3.7	Residents' Scholarly Activities	4
1.3.8	Conferences	5
1.3.9	Documentation of Activities	5
1.3.10	Library Resources	5
1.4	Medical Physics Educational Competencies	5
1.5	Didactic Knowledge Requirements	8
1.6	Number of Residents	9
1.7	Resident Evaluation	9
1.7.1	Staff and Program Evaluations	10
1.7.2	Internal Program Review	11
1.8	Working Environment	11
1.8.1	Professionalism, Personal Responsibility, and Patient Safety	11
1.8.2	Access and Use of Medical Information	11

CONTENTS

1.8.3	Ethics	11
1.8.4	Supervision of Residents	11
1.8.5	Levels of Supervision.....	12

CHAPTER 2

Guidelines for Imaging Physics Residency Training Programs

2.1	Training Content.....	13
2.2	Facilities.....	13
2.3	Clinical Resources.....	15
2.4	Training Requirements.....	15
2.5	Expected Areas of Competence for a Clinical Medical Physicist in Imaging.....	16
2.5.1	General Radiography	17
2.5.2	Hard-copy and Image Displays	17
2.5.3	Angiography and Fluoroscopy	18
2.5.4	Computed Tomography (CT)	18
2.5.5	Ultrasound (US).....	19
2.5.6	Mammography	19
2.5.7	Magnetic Resonance Imaging (MRI)	19
2.5.8	Nuclear Medicine and Positron Emission Tomography (PET).....	20
2.5.9	Imaging Informatics.....	21
2.5.10	Safety	21

CHAPTER 3

Guidelines for Nuclear Medicine Physics Residency Training Programs

3.1	Training Content.....	23
3.2	Facilities.....	23
3.3	Clinical Resources.....	24
3.4	Training Requirements.....	24

3.5	Expected Areas of Competence for a Clinical Medical Physicist in Nuclear Medicine	24
3.5.1	Gamma Camera with/without SPECT	25
3.5.2	Positron Emission Tomography (PET and PET/CT)	26
3.5.3	CT Scanner (with SPECT or PET)	27
3.5.4	Non-imaging equipment	28
3.5.5	Radiation Safety	29
3.5.6	Patient Dosimetry	31
3.5.7	Informatics	31
3.5.8	Radiopharmacy	32
3.5.9	Clinical Studies	32
3.5.10	Radionuclide Therapy	32

CHAPTER 4

Guidelines for Radiation Oncology Physics Residency Training Programs

4.1	Training Content	33
4.2	Facilities	33
4.3	Clinical Resources	34
4.4	Training Requirements	34
4.5	Expected Areas of Competence for a Clinical Medical Physicist in Radiation Oncology	35
4.5.1	Treatment Equipment	35
4.5.2	Patient Treatment	37
4.5.3	Patient Safety	47
4.5.4	Brachytherapy	49
4.5.5	Detectors and Dosimeters	52
4.5.6	Imaging	54
4.5.7	Radiation Safety	59
4.5.8	Informatics	62
4.5.9	Elective Rotations	63

CONTENTS

APPENDIX A

Sample Evaluations

A. Resident Evaluation.....	72
B. Staff Evaluation.....	73
C. Program Evaluation.....	74

APPENDIX B

Sample Clinical Objective Templates

A. Template for Medical Physics Residents in Imaging.....	77
B. Template for Medical Physics Residents in Nuclear Medicine.....	79
C. Template for Medical Physics Residents in Radiation Oncology.....	81

APPENDIX C

Combining Imaging and Nuclear Medicine Residencies

A. Introduction.....	86
B. Common Competencies.....	86
C. Conclusion.....	87
Epilogue.....	88
Acronyms.....	89
Bibliography.....	93
Relevant Published Guidelines and Reports.....	94

FOREWORD

There is a clear need for established standards for medical physics residency training. The complexity of techniques in imaging, nuclear medicine, and radiation oncology continues to increase with each passing year. It is therefore imperative that training requirements and competencies are routinely reviewed and updated to reflect the changing environment in hospitals and clinics across the country. In radiation oncology, technology and procedures that were known and available only at the largest academic and research centers in years past—such as image-guided radiotherapy, respiratory-gated radiotherapy, intensity-modulated arc therapy, and stereotactic body radiotherapy—are becoming widely used. In imaging, recent advances include the evolution from film-based to digital radiography, which has resulted in a significant increase in the responsibilities of imaging physicists in the area of informatics. In nuclear medicine, new therapeutics such as microspheres, alpha-emitting agents, SPECT/CT, and PET/CT are increasingly being used in patient care.

The first AAPM report on residency training was published in 1992 (*AAPM Report Number 36*) by the Ad Hoc Committee on Clinical Training of Radiological Physicists. In 2003, the AAPM Committee on the Education and Training of Medical Physicists was charged with revisiting and updating that report. This group published their revision of Report Number 36 in August 2006 as *AAPM Report Number 90*, which concentrated on the clinical and professional knowledge needed to function independently as a practicing medical physicist in the areas of radiation oncology, diagnostic imaging, and nuclear medicine. In 2010, the AAPM Executive Committee asked the AAPM Committee on the Education and Training of Medical Physicists (ETC) to consider establishing a working group to periodically review these essentials and guidelines.

In 2010, the AAPM Work Group on Periodic Review of Medical Physics Residency Training was formed and charged with updating *AAPM Report Number 90*. This work group included AAPM members with extensive experience in clinical, professional, and educational aspects of medical physics. The work group members recognized that the recent publication of the *AAPM Report Number 197* (“Academic Program Recommendations for Graduate Degrees in Medical Physics”) and *AAPM Report Number 197S* (“The Essential Medical Physics Didactic Elements for Physicists Entering the Profession through an Alternative Pathway”) addressed the didactic training requirements of a medical physics resident. This report, therefore, concentrates on the clinical and professional knowledge needed to function independently as a practicing

FOREWORD

medical physicist in the areas of radiation oncology, imaging, and nuclear medicine. It constitutes a revision to *AAPM Report Number 90*.

It is the sincere hope of the work group that this report will provide clear guidelines and expectations for medical physics residency training for residency programs and residents, and will also serve the medical physics community at large.

CHAPTER 1

ESSENTIALS AND GUIDELINES FOR MEDICAL PHYSICS RESIDENCY TRAINING PROGRAMS

1.1 INTRODUCTION

According to the AAPM, medical physics is a branch of physics that applies the concepts and principles of physics to the diagnosis and treatment of human diseases [1]. Medical physics encompasses four subfields: imaging physics, nuclear medicine physics, radiation oncology physics, and medical health physics. This document will concentrate on the essential clinical training requirements for the first three of these subfields.

Terms such as “shall,” “must,” “should,” and “recommend” are frequently used in this report. The terms “shall” or “must” are used to denote items or activities the work group considers as mandatory requirements of the residency program. The terms “should” and “recommend” refer to items or activities the work group believes are important but which are not mandatory. Recommended items may be optional because they rely on faculty or resources not readily available in all practice settings.

1.2 OBJECTIVES OF A MEDICAL PHYSICS RESIDENCY TRAINING PROGRAM

The objective of a medical physics residency training program is to educate and train medical physicists to a level of competency sufficient for independent, professional practice in their specified subfield of medical physics [2,3]. To accomplish this goal, adequate organization, facilities, staff, patient resources, and educational environments must be provided [2]. A program shall document a description of its curriculum, facilities, faculties, policies, and evaluation criteria in a compilation known as a self-study.

1.3 STRUCTURE AND CONDUCT OF MEDICAL PHYSICS RESIDENCY PROGRAMS

1.3.1 Length of Training

Following the appropriate didactic training (see Section 1.5) [2], a clinical training period of at least two years is required. The first goal in these two years should be to provide the trainee with a broad experience in clinical medical physics in the subfield in which the residency

program specializes. This provides the foundation for the physicist to manage the broad range of medical physics tasks involved in caring for patients in diagnostic and interventional radiology, nuclear medicine, or radiation oncology.

Next, training should build on this clinical foundation in terms of both level of responsibility and coverage of topics such as specification, commissioning and acceptance testing, quality assurance, special procedures, and patient safety measures. After two years of clinical training, residents are expected to have sufficient competence to function independently and safely as medical physicists in a clinical environment. Some residency programs may choose to require more than two years of training, allowing residents time to obtain further supervised experience.

It is important to note that portions of clinical training may take place at affiliated institutions. This form of training is acceptable provided the recommendations and requirements described in this document are followed and the residency model is consistent with the *AAPM Task Group 133 Report* [4].

1.3.2 Program Director

There must be a single, identified program director who is authorized to oversee the medical physics residency program and is accountable for the operation of the program [5]. The program director [2,5]:

- 1) must contribute sufficient time to the program to ensure adequate direction;
- 2) is responsible for program organization and direction, as well as instruction and supervision of physics residents;
- 3) must arrange for the provision of adequate facilities, teaching staff, and clinical and educational resources;
- 4) must oversee and ensure the quality of the didactic and clinical education at all sites participating in resident education;
- 5) must oversee and approve all assigned supervisors or lead mentors for resident education at either the primary facility or affiliated institutions;
- 6) is responsible for the recruitment and appointment of physics residents and must ensure that the appointed residents meet the eligibility requirements listed in Section 1.5;
- 7) is responsible for ensuring that physics residents are making satisfactory progress and for providing appropriate remedial action should this not be the case; and
- 8) must ensure physics residents' performance is periodically evaluated and that documented feedback is provided to residents in a timely manner.

With regard to qualifications, the program director:

- 1) must be certified in the subfield of medical physics that he or she is overseeing by an appropriate certifying board; and
- 2) should have at least five years of full-time experience beyond clinical residency training as a qualified medical physicist practicing in the subfield of medical physics that he or she is overseeing.

1.3.3 Program Steering Committee

A program steering committee shall be formed to review the status of the residency program, track the progress of individual residents, address specific issues that may arise concerning the program or the residents, and discuss any necessary changes to the program. The committee should meet on a schedule sufficient to attend to program matters, but no less than three times annually. The steering committee should consist of the program director, relevant staff, and faculty members involved in residency training. It is recommended that a physician and a resident representative be involved, at least during select portions of the meeting or select meetings. At a minimum, there should be a pathway for residents' concerns to be expressed to the committee. It may also be helpful to have an institutional administrative representative on the committee in a nonvoting position or as a liaison to the committee. Minutes of all meetings should be maintained.

1.3.4 Other Program Staff and Personnel

The program must provide adequate staff for the teaching of medical physics in the program's area of specialty [2]. Teaching staff must be qualified in those areas in which they are assigned to instruct and supervise physics residents, and they must devote the necessary time and effort to the educational program. In addition, staff must maintain a professional and respectful work environment that is conducive to inquiry and scholarship [5]. A commitment to the physics resident training program on the part of staff is essential to the success of the program. Staff should be engaged in scholarly activities, such as:

- 1) participating in regional and national scientific societies,
- 2) participating in their own continuing education,
- 3) producing scientific publications and presentations, and
- 4) teaching, mentoring, or supervising trainees.

An adequate staff should include at least two full-time medical physicists certified by an appropriate certifying board and a diagnostic or imaging radiologist, radiation oncologist, or nuclear medical physician certified by the American Board of Radiology (ABR) or its equivalent, depending on the subfield of medical physics in which the program specializes. The ratio of full-time medical physicists participating in medical physics resident training to residents should be at least 1:1. It is recommended that access to training from a radiation biologist be available.

1.3.5 Institutional Support

The institution sponsoring the medical physics residency program should provide administrative support in terms of funding and space in addition to clinical and educational resources [2]. Adequate conference room and audiovisual facilities should be provided. A commitment to long-term funding of the program is essential.

Each resident should be allotted office space within the department and be provided a personal computer with network connections, an e-mail account, telephone, office supplies, and access to a copying machine and scanner.

The financial support provided, including benefits, should be clearly defined for the resident prior to his/her entry into the residency program.

1.3.6 Educational Environment

The medical physics residency program should be conducted in an environment that encourages the exchange of knowledge, experience, and ideas [2]. Open pathways of communication between residents, physics staff, physician staff, dosimetrists, technologists, therapists, physician residents, and other staff and trainees in the facility are imperative. The existence of other training programs for physicians, dosimetrists, technologists, and other allied health personnel helps foster a productive educational environment.

1.3.7 Residents' Scholarly Activities

The training program should include opportunities for residents to participate in scholarly activities. These may include presentations at departmental conferences and journal clubs, teaching opportunities, and research. Although optional, clinical research and development projects should be included as part of the clinical training program, provided they do not detract from the residents' clinical training. Opportunities for residents to participate in the clinical commissioning of new technology introduced into a facility will prepare residents and provide them with the necessary skills to practice independently as clinical medical physicists.

1.3.8 Conferences

Conferences and teaching rounds should provide for progressive resident participation [2]. Adequate frequency of conferences and attendance by physics residents, staff physicists, physicians, and other staff should be documented. These gatherings available to residents could include intradepartmental clinical conferences, such as staff meetings, patient case conferences, and physics meetings. Other conferences could include radiation safety training sessions, quality assurance (QA) committee meetings, and journal reviews. As a complement to resident education, it is encouraged that the physics residents periodically present at institutional conferences.

1.3.9 Documentation of Activities

The program should maintain documentation of residents' attendance at departmental conferences, seminars, journal clubs, or other educational activities. In addition, to monitor residents' progress, a log detailing their clinical and didactic activities should be maintained. Residents should maintain these records, but it is the program director's responsibility to periodically review these documents to ensure that they are kept current and residents are progressing adequately in the program.

1.3.10 Library Resources

A sufficient variety of journals, reference books, and other resource materials pertinent to medical physics, basic sciences, diagnostic and interventional radiology, nuclear medicine, and radiation oncology should be provided and be immediately accessible for resident study [2]. Physics residents must also have access to a general medical library and to the educational resources available on the Internet.

1.4 MEDICAL PHYSICS EDUCATIONAL COMPETENCIES

Medical physics residency programs must develop a curriculum and competencies for their residents. Written expectations regarding residents' performance, behavior, and training schedule should be provided to residents upon their entry into the residency program. These objectives should be discussed with each resident and periodically monitored through an established evaluation process. Following their evaluation, residents should be provided with written feedback regarding their performance. If their performance is deemed inadequate, a course of action for remediation should be developed in a timely manner.

Specific recommendations for curricula and competencies in imaging, nuclear medicine, and radiation oncology physics are detailed in chapters 2–4. In addition to providing training in

the specific competencies related to a given subfield of medical physics, it is recommended that residency programs include training in the following areas:

- 1) ethics and professionalism, e.g., AAPM Code of Ethics, *AAPM TG 159*, American Board of Radiology Foundation (ABRF) ethics and professionalism modules [6];
- 2) professional liability;
- 3) professional activities and societies, e.g., AAPM, Radiological Society of North America (RSNA), ABR, American College of Radiology (ACR), American Society for Radiation Oncology (ASTRO), Canadian College of Physicists in Medicine (CCPM), Canadian Organization of Medical Physicists (COMP), Society of Nuclear Medicine (SNM), Society for Imaging Informatics in Medicine (SIIM), and International Society for Optics and Photonics (SPIE);
- 4) soft skills such as communication, teamwork, and leadership training;
- 5) administration, including
 - a. personnel management (staffing models),
 - b. budgeting, and
 - c. billing;
- 6) accreditation and regulatory agencies;
- 7) continuous quality improvement (CQI); and
- 8) U.S. Food and Drug Administration (FDA)/Safe Medical Devices Act of 1990 (SMDA).

Programs should be mindful of the six core competencies specified by the American Board of Medical Specialties (ABMS) and the Accreditation Council for Graduate Medical Education (ACGME) and make efforts to integrate these competencies in their curricula and evaluation process. These competencies include: (1) patient care and procedural skills, (2) medical physics knowledge, (3) practice-based learning and improvement, (4) interpersonal and communication skills, (5) professionalism, and (6) systems-based practice [5,7–9]. Below are some examples of how these six competencies may be evaluated in medical physics resident education [8,10].

- 1) **Patient Care and Procedural Skills.** Medical physics residents should provide information that is appropriate, accurate, and relevant to the diagnosing or treating of medical conditions. Residents shall develop patient care and procedural skills by:
 - a. demonstrating an understanding of radiological anatomy and physiology in clinical contexts;
 - b. demonstrating an understanding of the major factors that affect patient care;

- c. providing physicians with appropriate technical and dosimetric information; and
 - d. improving and maintaining medical image quality on a variety of systems.
- 2) **Medical Physics Knowledge.** Medical physics residents should be knowledgeable, scholarly, and committed to lifelong learning. A resident's knowledge of medical physics shall include:
- a. specification, acceptance testing, and quality assurance of imaging and therapeutic equipment;
 - b. measurement and calculation of radiation exposure and dose;
 - c. demonstrations of investigatory and analytic thinking in solving clinical problems; and
 - d. applications of physics problem-solving skills to clinical medical physics problems.
- 3) **Practice-based Learning and Improvement.** Medical physics residents should investigate and evaluate patient care practices and appraise and assimilate scientific evidence and improve patient care practices. The resident shall pursue practice-based learning and improvement which will include:
- a. investigating and evaluating patient care practices;
 - b. understanding and applying radiation biology and epidemiology to clinical situations;
 - c. assimilating scientific evidence to improve patient care practices;
 - d. contributing to research and development projects in cooperation with radiologists, nuclear medicine physicians, radiation oncologists, and others;
 - e. analyzing results of testing and recognizing unexpected findings;
 - f. investigating equipment performance and possible performance problems; and
 - g. recognizing and correcting personal errors.
- 4) **Interpersonal and Communication Skills.** Medical physics residents should demonstrate effective communication with physicians, technologists, service personnel, and professional associates. The medical physics resident shall develop interpersonal and communication skills by:
- a. demonstrating clear and concise expression, both orally and in writing;
 - b. independently communicating with clinicians, technologists, and others regarding the physical principles of clinical problems;
 - c. demonstrating effective teaching of medical physics and radiation effects to trainees, technologists, and other healthcare professionals;
 - d. interfacing with agents external to the institution, including equipment service personnel, government regulators, and accreditation agency representatives;
 - e. producing accurate, concise, and grammatically correct written reports; and
 - f. listening effectively.

- 5) **Professionalism.** Medical physics residents should carry out all assigned duties, adhere to ethical principles, and show sensitivity to a diverse patient population. Residents shall develop professionalism by:
 - a. demonstrating a commitment to carrying out responsibilities;
 - b. understanding professional issues and participating in the activities of professional societies;
 - c. showing leadership and adhering to ethical principles;
 - d. demonstrating sensitivity to diverse patient populations;
 - e. being responsive to the needs of patients and prioritizing those needs over self-interest;
 - f. respecting patient privacy and confidentiality; and
 - g. demonstrating a commitment to excellence and ongoing professional development.
- 6) **Systems-based Practice.** Medical physics residents should be aware of the system of health care at their institution and effectively call on system resources to provide optimal care. Residents shall undertake systems-based practices that may include:
 - a. showing competence in information technology (IT) issues such as electronic media, software licensing, levels of access, and information security;
 - b. understanding policy development procedures and quality management systems at the departmental and institutional levels;
 - c. developing knowledge of aspects of the institution's capital equipment procurement process, such as relevant business plans and tender documents;
 - d. being aware of and responsive to the larger context and system of healthcare provision; and
 - e. partnering with managers and providers to assess, coordinate, and improve health care.

1.5 DIDACTIC KNOWLEDGE REQUIREMENTS

Upon satisfactory completion of a medical physics residency program, the graduate will have knowledge of medical physics comparable to that of a graduate of a CAMPEP-accredited medical physics graduate program. This is accomplished most directly by accepting graduates from accredited medical physics graduate programs into the residency program [11].

Alternatively, graduates of non-accredited medical physics graduate programs and graduates of physics or related graduate programs may be accepted into a medical physics residency program if they can demonstrate they have successfully completed the undergraduate and graduate didactic prerequisites as mandated by the ABR and AAPM. To demonstrate that the resident has

the equivalent of a minor in physics, the resident's undergraduate or graduate transcript should include at least three upper-division (third- or fourth-year undergraduate) physics courses or their equivalent. In addition, *AAPM Report Number 197S* has defined six core graduate-level topics that must be covered prior to the candidate's completion of a medical physics residency program [12]:

- 1) radiological physics and dosimetry;
- 2) radiation protection and radiation safety;
- 3) fundamentals of imaging in medicine;
- 4) radiobiology;
- 5) anatomy and physiology; and
- 6) radiation therapy physics.

These core topics are equivalent to 18 semester credits of coursework.

The contents of these courses should comply with the recommendations provided in *AAPM Report Number 197* [11]. A resident may take these courses during the residency. The program director must approve any coursework taken by a resident during residency training and ensure that the didactic work does not interfere with the resident's clinical training or responsibilities.

1.6 NUMBER OF RESIDENTS

The number of residents in the training program must be commensurate with the program's capacity to offer an adequate educational experience [2]. The maximum number of residents in the training program must not exceed the number of full-time equivalent staff physicists participating in medical physics training in the training program's field of specialization.

1.7 RESIDENT EVALUATION

The program director is responsible for continuing evaluation of the program and documentation of the educational progress and performance of each resident [2]. To ensure continuous progress assessment, the resident should meet periodically (e.g., biweekly) with the clinical coordinator or rotation supervisor. Monthly meetings of the resident with the program director are recommended. Proper documentation of these meetings will ensure compliance and continuity of assessment.

The resident must be evaluated upon completion of an area of study or clinical rotation. The resident's performance and progress should be assessed periodically by the program faculty

(e.g., via an oral or written examination). The results of these evaluations should be discussed with the resident and be documented. Sample resident evaluations are provided in Appendix A. There are currently no standardized criteria/scales for evaluating residents, however.

The program director should document any prior training from another institution that is being used to satisfy the training requirements of the program. A resident's prior training may be a reason to modify the training content of a rotation (e.g., by providing the resident with more advanced training). The duration of a rotation or the total length of the clinical residency may not be modified, however. It is the program director's responsibility to counsel, censure, and, after due process, dismiss residents who fail to demonstrate appropriate industry, competence, responsibility, learning abilities, or ethical behavior.

1.7.1 Staff and Program Evaluations

The training program should provide a means by which residents can give feedback regarding the performance of their clinical supervisors or rotation mentors. Measures should be taken to ensure the confidentiality of residents comments (e.g., the compilation of aggregate reports). Staff evaluations should be reviewed by the program director as evaluations are submitted. If an area of concern is identified, a plan of remediation should be developed and discussed with the staff member/s of interest. Sample staff evaluations are provided in Appendix A.

Upon completion of the program, the resident should be given an opportunity to evaluate the training program in its entirety. This evaluation should include a discussion of the teaching abilities, commitment to the training program, clinical knowledge, and professionalism of the staff and program director [5]. These program evaluations should be reviewed by the program steering committee; items of concerns should be identified and addressed. Sample program evaluations are provided in Appendix A.

1.7.2 Internal Program Review

The program steering committee should convene an annual meeting to discuss the training program in its entirety. During this meeting, the committee should review evaluations of residents, staff, and the program. Any issues or concerns should be identified and, if necessary, a plan of improvement should be developed. The program steering committee shall ensure the training program remains in compliance with the program self-study. Changes to the program made after the writing of the self-study should be identified and discussed. The training program should maintain documentation of the program steering committee minutes.

1.8 WORKING ENVIRONMENT

1.8.1 Professionalism, Personal Responsibility, and Patient Safety

The program director, mentors, and staff must set a positive example of professional behavior and educate residents regarding proper professional behavior in the clinic. The clinical culture must stress personal responsibility for each team member's role in patient care. Residents should be provided with direct instruction regarding the medical physicist's responsibility in patient care, as well as the roles of physicians and other staff.

The institution and program should promote and demonstrate a commitment to patient safety, emphasizing that patient safety is first and foremost amongst their core values. Direct instruction on the role of the medical physicist in the safe use of imaging and therapeutic equipment and procedures is integral to a successful program. Resources regarding patient safety are available through several professional societies and national and international organizations [13–16] and should be included in the program curriculum.

1.8.2 Access and Use of Medical Information

Residents should be permitted access to relevant medical records and patient information (e.g., hard-copy or electronic charts). If such access is permitted, Health Insurance Portability and Accountability Act (HIPAA) compliance training must first be provided. Additionally, the program director or program faculty should have an open discussion with the residents about the proper use of patient and human research data; it should be made clear that collecting patient-related data for research purposes without institutional review board (IRB) approval is not permissible.

1.8.3 Ethics

A residency program should include instruction on medical ethics. Specific attention should be given to ethical decision making in medical physics practice. Guidance for ethical training of medical physicists has been provided in *AAPM Report Number 159*. Additional resources, such as open courseware from major universities and the ABR Foundation Ethics and Professionalism modules [17], are available on-line.

1.8.4 Supervision of Residents

All clinical duties performed by residents should involve some level of supervision commensurate with the task by staff physicists, physicians, or other qualified staff. Supervision of residents performing clinical duties shall also comply with the statutes of the state/province in

which the program resides. These statutes may vary widely between states/provinces. Generally, first-year residents require closer supervision and oversight for day-to-day tasks than do second-year residents. Second-year residents should be working toward doing more independent duties. The program steering committee and institution or department physician leadership should approve any independent duties given to residents.

1.8.5 Levels of Supervision

- 1) **General Supervision.** This includes clinical duties that are performed under the overall direction and authorization of a supervisor. Performance of these duties does not require the presence of the supervisor [18,19].
- 2) **Direct Supervision.** This includes clinical duties that are performed while a supervisor is available within the immediate vicinity of a resident. The supervisor is not required to be physically present, but he or she is available to provide assistance and direction as needed throughout the performance of the procedure [18,19].
- 3) **Personal Supervision.** This includes clinical duties that are performed in the physical presence of a supervisor [18,19].

CHAPTER 2

GUIDELINES FOR IMAGING PHYSICS RESIDENCY TRAINING PROGRAMS

2.1 TRAINING CONTENT

Training in the clinical and technical areas of imaging physics should include the following: principles and procedures involved in the production of clinical images, methods of image evaluation, techniques for optimizing radiation exposure for diagnostic or interventional examinations, methods of calculating specific organ doses and estimating risk, calibration and monitoring of imaging equipment, and radiation safety procedures [2]. Residents must obtain an in-depth knowledge of the clinical physics areas listed in Section 2.5.

The growing number of commonalities between imaging and nuclear medicine physics practice has created an opportunity for residency programs to offer combined imaging and nuclear medicine physics residency programs in a highly efficient manner. Utilizing the commonalities between these residencies may allow a program to provide a nuclear medicine physics experience in one year following completion of an imaging residency program. Details on such an approach are provided in Appendix C.

The clinical imaging physics training staff should provide a systematic course of instruction that encourages progressive supervised resident responsibility for patient care. Staff must ensure that the physics resident personally performs the full range of common clinical physics procedures in diagnostic and interventional imaging. The resident should keep a detailed list of clinical physics procedures he or she has performed. This list should be reviewed periodically by the program director and the program steering committee, and it should be available for external review of the program.

2.2 FACILITIES

Adequate space must be available for the conduct of a good medical physics practice and clinical training program [2]. At a minimum, the following capabilities are required to ensure that adequate imaging modalities are available for observation and training:

- 1) Digital radiography systems, including both computed radiography and flat-panel imaging systems, must be provided.

- 2) Fluoroscopy systems using flat-panel imager systems must be provided. Programs should also provide access to image intensifier fluoroscopy systems, although their availability may be limited. Systems for general fluoroscopy should include at least one example each of under-table and over-table tube configuration. Fixed C-arm systems should include both single-plane and biplane versions. At least one mobile C-arm system must be available. A mini C-arm system should also be available.
- 3) Full-field digital mammography systems must be available and should include systems from at least two different manufacturers. A stereotactic biopsy system must also be available. If available, programs should provide access to screen–film mammography systems. Because their availability may be limited, a discussion on their use (i.e., screen–film mammography systems) is recommended. A computer-aided detection (CAD) system should also be available.
- 4) At least one multi-slice computed tomography (CT) scanner must be available. Multi-slice CT scanners from two different vendors should be available.
- 5) Magnetic resonance imaging (MRI) systems at two different field strengths must be available.
- 6) Ultrasound (US) imaging systems from at least two different manufacturers must be available.
- 7) At least one single photon emission computed tomography (SPECT) system and one positron emission tomography (PET) system must be available. At least one hybrid imaging system (e.g., SPECT/CT or PET/CT) should also be available.
- 8) The capability of exporting digital images to a workstation for specialized processing and analysis must be available for at least one imaging modality.
- 9) An electronic image management system, e.g., a picture archiving and communications system (PACS), must be available.
- 10) An electronic scheduling and reporting system, e.g., a radiology information system (RIS), should be available.

If any of the required modalities are not available on-site, the program must provide clinical training on such equipment at another approved institution. Research imaging equipment can be substituted for systems in clinical operation only when substitutes are substantially equivalent to commercial clinical equipment for imaging humans.

It is recognized that other clinical imaging modalities such as tomosynthesis and cone-beam CT imaging, are in clinical use. Training on other modalities can augment clinical training on the core imaging systems, but is not required.

2.3 CLINICAL RESOURCES

The training program in imaging physics must provide a sufficient volume and variety of patients for a comprehensive resident experience [2]. The number of diagnostic or interventional examinations per year should be sufficient for clinical residents to become competent in imaging physics.

2.4 TRAINING REQUIREMENTS

The training essentials outlined in this section constitute the specific accomplishments required on the part of a resident to prepare the resident to practice independently as a clinical medical physicist.

For systems for which accrediting agencies have defined requirements, the minimum number of systems that must be tested for the individual to be considered a qualified medical physicist (QMP) shall be the number specified by the accrediting agency. In all other cases, the number of systems that must be tested to demonstrate competency should be at the discretion of the QMP mentoring the resident. The minimum requirements that constitute adequate residency training in imaging physics include the following:

- 1) completion of 24 months in the residency program, including participation in any external rotations, with satisfactory performance documented by faculty evaluations;
- 2) completion of mammography annual system evaluations under the direct supervision of a Mammography Quality Standards Act (MQSA-certified) physicist;
- 3) completion of stereotactic breast biopsy system performance evaluation under the direct supervision of an MQSA-certified physicist;
- 4) completion of CT system performance evaluation performed under the direct supervision of a qualified CT medical physicist or independently;
- 5) completion of MRI system performance evaluation performed under the direct supervision of a qualified magnetic resonance (MR) medical physicist or independently;
- 6) completion of nuclear medicine (NM) camera system performance evaluation performed under the direct supervision of a qualified NM medical physicist or independently;
- 7) completion of positron emission tomography (PET) system performance evaluation performed under the direct supervision of a qualified NM medical physicist or independently;

- 8) completion of general purpose radiography system performance evaluation, performed independently;
- 9) completion of fluoroscopy system performance evaluation, performed independently;
- 10) completion of interventional x-ray system performance evaluation, performed independently;
- 11) completion of storage phosphor (e.g., computed radiography) or digital detector performance evaluation, performed independently;
- 12) completion of an ultrasound (US) system performance evaluation, performed independently;
- 13) attendance of all seminars required by the program;
- 14) successful completion of all required oral or written examinations; and
- 15) presentation of a research project at an internal seminar, or a regional or national scientific meeting if clinical research is a component of the program.

2.5 EXPECTED AREAS OF COMPETENCE FOR A CLINICAL MEDICAL PHYSICIST IN IMAGING

Competence should be demonstrated in the following major areas of responsibility:

- 1) specification, acceptance testing, and quality assurance of imaging equipment (training in this topic area should cover the principles of operation, appropriate uses, and limitations of test equipment);
- 2) equipment specifications and how they are used in a request for proposal (RFP);
- 3) measurement and calculation of radiation exposure and dose;
- 4) improving and maintaining medical image quality;
- 5) training of physicists, clinical diagnostic imaging residents, radiological technologists, ultrasonographers, and other allied health professionals in imaging physics; and
- 6) education of health professionals in imaging physics and radiation effects.

The program should develop a written list of objectives for or expectations of residents that should be presented to and discussed with residents. A list of specific competencies recommended for clinical medical physics in diagnostic imaging is provided below. Sample templates for presenting these objectives are provided in Appendix B; however, at this time there are no standardized criteria or scales for evaluating residents' performance during their clinical rotations. Competency in clinical research in imaging physics is recommended.

2.5.1 General Radiography

General radiography competency includes:

- 1) performing acceptance and annual compliance testing of general radiographic systems;
- 2) performing acceptance testing and annual testing of digital detector systems, including computed radiography and direct and indirect digital detector systems;
- 3) determining entrance skin exposure for radiographic examinations;
- 4) estimating patient radiation organ dose and relating dose to potential risk from radiographic examinations;
- 5) estimating radiation dose to conceptus and relating dose to potential risk from radiographic examinations;
- 6) explaining the complete radiographic imaging chain from production of x-rays to image formation;
- 7) explaining the origin of radiographic contrast and the mechanisms that compromise and enhance contrast; and
- 8) explaining methods of exposure control in general radiography.

2.5.2 Hard-copy and Image Displays

Hard-copy and image displays competency includes:

- 1) understanding the human visual system, visual performance in imaging tasks, and the statistical methods used to measure display performance;
- 2) reviewing quality control tests for processors and printers;
- 3) reviewing methods for acceptance and quality control testing of image printers;
- 4) reviewing methods of identifying and isolating common artifacts from processors, laser printers, and displays;
- 5) evaluating viewing conditions and ambient illumination in a room;
- 6) demonstrating an ability to assess the display quality of imaging workstations used for primary interpretation and for secondary review;
- 7) explaining the contrast transfer function for diagnostic displays; and
- 8) explaining the operation of sensitometers, densitometers, daylight film loaders, and darkroom processors.

2.5.3 Angiography and Fluoroscopy

Angiography and fluoroscopy competency includes:

- 1) performing acceptance and compliance testing of fluoroscopic and interventional x-ray systems;
- 2) configuring and operating fluoroscopic systems with appropriate regard for radiation safety;
- 3) determining entrance exposure rate for fluoroscopic examinations on both fluoroscopic and x-ray interventional systems;
- 4) estimating patient ionizing radiation dose and risk from fluoroscopic examinations;
- 5) estimating ionizing radiation dose to conceptus and risk from fluoroscopic examinations;
- 6) explaining the complete fluoroscopic imaging chain from production of x-rays to image formation;
- 7) understanding the composition and use of radiographic contrast agents in fluoroscopy and angiography examinations;
- 8) explaining how choices made by the operator affect patient dose and image quality; and
- 9) explaining methods of exposure control in fluoroscopic systems that use image intensifiers and flat panel receptors.

2.5.4 Computed Tomography (CT)

Computed tomography competence includes:

- 1) performing acceptance and compliance/accreditation testing of CT systems;
- 2) reviewing daily quality control tests of CT systems;
- 3) determining computed tomography dose index (CTDI) for CT examinations;
- 4) estimating patient ionizing radiation dose and risk from CT examinations;
- 5) estimating ionizing radiation dose to conceptus and risk from CT examinations;
- 6) explaining the complete CT imaging chain from production of x-rays to image reconstruction;
- 7) explaining the physical meaning of CT values (i.e., Hounsfield units); and
- 8) explaining how the specifics of CT imaging protocol affect the image quality, patient dose, and diagnostic benefits of an examination.

2.5.5 Ultrasound (US)

Ultrasound competence includes:

- 1) reviewing the requirements for acceptance and annual compliance testing of US systems;
- 2) performing periodic quality control tests of an US system and transducer;
- 3) explaining the complete US imaging chain, from production of vibrations to image reconstruction;
- 4) explaining the sources of contrast in US imaging; and
- 5) explaining how the specifics of US imaging protocol affect the diagnostic benefits of examination.

2.5.6 Mammography

Mammography competence includes:

- 1) performing acceptance and annual compliance testing of mammography systems (this should include digital and, if available, film/screen mammography systems);
- 2) performing acceptance and annual compliance testing of stereotaxic biopsy mammography systems;
- 3) determining mean glandular dose for mammography examinations;
- 4) reviewing quality control procedures and records for mammography systems;
- 5) evaluating viewing conditions for evaluating or interpreting mammography images;
- 6) explaining the complete mammographic imaging chain from the production of x-rays to image formation;
- 7) explaining the origins of radiographic contrast and mechanisms that compromise and enhance contrast;
- 8) explaining methods of exposure control in mammography and the purposes of breast compression; and
- 9) demonstrating knowledge of the relationships between dose and image quality and how both are affected by x-ray technique factors and image receptors.

2.5.7 Magnetic Resonance Imaging (MRI)

Magnetic resonance imaging competence includes:

- 1) performing acceptance and annual compliance/accreditation testing of an MRI system;

- 2) reviewing daily quality control tests performed by technologists on an MRI system;
- 3) performing quality control tests on a variety of radiofrequency (RF) coils;
- 4) understanding the requirements for MRI safety and practicing MRI safety procedures;
- 5) developing siting plans for an MRI system;
- 6) explaining the complete MRI chain, from production of signal to image reconstruction;
- 7) explaining the role of the k-space formalism in MRI; and
- 8) explaining how specific pulse sequences affect contrast in MRI, and explaining their relationships to the diagnostic benefits of examinations.

2.5.8 Nuclear Medicine and Positron Emission Tomography (PET)

Nuclear medicine and positron emission tomography competence includes:

- 1) performing annual compliance and acceptance testing procedures of a nuclear medicine gamma camera, including a single-photon emission computed tomography (SPECT) system;
- 2) performing annual compliance testing and demonstrating knowledge of the acceptance testing procedures of a PET system;
- 3) performing quality control tests and calibrations of nuclear medicine systems, dose calibrators, and counting systems;
- 4) monitoring the quality control program appropriate for nuclear medicine systems, dose calibrators, and counting systems, and demonstrating an understanding of the daily, monthly, quarterly, and annual tests required for each equipment type;
- 5) estimating basic patient and conceptus ionizing radiation doses and risks for nuclear medicine examinations;
- 6) explaining how uptake and clearance of radionuclides affects patient dose and the benefits of examination;
- 7) becoming familiar with radiopharmacy, radiation safety, protection procedures, and associated regulations;
- 8) calculating shielding for a nuclear medicine facility;
- 9) performing basic patient release calculations and demonstrating an understanding of release criteria; and
- 10) explaining the complete nuclear medicine imaging chain, from the ionizing radiation source to image reconstruction.

2.5.9 Imaging Informatics

Imaging informatics competence includes:

- 1) using the Digital Imaging and Communications in Medicine (DICOM) standard to configure modality devices for picture archiving and communication systems (PACS) integration, obtaining information for quality control purposes, and diagnosing problems involving the acquisition, storage, communication, and display of medical images;
- 2) understanding the aspects of imaging informatics peculiar to each imaging modality (e.g., radiography, fluoroscopy, mammography, CT, US, and MR);
- 3) understanding dose reporting features for radiography, fluoroscopy, mammography, and CT;
- 4) applying the Integrating the Health Enterprise (IHE) radiology profiles for workflow, content, presentation, and infrastructure to effect department workflow improvements and to improve imaging operations;
- 5) using open-source software resources to address clinical medical physics problems;
- 6) assessing the display quality of imaging workstations used for primary interpretation and secondary review;
- 7) using information technology to retrieve and store patient demographic, examination, and imaging information;
- 8) understanding the functions of radiology information systems (RIS) as they pertain to the ordering, tracking, billing, and reporting of images;
- 9) understanding how image processing is used to create radiographic images for display presentation, to depict 3D structures in CT and MRI, to augment interpretation with computer automated diagnosis (CAD), and to provide image fusion in SPECT/CT and PET/CT; and
- 10) using information technology to investigate clinical, technical, and regulatory questions.

2.5.10 Safety

Safety competence includes:

- 1) determining appropriate facility design and radiation shielding for radiographic, fluoroscopic, mammography, CT, MRI, nuclear medicine (including gamma camera, SPECT, SPECT/CT, and PET/CT installations) and radioactive materials use areas;

- 2) understanding the testing equipment and procedure for radiation protection surveys for radiographic, fluoroscopic, mammographic, CT, MRI, nuclear medicine (including gamma camera, SPECT, SPECT/CT, and PET/CT installations), and radioactive materials use areas;
- 3) reviewing MRI safety policies and procedures, including MRI screening for patients, technologists, hospital staff, and the general public;
- 4) understanding the bioeffects associated with ultrasound;
- 5) reviewing local, state/provincial, national, and international regulations and recommendations regarding the use of radiation, including recommendations of accrediting agencies and the implementation of the as-low-as-reasonably-achievable (ALARA) concept;
- 6) performing audits of all areas that use radiation for compliance with local, state/provincial, national, and international regulations and recommendations, including written directive requirements for therapeutic use of radiation;
- 7) understanding the use of patient and staff radiation personnel shielding;
- 8) explaining how to apply external radiation exposure protection principles;
- 9) explaining how radiation exposure to the public can occur by means such as internal uptake and radioactive material, and explaining how to protect personnel from exposure;
- 10) understanding personnel radiation dose limits and the theory and use of personnel dosimetry systems;
- 11) understanding counting and energy-integrating detector systems for both monoenergetic and polyenergetic radiation sources;
- 12) understanding radiation detector design considerations, including detection mechanisms, sensitivity, detection element size, energy dependence, dose and dose rate range, and stability of readings;
- 13) understanding the bioeffects and appropriate use of ultrasound equipment; and
- 14) reviewing the advantages and disadvantages of each detector type in relation to different uses.

CHAPTER 3

GUIDELINES FOR NUCLEAR MEDICINE PHYSICS RESIDENCY TRAINING PROGRAMS

3.1 TRAINING CONTENT

Training should include a systematic course of instruction with demonstrations relating to clinical and technical subjects pertinent to the various phases of nuclear medicine physics. Subjects should include the calibration and monitoring of nuclear medicine equipment, assay of radiopharmaceuticals, image processing, computer applications, and radiation safety procedures [2]. Residents must develop in-depth knowledge of the clinical physics areas listed in Section 3.5.

The growing number of commonalities between imaging and nuclear medicine physics practice has created an opportunity for residency programs to offer combined imaging and nuclear medicine physics residency programs in a highly efficient manner. Utilizing the commonalities between these programs may allow a program to provide a nuclear medicine physics experience in one year following completion of an imaging residency program. Details on such an approach are provided in Appendix C.

The clinical physics training staff should provide a systematic course of instruction that encourages progressive, supervised resident responsibility for patient care and must ensure that residents personally perform those clinical physics procedures commonly accepted in all aspects of nuclear medicine.

The resident should maintain a detailed list of clinical physics procedures that he or she has performed. This list should be reviewed periodically by the program director and the program steering committee and should be available for external review of the program.

3.2 FACILITIES

Space adequate for the conduct of a good clinical physics practice and training program must be available [2]. There must be:

- 1) two or more gamma cameras,
- 2) a single photon emission computed tomography (SPECT) unit,
- 3) access to a SPECT/CT unit,

- 4) access to a positron emission tomography (PET) or PET/CT unit,
- 5) a computer for image analysis,
- 6) nuclear medicine dose calibration instrumentation,
- 7) thyroid probe and a gamma well counter, and
- 8) access to a nuclear pharmacy.

If any of the required facilities are not available on site, the program must provide clinical training on such equipment at another approved institution.

3.3 CLINICAL RESOURCES

The training program in nuclear medicine physics must provide a volume and variety of patients sufficient for adequate resident experience [2]. The number of nuclear medicine diagnostic and therapeutic procedures should be sufficient to provide experience in this area. These procedures must include high-dose iodine therapies and should ideally include hepatic therapies using microspheres and palliative therapies.

3.4 TRAINING REQUIREMENTS

Upon completing a nuclear medicine residency program, the resident should possess the following competencies:

- 1) tests the minimum number of systems required to achieve Qualified Medical Physics status as defined by accrediting agencies;
- 2) demonstrates sufficient focus on each rotation to create an atmosphere of understanding of the modality;
- 3) demonstrates knowledge of professional interactions, such as with institutional personnel and vendors; and
- 4) demonstrates an understanding of professional consultations, clinical commitment, workflow cost, technical expertise, risk management, and regulatory compliance.

3.5 EXPECTED AREAS OF COMPETENCE FOR A CLINICAL MEDICAL PHYSICIST IN NUCLEAR MEDICINE

Competence should be demonstrated in the following major areas of responsibility:

- 1) specification, acceptance testing, and quality assurance of nuclear medicine equipment, all based on an understanding of the principles of operation, appropriate uses, and limitations of test equipment;
- 2) equipment specifications and how they are used in a request for proposal (RFP);
- 3) measurement and calculation of radiation exposure and dose;
- 4) improvement and maintenance of medical image quality; and
- 5) training of physicists, clinical residents, nuclear medicine technologists, and other health professionals in nuclear medicine physics and radiation effects.

The program should develop a written list of objectives for and expectations of residents. This list should be presented to and discussed with the residents. A list of specific competencies expected of residents in clinical medical physics in nuclear medicine is provided below. Sample templates for presenting these objectives are provided in Appendix B. Competency in clinical research in nuclear medicine physics and instrumentation is recommended.

3.5.1 Gamma Camera with/without SPECT

Gamma camera competency includes:

- 1) Selection of a gamma camera based on performance specifications
 - a. demonstrates an understanding of the components, operation, and clinical use of a gamma camera;
 - b. reviews the steps necessary to select a gamma camera, focusing on feature specification, performance specification, and clinical usage; and
 - c. reviews and discusses the mechanical and architectural considerations important in installing a new nuclear imaging room.
- 2) Acceptance testing
 - a. demonstrates an understanding of the references, e.g., AAPM, National Electrical Manufacturers Association (NEMA), International Electrotechnical Commission (IEC), available for acceptance testing and their limitations;
 - b. lists and explains the tests to be performed during acceptance testing;
 - c. lists the equipment needed to perform intrinsic, extrinsic, and SPECT acceptance tests;
 - d. performs physical inspections of equipment that include assessments of the adequacy of installation, detector level, and accuracy of angle indicators; and
 - e. independently performs intrinsic, extrinsic, and SPECT initial performance (acceptance) tests.

- 3) Calibration and quality assurance
 - a. demonstrates an understanding of and is able to describe the calibrations required for nuclear imaging using modalities such as SPECT;
 - b. develops and monitors a calibration and quality control program for nuclear cameras, including SPECT systems. (This includes the ability to describe the specific requirements for daily, weekly, monthly, and quarterly quality control.); and
 - c. performs calibration and routine quality control on planar and SPECT cameras.
- 4) Annual tests of a gamma camera
 - a. demonstrates an understanding of the planar and SPECT tests to be performed on an annual basis;
 - b. discusses the relationship between the acceptance test and the annual test; and
 - c. performs annual planar and SPECT tests and analyzes test results and compares them to the initial results.

3.5.2 Positron Emission Tomography (PET and PET/CT)

PET and PET/CT competency includes:

- 1) Selection of scanners based on performance specifications
 - a. demonstrates an understanding of the components of PET and PET/CT scanners;
 - b. demonstrates an understanding of the operation and clinical use of PET and PET/CT scanners;
 - c. reviews the steps necessary to select a PET or PET/CT scanner, focusing on feature specification, performance specification, and clinical usage; and
 - d. reviews and discusses the mechanical and architectural considerations important in installing a new PET or PET/CT scanner. (This includes the scanner itself, patient uptake rooms, the hot lab, and shielding considerations for all.).
- 2) Acceptance testing
 - a. demonstrates an understanding of the references available (e.g., AAPM, NEMA, IEC) for acceptance testing and the limitations of these methods;
 - b. demonstrates familiarity with NEMA tests, even if it is not feasible for the resident to perform tests;
 - c. lists and explains the tests to be performed during acceptance testing;
 - d. lists the equipment needed to perform intrinsic acceptance tests;
 - e. performs acceptance tests, if possible, that are appropriate for the scanner; and
 - f. independently performs phantom scanning for accreditation (e.g., ACR).

- 3) Calibration and quality assurance
 - a. demonstrates knowledge of any required calibrations for PET or PET/CT scanners (will vary with vendor);
 - b. develops and monitors a calibration and quality control program for PET systems, including the ability to describe the specific requirements for daily, monthly, and quarterly quality control; and
 - c. performs calibration and routine quality control on a PET scanner.
- 4) Annual testing
 - a. demonstrates an understanding of annual tests that is adequate to ensure a scanner is performing properly;
 - b. discusses the relationship between acceptance and annual tests; and
 - c. performs annual tests of a PET system.

3.5.3 CT Scanner (with SPECT or PET)

CT scanner competency includes:

- 1) Selection of scanners based on an understanding of performance specifications
 - a. demonstrates an understanding of the components of a CT scanner;
 - b. demonstrates an understanding of the operation and clinical use of a CT scanner;
 - c. reviews the steps necessary to select a CT scanner, focusing on feature specification, performance specification, and clinical usage in the context of a system integrated with a SPECT or PET system; and
 - d. reviews and discusses the mechanical and architectural considerations important in installing a CT scanner integrated with SPECT or PET.
- 2) Acceptance testing
 - a. demonstrates an understanding of the tests to be performed during CT acceptance testing;
 - b. lists the equipment required to perform CT acceptance tests;
 - c. performs physical inspections of equipment that include assessments of adequacy of installation and shielding in relation to specified requirements;
 - d. performs acceptance tests of the CT scanner. (These tests must include an evaluation of dose such as the computed tomography dose index [CTDI]); and
 - e. independently performs acceptance tests related to the requirements for a system integrated with SPECT or PET.

- 3) Calibration and quality control
 - a. demonstrates knowledge of any required calibrations for a CT scanner integrated with SPECT or PET (will vary with the vendor);
 - b. develops and monitors a calibration and quality control program for CT systems used in conjunction with SPECT or PET hybrid systems. (This includes the ability to describe the specific requirements for daily, monthly and quarterly quality control.); and
 - c. demonstrates familiarity with routine quality control tests performed by technologists and required for a CT scanner as part of an integrated system.
- 4) Annual testing
 - a. demonstrates an understanding of annual tests adequate to ensure the CT scanner is performing properly;
 - b. performs an annual test of the CT scanner; and
 - c. performs tests required to validate performance as part of an integrated system with SPECT or PET.

3.5.4 Non-imaging Equipment

Non-imaging equipment competency includes:

- 1) Dose calibrator, well counters, and uptake probes
 - a. Selection of equipment based on an understanding of performance specifications
 - i. describes the design and operational characteristics of each type of non-imaging equipment and
 - ii. demonstrates an understanding of the clinical use and limitations of each type of equipment.
 - b. Acceptance testing
 - i. demonstrates knowledge of the tests used to evaluate the performance of the non-imaging equipment;
 - ii. performs acceptance tests on equipment, including any tests required by regulatory agencies as well as tests using measures of energy resolution, efficiency, and sensitivity as appropriate for the equipment being evaluated; and
 - iii. performs tests for minimum detectable activity on counting systems as appropriate.

GUIDELINES FOR NUCLEAR MEDICINE PHYSICS RESIDENCY TRAINING PROGRAMS

- c. Calibration and quality control
 - i. describes the routine quality control necessary for each non-imaging instrument;
 - ii. monitors the quality control program appropriate for each piece of non-imaging equipment and demonstrates an understanding of the daily, monthly, quarterly, and annual tests required for each type of non-imaging equipment; and
 - iii. performs calibration and routine quality control on each type of non-imaging equipment.
- d. Annual tests
 - i. describes the annual tests necessary for non-imaging equipment and
 - ii. performs annual tests for each type of non-imaging equipment.

3.5.5 Radiation Safety

Radiation safety competency includes:

- 1) Contamination control
 - a. lists federal and state/provincial regulatory requirements related to receipt of radionuclides, disposal of radioactive waste, and daily checks for contamination in a nuclear medicine department;
 - b. demonstrates familiarity with and reviews the records required in a nuclear medicine department;
 - c. demonstrates the ability to use a Geiger counter (and ionization measurement chambers as appropriate) to perform surveys for contamination control, radionuclide package receipt, and radioactive waste disposal; and
 - d. demonstrates the ability to perform wipe tests with a well counter to test for area contamination and radionuclide package receipt.
- 2) Protection
 - a. Shielding design for general nuclear medicine, PET, and CT
 - i. demonstrates familiarity with shielding design concepts and describes what information is required to perform shielding calculations;
 - ii. demonstrates knowledge of radiation exposure limits pertaining to workers and the general public and their relation to shielding design;
 - iii. discusses shielding considerations for a nuclear medicine department;
 - iv. performs shielding calculations for a PET/CT suite, including calculations for the scanner room, patient dosing rooms, and hot lab;

- v. performs shielding calculations for a SPECT/CT scanner in a nuclear medicine department; and
 - vi. performs exposure measurements in areas in which radiopharmaceuticals are used or produced.
- b. Radiation exposure to personnel and the public
- i. demonstrates knowledge of radiation exposure limits to staff and the general public;
 - ii. describes radiation signage required for radiation areas; and
 - iii. demonstrates knowledge of regulations related to the release of patients who have been administered a radiopharmaceutical and, in particular, is able to describe the patient release regulations and procedures for I-131 therapy.
- c. Radiation incidents
- i. describes the action plan for controlling the spread of contamination after a spill;
 - ii. describes the procedure for decontamination after a spill of radioactive material; and
 - iii. participates in a decontamination event, if possible.
- d. Medical events
- i. demonstrates knowledge of the definition of a medical event under federal or state/provincial regulations and of the rules for reporting a medical event;
 - ii. demonstrates familiarity with the resources related to patient dose calculations for radiopharmaceuticals; and
 - iii. demonstrates an ability to perform calculations required to determine if an event is reportable.
- e. Dose to fetus/embryo
- i. demonstrates knowledge of the definition of a medical event under federal or state/provincial regulations with regards to unplanned fetal exposure and determining if the event is reportable;
 - ii. demonstrates familiarity with the resources related to fetal dose calculations; and
 - iii. demonstrates an ability to perform fetal dose calculations.

- 3) Knowledge of regulations and recommendations
 - a. demonstrates familiarity with federal or state/provincial regulations relevant to nuclear medicine, including regulations governing transportation of radioactive material;
 - b. knows what an agreement state is, including what the general requirements are for being an agreement state;
 - c. demonstrates familiarity with the contents and requirements of a radioactive materials license; and
 - d. demonstrates knowledge of the concept of as low as reasonably achievable (ALARA) and familiarity with the recommendations organizations such as the National Council on Radiation Protection (NCRP), International Commission on Radiological Protection (ICRP), and The Joint Commission (TJC) as they relate to radiation protection.

3.5.6 Patient Dosimetry

Patient dosimetry competency includes:

- 1) demonstrates a thorough understanding of dose quantities and units,
- 2) demonstrates an understanding of internal organ dose calculations using the medical internal radiation dose (MIRD) method,
- 3) performs dose calculations using the MIRD method, and
- 4) demonstrates an understanding of dosage determination for therapeutic procedures.

3.5.7 Informatics

Informatics competency includes:

- 1) Understands modality-specific systems
 - a. demonstrates an understanding of the requirements of modality systems, including software required for the acquisition, processing, and display of clinical studies;
 - b. demonstrates an understanding of the requirements for connectivity to department imaging/non-imaging equipment (DICOM);
 - c. demonstrates familiarity with the processing of nuclear medicine studies such as tomographic reconstruction and quantitative analysis; and
 - d. performs annual testing, including display evaluation.
- 2) Understands radiology information systems (RIS)
- 3) Understands PACS, including connectivity to modality systems (DICOM)

3.5.8 Radiopharmacy

Radiopharmacy competency includes:

- 1) The resident should rotate through a nuclear pharmacy to observe the following activities and demonstrate an understanding of these procedures:
 - a. generator elution procedures,
 - b. quality control for generator eluates,
 - c. assays of activity,
 - d. kit preparations,
 - e. calculations of dosage for administration, and
 - f. unit and therapeutic dosage preparations (including beta emitters).
- 2) The resident should demonstrate knowledge of the physics of radionuclide production using reactors and accelerators and of the operation of an in-house cyclotron.

3.5.9 Clinical Studies

Clinical studies competency includes:

- 1) demonstrates an understanding of the anatomy and physiology relevant to pharmaceutical uptake and elimination;
- 2) demonstrates an understanding of computer analysis and techniques such as region of interest (ROI)/curve generation, histogram analysis, and cardiac analysis;
- 3) demonstrates an understanding of the principles of kinetic modeling; and
- 4) demonstrates the ability to review data and use data to solve a technical problem.

3.5.10 Radionuclide Therapy

Radionuclide therapy competency includes:

- 1) demonstrates an understanding of the regulatory requirements related to therapeutic procedures, including the requirements pertaining to written directives and the release of the patient after therapy;
- 2) performs patient release calculations and demonstrates an understanding of the release criteria; and
- 3) demonstrates an understanding of the circumstances in which written instructions are required after radionuclide therapy.

CHAPTER 4

GUIDELINES FOR RADIATION ONCOLOGY PHYSICS RESIDENCY TRAINING PROGRAMS

4.1 TRAINING CONTENT

Training in clinical and technical subjects pertinent to the various areas of radiation oncology physics should include the following topics: external beam megavoltage irradiation (both with low- and high-energy [10 MV or greater] photon beams), electron beam therapy, interstitial and intracavitary brachytherapy irradiation, CT-based virtual simulation, computerized 3D dose planning, construction of treatment aids, calibration and monitoring of radiation therapy equipment, radiation safety procedures, and methods to ensure patient safety [2]. Residents must obtain in-depth knowledge of the clinical physics areas listed in Section 4.5.

The clinical physics training staff should provide a systematic course of instruction that encourages progressive, supervised resident responsibility for patient care. Additionally, training staff must ensure that the physics resident personally performs the commonly accepted clinical physics procedures in all aspects of radiation oncology. The resident should keep a detailed list of clinical physics procedures that he or she has performed. This list should be reviewed periodically by the program director and the program steering committee and should be available for external review of the program.

4.2 FACILITIES

Space adequate for the conduct of a good clinical physics practice and training program must be available [2]. Clinical facilities must include the following:

- 1) a megavoltage machine that includes high-energy photons (10 MV or greater), electron beams, a multi-leaf collimator, and integrated imaging capability;
- 2) access to a CT scanner used for virtual simulation;
- 3) equipment required to perform interstitial and intracavitary brachytherapy procedures, including a high dose rate (HDR) afterloading treatment unit;
- 4) a computerized 3D external beam treatment planning system that uses modern model-based or Monte Carlo calculation algorithms; and

- 5) a physics dosimetry laboratory housing dosimeters that include ionization chambers and in vivo dosimeters (e.g., diodes, thermoluminescence dosimeters [TLDs], optically stimulated luminescent dosimeters [OSLDs]) for calibration and measurement, phantoms, solid water, and water scanning systems.

Availability of electronics and machine shops is desirable. If any of the required facilities are not available on-site, the program must provide clinical training on such equipment at another participating institution.

4.3 CLINICAL RESOURCES

The training program in radiation oncology physics must provide a sufficient volume and variety of cancer patients for an adequate resident experience [2]. The number of new external beam and brachytherapy patients treated per year should be sufficient to ensure that the resident is adequately trained in all aspects of medical physics appropriate for these treatments. The number of new external beam (3D and intensity-modulated radiation therapy [IMRT]), brachytherapy, and special-procedure patients treated per year should be sufficient to permit a clinical resident to become competent and proficient in radiation oncology physics. Arrangements should be made for the resident to receive training on those treatment procedures that are not performed at the training facility.

4.4 TRAINING REQUIREMENTS

Upon completing a radiation oncology physics residency program, the resident should possess the following competencies:

- 1) demonstrates sufficient focus on each rotation to have acquired an understanding of the modality;
- 2) demonstrates knowledge of professional interactions with individuals internal to a department and medical institution, and with vendors and others outside the institution; and
- 3) demonstrates an understanding of professional consultations, clinical commitment, workflow cost, technical expertise, risk management, and regulatory compliance.

4.5 EXPECTED AREAS OF COMPETENCE FOR A CLINICAL MEDICAL PHYSICIST IN RADIATION ONCOLOGY

Competence should be demonstrated in the following major areas of responsibility:

- 1) specification, acceptance testing, and quality assurance of radiotherapy and radiotherapy-related imaging equipment, including the principles of operation, appropriate uses, and limitations of test equipment;
- 2) equipment specifications and how they are used in a request for proposal (RFP);
- 3) measurement and verification of the output of ionizing radiation from radiotherapy treatment equipment prior to clinical use and on a routine basis;
- 4) development, implementation, and oversight of radiotherapy procedures and techniques;
- 5) development and oversight of quality assurance and radiation safety measures for therapeutic procedures pertaining to departmental personnel, patients, and the public;
- 6) consultation with radiation oncologists on treatment modalities, techniques, and radiobiological aspects of treatments; and
- 7) training of physicists, radiation oncology residents, radiation technologists, or allied health professionals in radiation oncology physics.

The program should develop a written list of objectives for or expectations of the residents. This list should be presented and discussed with the residents. A list of specific competencies for clinical medical physics in radiation oncology is listed below. Sample templates for presenting these objectives are provided in Appendix B. Competency in clinical research in radiation oncology physics is recommended.

4.5.1 Treatment Equipment

Medical physics residents should have the following competencies with respect to megavoltage photons (linear accelerators or cobalt-60 units), electrons, and protons:

- 1) Equipment selection
 - a. demonstrates an understanding of the theory of operation of megavoltage electron and proton accelerators currently used in radiation oncology treatment and their limitations, e.g., linear accelerators (linacs), synchrotrons, and cyclotrons;
 - b. demonstrates an understanding of the major subsystems and uses of cobalt units;
 - c. demonstrates an understanding of the major subsystems and components of megavoltage accelerators;

- d. reviews the steps required to select a new electron linear accelerator (linac) for use in radiation oncology on the basis of an understanding of performance specifications and features comparisons; and
 - e. reviews and discusses mechanical/architectural considerations when installing a new particle accelerator in both new and existing vaults (with discussion addressing heating, ventilation, and air conditioning [HVAC] openings, cabling for communication and dosimetry systems, electrical ports, plumbing, and skyshine).
- 2) Acceptance/Commissioning
- a. competently performs the mechanical, safety, and radiation tests required during accelerator acceptance and commissioning;
 - b. demonstrates an understanding of the process for defining the treatment beam isocenter of a gantry-based particle accelerator and its relation to the gantry's mechanical isocenter and any on-board imaging isocenters;
 - c. discusses how to perform treatment unit head radiation leakage and shielding adequacy tests;
 - d. independently sets up and performs water tank scans for photon and electron beam measurements that calibrate and characterize those external beams to facilitate computerized treatment planning and hand calculations of radiation dose to a point;
 - e. analyzes water tank scans and demonstrates an understanding of the results of these scans, including typically accepted tolerances for each test performed; and
 - f. demonstrates an understanding of acceptance, commissioning, and on-going annual QA requirements for radiation treatment planning system modules dealing with external beam treatments.
- 3) Calibration
- a. demonstrates an understanding of and an ability to use the instrumentation (e.g., theory of operation, limitations) and protocols that may be employed in calibrating of radiation treatment beams of energy in the megavoltage range;
 - b. demonstrates an understanding of how and why phantoms are used for physical measurements;
 - c. demonstrates an understanding of the correction factors used for photon and electron calibration measurements; and
 - d. competently calibrates megavoltage external beams of photons and electrons using a recognized national or international protocol.

- 4) Quality assurance
 - a. demonstrates an understanding of the pertinent recommendations for quality assurance of linacs used in radiation therapy;
 - b. demonstrates an understanding of in-house quality assurance documentation and procedures;
 - c. competently performs routine (daily/weekly/monthly/annual) quality assurance tests of external beam treatment units;
 - d. competently analyzes routine quality assurance tests of external beam treatment units;
 - e. demonstrates an understanding of the basis of accepted tolerances for routine quality assurance tests performed on treatment units and of required actions should any of the checks fall out of tolerance;
 - f. demonstrates an understanding of external beam treatment unit malfunction management;
 - g. competently performs end-to-end checks of patient treatment plans using phantom images and data; and
 - h. understands the connectivity requirements of external beam treatment units to treatment simulators, on-board imaging systems, record and verify systems, and electronic medical records systems.

4.5.2 Patient Treatment

4.5.2.1 Treatment Techniques

Treatment technique competencies include the following:

- 1) demonstrates an understanding of 2D coplanar beam treatment planning;
- 2) demonstrates an understanding of the placement of non-coplanar beams (3D) in external beam treatment planning;
- 3) demonstrates an understanding of the following image-guided radiation therapy techniques:
 - a. planar MV imaging;
 - b. planar kV imaging;
 - c. cone beam computed tomography (CBCT);
 - d. ultrasound (US); and
 - e. non-radiographic localization, e.g., US, surface camera, radiofrequency (RF) beacon tracking.

- 4) demonstrates an understanding of image registration techniques, e.g., rigid and deformable registration;
- 5) demonstrates an understanding of site-specific techniques (photons and electrons):
 - a. performs 3D or IMRT treatment planning for breast and chest wall that includes axilla fields and the single isocenter technique;
 - b. performs 3D or IMRT treatment planning for the brain, spine, and craniospinal irradiation;
 - c. performs 3D or IMRT treatment planning for the bladder, prostate, and testis;
 - d. performs 3D or IMRT treatment planning for gynecological tumors;
 - e. performs 3D or IMRT treatment planning for gastrointestinal tumors, e.g., colorectal tumors, tumors of the esophagus, stomach, and liver;
 - f. performs 3D or IMRT treatment planning for head and neck tumors;
 - g. performs 3D treatment planning for common lymphomas that includes the mantle field technique;
 - h. performs 3D treatment planning for skin cancers;
 - i. demonstrates an understanding of common 3D or IMRT treatment planning techniques for pediatric cancers and performs 3D treatment planning for pediatric craniospinal irradiation;
 - j. demonstrates an understanding of common 3D or IMRT treatment planning techniques for sarcoma of the trunk and extremities; and
 - k. performs 3D or IMRT treatment planning for the lungs, mediastinum, and thoracic region.

4.5.2.2 Treatment Planning

Treatment planning competencies include the following:

- 1) Beam properties
 - a. demonstrates an understanding of photon and electron percent depth dose in tissue and other media;
 - b. demonstrates an understanding of electron ranges (R_p , R_{80} , R_{90} , and d_{max}) for different energies;
 - c. demonstrates an understanding of proton percent depth dose in tissue and other media and proton ranges for different energies, e.g., stopping and scattering power and range;
 - d. demonstrates an understanding of the potential uncertainties in dose deposition in proton radiotherapy;

GUIDELINES FOR RADIATION ONCOLOGY PHYSICS RESIDENCY TRAINING PROGRAMS

- e. demonstrates an understanding of the flatness and symmetry of photon and electron beams;
 - f. demonstrates an understanding of the differences between source-to-axis distance (SAD) and source-to-skin distance (SSD) treatments;
 - g. demonstrates an understanding of the applicability of electron and photon therapy with regard to disease, depth, and critical normal structures;
 - h. discusses the impact of dose and fractionation on normal and tumor tissues;
 - i. demonstrates an understanding of the impact of beam quality (e.g., linear energy transfer [LET]) on the relative biological effectiveness (RBE) of different forms of ionizing radiation (e.g., electrons, photons, and protons); and
 - j. discusses the uncertainties related to electron and photon therapy (e.g., in terms of physics, biology, machine and patient setup accuracy) and how they may be detected and mitigated during the planning and delivery process.
- 2) Beam modifiers
- a. demonstrates an understanding of the effect of beam modifiers (e.g., wedges, compensators) on the dosimetric characteristics of the incident beam;
 - b. demonstrates an understanding of wedges (wedge angle, hinge angle) and the different types of wedges used clinically (physical, universal, dynamic);
 - c. demonstrates an understanding of the design of the different commercially available multileaf collimators (MLCs);
 - d. demonstrates an understanding of blocking and shielding for therapy beams;
 - e. demonstrates an understanding of the use of custom bolus; and
 - f. demonstrates an understanding of the design and use of tissue compensators.
- 3) Treatment simulation techniques
- a. demonstrates an understanding of common patient-positioning and immobilization devices;
 - b. demonstrates an understanding of when and how to use specific treatment devices for specific treatments; and
 - c. discusses how to account for beam attenuation from patient-positioning and immobilization devices in treatment planning.
- 4) Tumor localization and normal tissue anatomical contouring
- a. performs structure delineation on CT, MRI, PET, PET/CT, SPECT, or SPECT/CT data sets;
 - b. demonstrates an understanding of target volume determination, including the design of ICRU target structures (involving concepts such as gross tumor volume [GTV], clinical target volume [CTV], internal target volume [ITV], planning target volume [PTV], and planning organ at risk volume [PRV]);

- c. demonstrates an understanding of how 4D data is used for target definition and relevant radiation treatment prescription parameters such as GTV, PTV, CTV, and ITV;
 - d. demonstrates an understanding of the role of maximum intensity projection (MIP) images in the treatment planning process;
 - e. demonstrates an understanding of the role of digitally reconstructed radiographs (DRRs) in the treatment planning process; and
 - f. demonstrates an understanding of and performs image registration and fusion of data sets for modalities such as CT/CT, CT/MRI, and CT/PET; deformable registration; and image/dose registration.
- 5) Plan evaluation
- a. defines and discusses each of the following treating planning evaluation tools, including their limitations:
 - i. dose volume histograms (V(dose), D(volume), mean dose; cumulative and differential);
 - ii. conformity index;
 - iii. homogeneity index; and
 - iv. biological evaluators (e.g., generalized equivalent uniform dose [gEUD], equivalent uniform dose [EUD], normal tissue complication probability [NTCP], and tumor control probability [TCP]).
 - b. discusses dose tolerances for various normal tissue structures along with relevant volume effects.

4.5.2.3 Intensity-modulated Radiation Therapy (IMRT)

IMRT competencies include the following:

- 1) Inverse planning
 - a. demonstrates an understanding of the use of objective functions for IMRT optimization;
 - b. demonstrates an understanding of the optimization processes involved in inverse planning;
 - c. performs inverse planning optimization for a variety of treatment sites in sufficient number to become proficient in the optimization process (see Section 4.5.2.1); and
 - d. demonstrates an understanding of commonly used planning procedures and guidelines as well as optimization and dose calculation algorithms.

- 2) IMRT/volumetric modulated arc therapy (VMAT) delivery
 - a. demonstrates an understanding of various IMRT delivery techniques (e.g., compensators, static field IMRT, rotational delivery techniques) and their relative advantages and disadvantages;
 - b. discusses the differences between dynamic multileaf collimator (DMLC) and segmental multileaf collimator (SMLC) leaf sequencing algorithms in terms of delivery parameters and dose distributions; and
 - c. participates in IMRT or VMAT delivery for patients with a variety of treatment sites and demonstrates an understanding of the techniques and requirements for patient setup, immobilization, and localization.

4.5.2.4 Monitor Unit (MU) Calculations

Monitor unit calculation competencies include the following:

- 1) demonstrates an understanding and performs derivation of the following factors:
 - a. percent depth dose (PDD),
 - b. tissue-air ratio (TAR),
 - c. tissue-maximum ratio (TMR),
 - d. tissue-phantom ratio (TPR),
 - e. scatter factors (i.e., S_c , S_p , S_{cp}),
 - f. off-axis factors,
 - g. inverse square factors,
 - h. calibration factor (monitor unit [MU] reference conditions),
 - i. standard wedge factors,
 - j. virtual and dynamic wedge factors,
 - k. compensator factors, and
 - l. tray and other insert factors
- 2) performs manual MU calculations for photon or electron beams of the following configurations:
 - a. SSD setup,
 - b. SAD setup,
 - c. extended distance setup,
 - d. off-axis calculation points, and
 - e. rotational beams.
- 3) demonstrates an understanding of and performs MU calculations using heterogeneity corrections

4.5.2.5 Quality Assurance (QA)

Quality assurance competencies include the following:

- 1) performs treatment plan verification involving:
 - a. review of patient history (such as prior radiotherapy and potential overlap with current treatment), disease, course of treatment, and dose prescription;
 - b. review of appropriateness of the treatment plan and dose distribution to achieve the goals of the treatment course (see Section 4.5.2.2);
 - c. review of simulation (e.g., patient positioning and immobilization), planning, imaging, and treatment field parameters;
 - d. review of monitor unit or time calculations;
 - e. review of images to be used for patient positioning or monitoring; and
 - f. review of transfer of plan parameters and images to record and verify system and any other patient monitoring systems.
- 2) performs IMRT QA:
 - a. demonstrates an understanding of the appropriate level of quality control tests for IMRT;
 - b. demonstrates an understanding of commonly used QA procedures and guidelines, delivery and dosimetry equipment, and QA analysis techniques;
 - c. calculates verification plans within the treatment planning system along with independent checks using secondary MU calculation software;
 - d. performs IMRT delivery QA measurements using 2D/3D array, film, or ion chamber techniques, an activity that includes analysis of results and determination of passing criteria (which will involve familiarity with the concept of gamma analysis);
 - e. performs and analyzes MLC QA measurements designed for accelerators used for IMRT; and
 - f. reviews individual patient-specific QA results with staff physicists and physicians.
- 3) performs ongoing review of treatment records (e.g., chart checks, review of treatment or setup images), including verification of delivered treatments;
- 4) demonstrates an understanding of the following components of an *in vivo* dosimetry program:
 - a. acceptance, commissioning, calibration, and ongoing quality assurance procedures for *in vivo* dosimetry systems;
 - b. use of *in vivo* dosimetry systems for patient-specific measurement; and
 - c. limitations of specific *in vivo* dosimetry systems.

- 5) demonstrates familiarity with the dose limits relevant to sensitive structures outside of the treatment field (e.g., gonads, fetus, and electronic implanted device such as cardiac pacemaker and/or defibrillator) and the ability to determine the dose to these structures.

4.5.2.6 Special Procedures

Special procedures competencies include the following:

- 1) Small field
 - a. Stereotactic radiosurgery (SRS)
 - i. discusses rationales for SRS treatments, examples of malignant and non-malignant lesions treated with SRS, and typical dose and fractionation schemes for linac-based and Co-60 SRS techniques;
 - ii. describes in general terms the components of commissioning an SRS system (e.g., accurate localization, mechanical precision, accurate and optimal dose distribution, and patient safety);
 - iii. discusses the stereotactic localization of a target (e.g., on the basis of angiography as opposed to CT and MRI) and how the accuracy of this localization is measured;
 - iv. describes the alignment of coordinate systems (e.g., target frame of reference with linac frame of reference) and how the mechanical precision of this alignment is measured;
 - v. describes issues associated with dosimetry measurements for an SRS system (e.g., choice of dosimeter, phantom geometry, etc.); and
 - vi. describes the components of pre-treatment QA for an SRS system, including linac-based and Co-60 SRS techniques.
 - b. Stereotactic body radiation therapy (SBRT)
 - i. explains the rationale for SBRT treatments, common treatment sites, and typical dose and fractionation schemes;
 - ii. discusses immobilization and localization systems for SBRT treatments;
 - iii. discusses the use of simulation imaging for SBRT target definition, including multi-modality imaging and 4D imaging for cases requiring motion management;
 - iv. discusses treatment planning objectives for SBRT treatments, including dose limits, dose heterogeneity, dose gradient and fall-off, and beam geometry;

- v. discusses treatment verification and delivery for SBRT treatments as well as use of in-room imaging;
- vi. addresses the need for motion management in lung and abdomen SBRT treatments; and
- vii. discusses treatment planning system validation tests, and in this context, tissue inhomogeneity corrections and small-field dosimetry measurements.

Please note it is not expected that all clinics training medical physics residents will perform all of the following special procedures; however, all residents should have a level of knowledge of these procedures sufficient to prepare them for independent clinical practice. A list of the minimum clinical background for these procedures is provided below.

- 2) Total body (photon) irradiation (TBI)
 - a. discusses the rationale for TBI treatments for the treatment of malignant and benign conditions;
 - b. demonstrates an understanding of TBI prescription and delivery techniques and of issues related to the clinical commissioning and maintenance of a TBI program;
 - c. discusses and demonstrates an understanding of the significance of beam modifiers commonly used during TBI treatments (e.g., lung/kidney blocks, beam spoilers); and
 - d. participates in all aspects of TBI treatment (i.e., simulation, planning, plan verification, treatment, treatment verification, and *in vivo* measurements). (NOTE: this competency is optional.)
- 3) Total skin electron treatment (TSET)
 - a. discusses the rationale of TSET treatments for the treatment of malignant and benign conditions;
 - b. demonstrates an understanding of TSET delivery techniques and of issues related to the clinical commissioning and maintenance of a TSET program;
 - c. explains the significance of the B-factor;
 - d. discusses and demonstrates an understanding of the significance of beam modifiers commonly used during TSET treatments (e.g., shields, beam scatter); and
 - e. participates in all aspects of TSET treatment (i.e., simulation, planning, plan verification, treatment, treatment verification, and *in vivo* measurements). (NOTE: this competency is optional.)
- 4) Respiratory-correlated planning and delivery
 - a. discusses the rationale for using respiratory management systems in radiation therapy;

- b. describes the common issues introduced by respiratory motion in imaging, planning, and treatment delivery;
- c. discusses common treatment sites affected by respiratory motion and the typical range of tumor excursion;
- d. describes methods for evaluating and managing respiratory motion; and
- e. describes QA tests for common respiratory management systems and their recommended frequency.

4.5.2.7 Treatment Planning Workstations

Treatment planning workstation competencies include the following:

- 1) Data acquisition
 - a. explains the connection between linac commissioning and the data required for operation of a treatment planning system;
 - b. for a particular treatment planning system, describes the linac data needed for:
 - i. photon beams,
 - ii. electron beams, and
 - iii. IMRT and VMAT.
- 2) Acceptance testing
 - a. describes what tests of the treatment planning system need to be performed before patient-specific planning can commence for:
 - i. photon beams,
 - ii. electron beams, and
 - iii. brachytherapy sources.
- 3) Quality assurance
 - a. describes the tests that need to be performed and their accuracy;
 - b. describes accuracy checks for the following input devices and types of images:
 - i. digitizers;
 - ii. film scanners;
 - iii. imported images from instruments such as CT scanners, MRI scanners, and picture archiving and communication (PAC) systems.
 - c. describes accuracy checks for the following output devices:
 - i. printers,
 - ii. record and verify systems, and
 - iii. DICOM output.

- 4) Computer algorithms (models)
 - a. describes how the computer algorithm calculates dose for at least one major treatment planning system with regard to:
 - i. photon beams,
 - ii. electron beams,
 - iii. brachytherapy calculations, and
 - iv. proton beams (optional; see Elective Rotations, Section 4.5.9).
 - b. describes the advantages and disadvantages of the various treatment planning calculation algorithms; and
 - c. describes how the computer algorithm determines the number of monitor units per beam or segment (for step-and-shoot IMRT).
- 5) Plan normalization
 - a. describes the numerous normalization capabilities available on a treatment planning system;
 - b. describes how different normalization schemes affect final isodose curve representation; and
 - c. describes how the computer plan normalization relates to the calculation of monitor units for patient treatments.
- 6) Inhomogeneity (heterogeneity) corrections
 - a. describes the type of data that need to be taken on a CT scanner in preparation for treatment planning using inhomogeneous material;
 - b. describes how these CT data are converted into inhomogeneity data usable in a treatment planning system;
 - c. describes how computerized treatment planning systems take inhomogeneities into account;
 - d. identifies where the computer algorithm calculates dose with acceptable accuracy and in which regions calculational accuracy is suspect; and
 - e. describes how the accuracy of the inhomogeneity corrections performed by a treatment planning system would be checked.
- 7) Beam modeling
 - a. completely models at least one photon beam energy for a treatment planning system;
 - b. completely models at least one electron beam energy for a treatment planning system;
 - c. completely models at least one proton beam energy for a treatment planning system (optional; see Elective Rotations, Section 4.5.9); and

GUIDELINES FOR RADIATION ONCOLOGY PHYSICS RESIDENCY TRAINING PROGRAMS

- d. tests the accuracy of his or her modeling for the beams and is able to describe the criteria for acceptability of the modeling.
- 8) Imaging tests
- a. describes the tests that would be performed to ensure that the imported image data are correct;
 - b. demonstrates that images can be imported from CT, MR, and PET or PET/CT scanners;
 - c. demonstrates that the above imaging sets can be accurately fused with the primary treatment planning image set; and
 - d. describes the different image fusion algorithms available on a treatment-planning system (e.g., CT-CT, CT-MR, CT-PET).
- 9) Secondary monitor unit check computer programs
- a. describes what input data need to be acquired;
 - b. describes the checks of that input data that need to be performed to ensure that the monitor unit check program is working correctly (e.g., for the factors listed in Section 4.5.2.4);
 - c. describes how imported data from treatment-planning systems are handled in a monitor unit check program;
 - d. describes how the monitor unit check program calculates the number of monitor units for off central-axis normalization points; and
 - e. describes how the monitor unit check program calculates monitor units for treatments involving inhomogeneous material.

4.5.3 Patient Safety

Patient safety competencies include the following:

- 1) General
- a. understands the principles behind the development of a general patient and staff safety management program within the hospital;
 - b. discusses the physicist's role in developing and overseeing an overall quality assurance program for both equipment and procedures, including a discussion of allocation and management of resources necessary to carry out these tasks, incorporation of tools and techniques into these tasks, and inclusion of various groups within the structure of the radiation oncology department;

- c. discusses the principles and rationale of TJC Universal Protocol as well as the use of pre-procedure verification and time-outs for the prevention of treatment errors;
 - d. discusses internal, voluntary, and mandatory incident reporting systems and the role of root cause analysis (RCA) as a tool for continuous quality improvement;
 - e. discusses the concept of a failure mode and effect analysis (FMEA), design and implementation of an FMEA, and how to use the results of such an analysis to prevent errors and minimize risks to patients and staff;
 - f. discusses charting systems for the prescription, delivery, and recording of treatment information, standardization of such systems, and the use of such systems within a record and verify electronic medical record system; and
 - g. discusses mechanisms for independent checking of treatment information
- 2) Equipment
- a. discusses the implementation of an effective set of equipment operating procedures that would include preventative maintenance and repair, keeping of maintenance and repair records, emergency procedures, and systematic inspection of interlock systems;
 - b. discusses the development of a program to prevent mechanical injury caused by the machine or accessory equipment, with consideration of the need for visual and audio contact with the patient while the patient is under treatment;
 - c. understands potential patient safety hazards related to the use of blocks, block trays, wedges, and other ancillary treatment devices and accessories as well as mechanisms to minimize these risks;
 - d. understands potential patient safety hazards posed by patient support and immobilization systems, as well as mechanisms to minimize these risks; and
 - e. understands potential patient safety hazards of gantry–patient collision as well as mechanisms to minimize this risk.
- 3) Other patient/staff safety issues
- a. understands potential electrical hazards affecting patients and staff;
 - b. understands the potential hazards to patients and staff posed by strong magnetic fields;
 - c. understands the mechanisms of ozone production and related potential hazards to patients and staff; and
 - d. understands potential hazards to patients and staff arising from the use of cerrobend.

4.5.4 Brachytherapy

4.5.4.1 Sources

Brachytherapy source competencies include the following:

- 1) Sealed radionuclide sources
 - a. demonstrates an understanding of how commonly used sources are generated;
 - b. discusses the decay, decay energies (mean energy), and half-lives of commonly used sources;
 - c. discusses the form and construction of sealed sources;
 - d. discusses and defines the different units of source strength that have been used in the past and the present;
 - e. performs an example decay calculation of the total dose delivered for temporary and permanent implants;
 - f. discusses personal protection techniques (involving time, distance, and shielding) and safe handling of sealed sources;
 - g. discusses the appropriate methods of storing radioactive material (with regard to security and accountability);
 - h. performs routine receipt procedures and both checks into inventory and checks out temporary and permanent sources;
 - i. performs a source room survey and a quarterly inventory;
 - j. discusses and, if possible, performs leak checks on sealed sources;
 - k. demonstrates an understanding and gains hands-on experience of radioactive material packaging and transportation requirements, e.g., Title 49 of the U.S. Code of Federal Regulations (CFR);
 - l. demonstrates an understanding of the equipment used to calibrate sealed sources;
 - m. discusses the process by which sealed sources are calibrated;
 - n. discusses the process by which measurement equipment (e.g., electrometers, well ionization chambers) is calibrated;
 - o. explains the theory of operation of a well ionization chamber;
 - p. discusses and performs an assay for sealed sources;
 - q. demonstrates an understanding of licensing issues and requirements (e.g., NUREG 1556);
 - r. discusses the operation and appropriateness of different survey instruments (e.g., Geiger–Müller counters, ionization survey meters, scintillation counters); and

- s. demonstrates an understanding of the regulatory requirements pertaining to sealed sources, e.g., state/provincial or federal regulations such as Title 10 of the U.S. CFR Part 35 (10CFR35).
- 2) Unsealed radionuclide sources
- a. demonstrates an understanding of how commonly used radiopharmaceuticals (e.g., I-131, P-32, Sm-153, Sr-89) are generated;
 - b. demonstrates an understanding of the decay, decay energies (mean energy), and half- lives of commonly used radiopharmaceuticals;
 - c. discusses personal protection techniques (involving time, distance, and shielding) and safe handling of unsealed sources;
 - d. discusses the process by which unsealed sources are calibrated;
 - e. discusses the process by which measurement equipment (e.g., dose calibrator) is calibrated;
 - f. discusses and, if possible, performs an assay for unsealed sources;
 - g. demonstrates an understanding of licensing issues and requirements (e.g., NUREG 1556);
 - h. discusses the operation and appropriateness of different survey instruments (e.g. Geiger–Müller counters, ionization chambers, scintillation counters); and
 - i. demonstrates an understanding of the regulatory requirements for unsealed sources, e.g., state/provincial or federal regulations such as 10 CFR 35.

4.5.4.2 Clinical Applications

Brachytherapy clinical application competencies include the following:

- 1) discusses the various brachytherapy sources that have been used clinically in the past and which are used today, as well as the rationale for source selection;
- 2) discusses how a brachytherapy program is developed;
- 3) discusses in detail the use and operation of the following different brachytherapy modalities and their advantages and disadvantages:
 - a. low dose rate (LDR);
 - b. high dose rate (HDR);
 - c. pulsed dose rate (PDR; optional); and
 - d. electronic (optional; see Elective Rotations in Section 4.5.9).
- 4) discusses and performs verifications of source strength (air kerma rate, Sk) and comparisons between measured and vendor’s specifications;
- 5) discusses radiation protection for radiation workers and visitors;

GUIDELINES FOR RADIATION ONCOLOGY PHYSICS RESIDENCY TRAINING PROGRAMS

- 6) demonstrates an understanding of commissioning and acceptance of remote after-loaders (RALs);
- 7) demonstrates an understanding of gynecologic (GYN) and genitourinary anatomy;
- 8) demonstrates an understanding of the treatment of cervical and endometrial cancers with LDR, HDR, and PDR (optional);
- 9) demonstrates an understanding of prostate cancer and its treatment with HDR and LDR;
- 10) treatment planning:
 - a. demonstrates an understanding of treatment planning commissioning;
 - b. performs brachytherapy treatment plans for a cylindrical GYN applicator;
 - c. performs brachytherapy treatment plans for cervical applicator (e.g., tandem and ovoids, tandem and ring);
 - d. discusses the differences between point- and volume-based treatment planning as per the ICRU 38 and the Groupe Européen de Curiethérapie (GEC) European Society for Radiotherapy and Oncology (ESTRO) recommendations;
 - e. develops interstitial brachytherapy treatment plans (e.g., prostate cancer, GYN diseases, sarcoma);
 - f. develops a brachytherapy treatment plan for an eye plaque (optional); and
 - g. performs an activity/dose calculation for microsphere therapy (optional).
- 11) demonstrates an understanding of applicator acceptance, commissioning, and the performance of periodic QA;
- 12) demonstrates an understanding of and participates in/performs periodic spot checks, safety procedures, and source exchange QA, including source calibration;
- 13) describes emergency training requirements for RALs (e.g., as specified in 10 CFR 35);
- 14) demonstrates an understanding of quality management programs as required by federal or state/provincial regulations for auditing; and
- 15) discusses the criteria for recording/reporting and the subsequent handling of reportable events.

4.5.4.3 Imaging

Brachytherapy imaging competencies include the following:

- 1) demonstrates an understanding of the mathematics of localization of target volume and catheter reconstruction by orthogonal films (2D) and
- 2) demonstrates an understanding of CT-/MRI-/US-/PET-based localization of region of interests (ROIs) and of catheter reconstruction.

4.5.4.4 Treatment Planning

Brachytherapy treatment planning competencies include the following:

- 1) demonstrates an understanding of the source strength of radioactive sources;
- 2) discusses dose rates and dose calculation formalisms for high-energy brachytherapy dosimetry (HEBD) and low-energy brachytherapy dosimetry (LEBD);
- 3) demonstrates an understanding of the performance of computerized planning of various imaging modalities of LDR and HDR;
- 4) discusses in detail the advantages and disadvantages of dose optimization; and
- 5) discusses and performs secondary calculations as QA checks for computerized planning.

4.5.4.5 Quality Assurance (QA)

Brachytherapy QA competencies include the following:

- 1) demonstrates an understanding of and performs comprehensive periodic QA (daily, monthly, annually) of remote afterloader;
- 2) discusses and performs periodic treatment planning QA; and
- 3) demonstrates an understanding of implant-specific QA,

4.5.5 Detectors and Dosimeters

4.5.5.1 General

General detector/dosimeter competencies include the following:

- 1) demonstrates an understanding of absorbed-dose calculation and measurement;
- 2) demonstrates an understanding of Bragg–Gray, Spencer–Attix, and Burlin cavity theories; and
- 3) demonstrates an understanding of dosimeter design considerations (e.g., detection mechanism, sensitivity, size, shape, thickness of sensitive volume and wall, materials, energy dependence, detector/phantom media matching, dose and dose rate range, stability of reading).

4.5.5.2 Ionization Chambers

Ionization chamber detector/dosimeter competencies include the following:

- 1) demonstrates an understanding of design considerations pertaining to cylindrical ionization chambers, including size, shape, materials, and electrical characteristics;

- 2) demonstrates an understanding of design considerations pertaining to parallel-plate ionization chambers, including size, shape, materials, electrical characteristics, and use for measuring dose in the buildup region;
- 3) demonstrates an understanding of the advantages and disadvantages of each ionization chamber design, including detector limitations;
- 4) demonstrates an understanding of ionization chamber measurement techniques involving instruments such as electrometers, operational amplifiers, and triaxial cables and connections;
- 5) performs acceptance testing for ionization chamber and electrometer involving measurements of leakage and evaluation of relevance, polarity effects, and stem effects;
- 6) performs ionization chamber measurements using Farmer, parallel-plate, and scanning chambers, as well as large-volume survey ionization chambers;
- 7) demonstrates an understanding of ion chamber correction factors, including P_{TP} , P_{pol} , P_{elec} , P_{ion} , P_{wall} , P_{grad} , P_{fl} , and P_{cel} .
- 8) calculates corrected charge readings for ion chamber measurement using TG-51 formalism;
- 9) demonstrates an understanding of the ion chamber calibration process on the basis of NIST/ADCL; and
- 10) demonstrates an understanding of design and characteristics of monitor chambers.

4.5.5.3 Thermoluminescent Dosimeter (TLD)/Optically Stimulated Luminescent Dosimeter (OSLD)

TLD and OSLD detector/dosimeter competencies include the following:

- 1) demonstrates an understanding of the physical mechanisms involved in the process of radiation detection and readout using TLDs or OSLDs;
- 2) if possible, performs TLD or OSLD measurements and readout (including calibration) using standard irradiation;
- 3) demonstrates an understanding of the method and rationale for TLD annealing; and
- 4) discusses the advantages and disadvantages of TLDs or OSLDs.

4.5.5.4 Diodes

Diode detector/dosimeter competencies include the following:

- 1) demonstrates an understanding of the physical mechanisms involved in radiation detection and readout using semiconductor dosimeters;

- 2) if possible, performs diode measurements that include investigation of factors such as angular and dose rate dependence and temperature sensitivity; and
- 3) discusses the advantages and disadvantages of diodes, including their inherent limitations.

4.5.5.5 Film (Silver Bromide, Radiochromic)

Film detector/dosimeter competencies include the following:

- 1) demonstrates an understanding of the physical mechanisms involved in radiation detection and measurement using film, including measurement of the optical density and its characteristics as a function of absorbed dose, and film's dependence on radiation energy, handling, and processor conditions;
- 2) if possible, performs film dosimetry including creation of calibration curve; and
- 3) discusses the advantages and disadvantages of using film, including its inherent limitations.

4.5.5.6 Metal Oxide Semiconductor Field Effect Transistor (MOSFET) Detectors

MOSFET detector/dosimeter competencies include the following:

- 1) demonstrates an understanding of the physical mechanisms involved in radiation detection and readout using MOSFET dosimeters and
- 2) discusses the advantages and disadvantages of using MOSFETs, including their inherent limitations.

4.5.6 Imaging

4.5.6.1 Computed Tomography (CT) Simulators

CT simulator imaging competencies include the following:

- 1) General
 - a. compares the nuances of CT simulators with those of diagnostic CT scanners (e.g., in terms of lasers, table top indexing, localization software, bore size);
 - b. demonstrates an understanding of the theory of CT imaging reconstruction and of the operation of a CT simulator;
 - c. demonstrates an understanding of the major subsystems and components of a CT simulator; and
 - d. demonstrates an understanding of the room shielding and other radiation protection requirements of a CT simulator.

GUIDELINES FOR RADIATION ONCOLOGY PHYSICS RESIDENCY TRAINING PROGRAMS

- 2) Selection
 - a. reviews the steps required to select a new CT simulator, including performance specification and feature comparison and
 - b. reviews and understands the mechanical/architectural considerations relevant to installing a new CT simulator in both new and existing rooms.
- 3) Acceptance testing
 - a. demonstrates an understanding of the mechanical tests performed during a CT simulator acceptance procedure;
 - b. demonstrates an understanding of the tests of image quality and characteristics for a CT image and DRR for a CT simulator;
 - c. demonstrates an understanding of the measurement of dose and the computed tomography dose index (CTDI) from a CT simulator for different body sites;
 - d. demonstrates an understanding of the measurement of CT number as opposed to density calibration with kVp and CT number used in treatment planning systems;
 - e. demonstrates an understanding of the alignment of internal and external laser systems in a CT simulator;
 - f. demonstrates an understanding of network connectivity tests between other systems used in the radiation oncology process (e.g., treatment planning systems, treatment verification systems, PAC system); and
 - g. demonstrates an understanding of the validation tests related to the transfer of CT-imaged objects to treatment planning systems.
- 4) Dose calculations
 - a. understands the physical basis for the use of CT-simulator images in treatment planning as the current standard for dose calculations and
 - b. understands the calibration of these CT-simulator images for computing radiation dose deposition in different tissues.
- 5) Quality assurance
 - a. competently performs routine QA test processes for CT simulators and understands the QA test processes relationship to acceptance testing and commissioning measurements;
 - b. understands the bases of recommended measurements for CT-simulators and the measurements tolerances specified by the AAPM, ACR, and other professional bodies;
 - c. understands and competently determines the geometric accuracy of laser alignment, couch motion, gantry motion, and CT-simulator images for both static and moving objects;

- d. understands and competently assesses the quality of images produced by CT-simulators in any mode of operation and image reconstruction, and is able to discuss the impact of image artifacts and distortion on treatment planning; and
 - e. understands the connectivity requirements of a CT simulator to other computer systems that form part of a modern radiation therapy treatment process, including being familiar with Internet and DICOM-RT image data transfer protocols.
- 6) CT protocols
- a. demonstrates an understanding of the following parameters, their typical values, and how they are combined in CT protocols: slice thickness, pitch, kV, mAs, FOV, and scan length;
 - b. demonstrates an understanding of how CT protocols consider multi-slice capabilities, tube heating, and maximum scan time;
 - c. demonstrates an understanding of the relationship between image quality and patient dose from examination;
 - d. demonstrates an understanding of the need to define dose-optimized imaging protocols for various body parts and sizes of patient;
 - e. demonstrates an understanding of image artifacts that may arise in CT images, while being able to identify their causes and assess or mitigate their impact on radiation treatment planning;
 - f. understands the different imaging protocols used in tumor motion management (e.g., voluntary breath hold, active breathing control, shallow breathing by compression, free breathing helical CT, 4D-CT); and
 - g. understands the different CT image acquisition modes available with a modern CT simulator (e.g., prospective, retrospective, cine, helical, 4D, and image sorting based on breathing phase and breathing amplitude).

4.5.6.2 On-Board MV and kV Imaging

On-board MV and kV imaging competencies include the following:

- 1) General
 - a. discusses the different detector technologies that have been used for on-board MV and kV imaging;
 - b. discusses the imaging dose associated with on-board MV and kV imaging technologies; and
 - c. discusses the different measures of radiographic image quality.

- 2) QA
 - a. demonstrates an understanding of the QA processes and frequencies of checks for on-board MV and kV imaging, including cone-beam CT (e.g., image quality, image integrity, safety and mechanical checks, network connectivity, imaging dose, and localization software, isocenter calibration).

4.5.6.3 Magnetic Resonance Imaging (MRI)

MRI imaging competencies include the following:

- 1) General
 - a. demonstrates an understanding of the basic imaging principles behind MRI;
 - b. compares the treatment-planning-related advantages and limitations of MRI with those of CT; and
 - c. demonstrates an understanding of the role of MRI for radiation therapy applications, providing examples.
- 2) QA
 - a. demonstrates an understanding of the quality assurance processes and frequencies of checks for MR simulators (e.g., image quality, image integrity, safety and mechanical checks, network connectivity).

4.5.6.4 Ultrasound (US)

US imaging competencies include the following:

- 1) General
 - a. demonstrates an understanding of the basic imaging principles behind US imaging and
 - b. demonstrates an understanding of the role of US in external beam and brachytherapy treatments using trans-rectal as opposed to trans-abdominal probes, providing examples.
- 2) QA
 - a. discusses methods for QA of US imaging probes prior to clinical uses in procedures such as prostate implants and prostate external beam therapy.

4.5.6.5 Positron Emission Tomography (PET)

PET imaging competencies include the following:

- 1) General
 - a. demonstrates an understanding of the basic imaging principles behind PET;
 - b. compares the advantages and limitations of PET with those of CT for treatment planning; and
 - c. demonstrates an understanding of the role of PET for radiation therapy applications, providing examples.
- 2) QA
 - a. demonstrates an understanding of the quality assurance processes and frequencies of checks for PET-CT simulators (e.g., image quality, image integrity, safety and mechanical checks, network connectivity).

4.5.6.6 SPECT

SPECT imaging competencies include the following:

- 1) General
 - a. demonstrates an understanding of the basic imaging principles behind SPECT;
 - b. discusses the comparative advantages and limitations for treatment planning of SPECT and CT; and
 - c. demonstrates an understanding of the role of SPECT for external beam and radiopharmaceutical therapy applications, providing examples.

4.5.6.7 Image Registration/Fusion

Image registration/fusion competencies include the following:

- a. discusses the rationale behind and the advantages/challenges of image registration and image fusion;
- b. defines the image features on which registration can be based (e.g., landmarks, segments, intensities);
- c. defines the different forms of registration (e.g., rigid, affine, deformable) and discusses their advantages and limitations;
- d. defines similarity metrics used to assess quality of registration (e.g., squared intensity differences, cross-correlation, mutual information);
- e. discusses how to commission imaging modalities such as MRI, PET-CT, and diagnostic CT for the purpose of image registration to a radiation oncology planning CT;

- f. discusses issues associated with the transfer of images (e.g., connectivity, image dataset integrity);
- g. discusses issues associated with patient positioning (e.g., bore size, couch top, lasers, compatibility of immobilization devices, differences in patient position/organ filling, motion); and
- h. discusses issues associated with the choice of image acquisition technique (e.g., length of scan, slice thickness, FOV, kV, mAs).

4.5.7 Radiation Safety Protection/Design/Architecture

Radiation safety competencies include the following:

- 1) Megavoltage photons (linacs or cobalt-60 units) and electrons, kilovoltage, superficial x-rays, or protons
 - a. demonstrates an understanding of the federal (e.g., Nuclear Regulatory Commission [NRC], Canadian Nuclear Safety Commission [CNSC]) and state/provincial licensing requirements for by-product materials and x-ray-producing devices;
 - b. explains the principles behind a radiation protection program, including the rationale for the dose limits for radiation workers and members of the public;
 - c. demonstrates an understanding of federal, state/provincial, local, and institutional regulatory requirements;
 - d. explains the concept of ALARA;
 - e. demonstrates an understanding of site planning and how to supervise construction (i.e., key elements to monitor);
 - f. demonstrates an understanding of structural shielding designs relevant to a radiotherapy department (e.g., NCRP 151) and discusses the key parameters necessary to perform a shielding calculation;
 - g. performs shielding calculations for an accelerator vault, including primary and secondary barrier transmission calculations;
 - h. discusses the shielding requirements for the maze and door of a high-energy room;
 - i. performs a radiation survey of a facility that includes low-energy and high-energy (greater than 10 MV) units;
 - j. discusses the advantages and disadvantages of various materials that may be used for shielding; and

- k. discusses how special procedures such as TBI and SBRT may impact shielding parameters.
- 2) IMRT
- a. demonstrates an understanding of IMRT delivery's effects on leakage radiation and its potential effects on patients and personnel exposure;
 - b. demonstrates an understanding of the effects of different IMRT delivery techniques on the amount of leakage radiation produced; and
 - c. demonstrates an understanding of the effects of IMRT delivery on vault shielding requirements.
- 3) Conventional simulator (radiographic/fluoroscopic)
- a. demonstrates an understanding of state/provincial licensing of x-ray producing devices;
 - b. explains the principles behind a radiation protection program, including the rationale for the dose limits for radiation workers and members of the public;
 - c. discusses the key parameters necessary to perform a shielding calculation;
 - d. demonstrates an understanding of structural shielding designs for a conventional simulator and, if possible, performs a shielding calculation (with respect to the walls, ceilings, floor, and control area); and
 - e. demonstrates an understanding of film processing and darkroom design.
- 4) CT simulator
- a. demonstrates an understanding of state/provincial licensing of x-ray producing devices;
 - b. explains the principles behind a radiation protection program, including the rationale for the dose limits for radiation workers and members of the public;
 - c. discusses the key parameters necessary to perform a shielding calculation;
 - d. discusses the significance of an isodose distribution plot for a CT simulator;
 - e. demonstrates an understanding of structural shielding designs for a CT simulator and performs a shielding calculation (walls, ceilings, floor, and control area); and
 - f. demonstrates an understanding of film processing and darkroom design.
- 5) Brachytherapy
- a. demonstrates an understanding of shielding calculations for primary and secondary barriers (e.g., NCRP 151);
 - b. discusses the key parameters necessary to perform a shielding calculation;
 - c. discusses or performs a shielding calculation for a brachytherapy vault;
 - d. discusses or performs a radiation survey for a brachytherapy vault;

GUIDELINES FOR RADIATION ONCOLOGY PHYSICS RESIDENCY TRAINING PROGRAMS

- e. discusses requirements for personal radiation safety badges;
 - f. discusses labeling, shipping, and receiving requirements for radioactive material;
 - g. discusses management of an isotope inventory;
 - h. discusses release criteria for radioactive patients (i.e., patients with temporary or permanent implants and radiopharmaceuticals);
 - i. discusses how to handle changes in medical status for radioactive patients (i.e., in cases of medical emergency or death, as per NCRP 155);
 - j. explains the key concepts of state/provincial or federal regulations (e.g., Title 10 of CFR parts 19, 20, and 35); and
 - k. demonstrates how to safely operate a remote afterloader unit, including emergency procedures.
- 6) Regulations/recommendations/licensing
- a. demonstrates an understanding of federal (e.g., NRC, CNSC) or state/provincial licensing for by-product materials and x-ray producing devices;
 - b. demonstrates an understanding of the appropriate regulations for radiation protection and dose limits for radiation workers and members of the public;
 - c. demonstrates an understanding of federal, state/provincial, local, and institutional regulatory requirements;
 - d. explains the concept of ALARA;
 - e. discusses the role and significance of TJC;
 - f. discusses the role and responsibility of a radiation safety committee;
 - g. discusses the role and responsibility of a radiation safety officer;
 - h. discusses the significance of ACR, ASTRO, and AAPM recommendations; and
 - i. demonstrates an understanding of practices for the release of patients (with sealed or unsealed sources).
- 7) Survey meters (i.e., ionization chambers, Geiger–Müller (GM) counters, scintillation counters)
- a. discusses the operation and appropriateness of different survey instruments (i.e., GM counter, ionization survey meters, and scintillation counter);
 - b. performs battery and constancy checks with an understanding of the allowable deviation from a baseline reading; and
 - c. understands how a survey meter is calibrated, who may calibrate a meter (i.e., ionization versus GM), and the required calibration frequency.
- 8) Personnel monitoring
- a. demonstrates an understanding of the physical mechanisms involved in radiation detection and readout of personnel monitors (e.g., film, TLD, and OSLD);

- b. understands the rationale for occupational dose limits and federal or state/provincial limits;
 - c. understands the definition of a “declared pregnant woman;”
 - d. understands federal or state/provincial personnel monitoring requirements;
 - e. understands the rationale for ALARA investigation levels;
 - f. understands the role and responsibility of physicists in developing a radiation safety culture;
 - g. understands the requirements for providing personnel monitoring reports to staff; and
 - h. reviews and discusses the results of personnel monitoring reports.
- 9) Guidelines and instructions for personnel
- a. understands the roles and responsibilities of a radiation worker (e.g., NRC Form 3);
 - b. understands the requirements and frequency of radiation safety refresher courses for staff;
 - c. understands the personnel radiation safety hazards specific to the uses of radiation in therapeutic settings (e.g., linac, brachytherapy, radioisotope handling); and
 - d. demonstrates the ability to tailor a radiation safety training program for its intended audience (e.g., physicists, therapists, dosimetrists, nurses, physicians, physician residents, students, and maintenance staff).
- 10) Hazards of low levels of radiation
- a. understands the linear no-threshold (LNT) hypothesis, its origins, and its limitations;
 - b. understands the collective dose theory as it applies to large populations;
 - c. understands the potential biological effects associated with prolonged exposure to low levels of radiation;
 - d. knows the major natural sources of background radiation; and
 - e. knows the major man-made sources of background radiation.

4.5.8 Informatics

Informatics competencies include the following:

- 1) uses information technology to retrieve and store patient demographic, examination, and image information;
- 2) understands how image processing is used to create radiographic images for display presentation and depict 3D structures in CT and MR;

- 3) uses information technology to investigate clinical, technical, and regulatory questions;
- 4) uses and understands common information systems used in radiation oncology (e.g., record and verify, electronic medical records, image handling);
- 5) demonstrates an understanding of the various methods of data transfer, storage, and security, including:
 - a. PACS,
 - b. DICOM,
 - c. DICOM in radiation therapy (DICOM-RT),
 - d. Health Level 7 (HL7),
 - e. Integrating the Healthcare Enterprise (IHE),
 - f. IHE Radiation Oncology (IHE-RO); and
- 6) understands the roles of physics and information technology staff, including their work in network integration and maintenance.

4.5.9 Elective Rotations

The uses and types of technology in medical physics are continually evolving. Furthermore, some established technologies, such as proton therapy and electron arc therapy, are confined to relatively few cancer centers. Therefore, although it is important for residents to keep abreast of new technological advances, it is nearly impossible for them to gain significant clinical experience in all recently introduced technologies during a residency.

The suggestions set forth below are intended to apply only to technologies or treatment modalities that are newly developed or not widely disseminated and should be considered elective. The purpose of this section is to provide guidance to program directors at clinics that are equipped with these technologies or treatment modalities in order to help them develop a clinical rotation in one of these areas. This section is considered an optional rather than required or recommended component of a therapy residency program. If, or when, these technologies or treatment techniques are more widely adopted, it may be a necessary to require that residents complete rotations in these topics.

4.5.9.1 Kilovoltage or Superficial X-ray Treatment Equipment

Kilovoltage or superficial x-ray treatment equipment competencies (elective) include the following:

- 1) Selection
 - a. demonstrates an understanding of the theories of operation of kilovoltage or superficial treatment units used in radiation oncology treatments and

- b. demonstrates an understanding of the major subsystems and use of kilovoltage or superficial units.
- 2) Calibration
 - a. uses the instrumentation employed to calibrate radiation treatment beams of energy in the kilovoltage or superficial range and demonstrates an understanding of the features of that instrumentation and related protocols (e.g., theory of operation, limitations) and
 - b. competently calibrates kilovoltage or superficial external x-ray beams using a recognized national or internal protocol.
- 3) QA
 - a. demonstrates an understanding of the pertinent recommendations for quality assurance of kilovoltage or superficial units used in radiation therapy,
 - b. demonstrates an understanding of in-house quality assurance documentation and procedures, and
 - c. competently performs routine (daily/weekly/monthly/annual) QA tests for kilovoltage or superficial units.

4.5.9.2 Conventional Simulator—Radiographic/Fluoroscopic

Conventional simulator radiographic/fluoroscopic competencies (elective) include the following:

- 1) Selection
 - a. demonstrates an understanding of the theory of operation of a conventional simulator;
 - b. demonstrates an understanding of the major components of a conventional simulator;
 - c. reviews the steps required to select a conventional simulator, including performance specification and feature comparison;
 - d. reviews and discusses mechanical/architectural considerations when installing a new conventional simulator (room design);
 - e. demonstrates an understanding of how to design performance tests; and
 - f. reviews and demonstrates an understanding of acceptance test procedures for a conventional simulator.
- 2) Acceptance testing
 - a. demonstrates an understanding of the mechanical tests performed during an acceptance procedure,

GUIDELINES FOR RADIATION ONCOLOGY PHYSICS RESIDENCY TRAINING PROGRAMS

- b. demonstrates an understanding of the tests of image quality and characteristics, and
 - c. demonstrates an understanding of the measurement of dose from a simulator.
- 3) QA
- a. demonstrates an understanding of routine mechanical and radiation quality assurance tests,
 - b. demonstrates an understanding of routine radiographic and fluoroscopic quality assurance tests, and
 - c. demonstrates an understanding of film processor QA.
- 4) Radiographic techniques
- a. explains the complete radiographic imaging chain of events from the production of x-rays to image formation,
 - b. explains the origin of radiographic contrast and mechanisms that compromise and enhance contrast,
 - c. demonstrates an understanding of the methods of exposure control,
 - d. demonstrates an understanding of the tradeoffs between patient dose and image quality, and
 - e. explains the methods of exposure control used in fluoroscopic systems and the use of image intensifiers and digital receptors.

4.5.9.3 Intraoperative Radiation Therapy (IORT)—Electron and HDR Brachytherapy

IORT electron and HDR brachytherapy competencies (elective) include the following:

- 1) discusses the rationale for IORT treatments (i.e., treating malignant conditions);
- 2) demonstrates an understanding of the delivery techniques and issues related to the clinical commissioning and maintenance of an IORT program;
- 3) describes the differences between mobile and stationary linacs used for IORT delivery;
- 4) discusses the technical challenges associated with IORT treatments with respect to whether the stationary linac is located inside and outside of the operating room environment;
- 5) discusses radiation shielding and safety considerations for mobile and stationary linacs in an OR setting;
- 6) discusses the different applicators used for delivering treatment and reviewing sample dose calculations (e.g., monitor units for linacs and dwell times for intraoperative HDR);

- 7) discusses and demonstrates an understanding of the significance of beam modifiers commonly used during IORT treatments (e.g., shields, bolus); and
- 8) demonstrates an understanding of the pertinent recommendations for QA for mobile and stationary linac or HDR afterloaders (e.g., per 10 CFR 35.647).

4.5.9.4 Electron Arc Therapy

Electron arc therapy competencies (elective) include the following:

- 1) discusses the rationale for electron arc therapy;
- 2) discusses sites commonly treated with electron arc therapy;
- 3) describes the differences between stationary and electron arc beam delivery (e.g., in terms of setup and delivery techniques);
- 4) discusses the dosimetric differences between stationary and arc electron beams; and
- 5) discusses treatment planning challenges posed by electron arc therapy.

4.5.9.5 Adaptive Radiation Therapy (ART)

ART competencies (elective) include the following:

- 1) discusses the differences between on- and off-line ART strategies;
- 2) describes ART replanning techniques;
- 3) discusses anatomic sites that would most benefit from ART;
- 4) discusses the challenges of ART (e.g., in terms of resources, time, frequency of replanning, data storage);
- 5) discusses the types and quality of images used for analysis and dose recalculation;
- 6) discusses how ART impacts CTV-to-PTV margins; and
- 7) describes QA tests required for ART and their frequency.

4.5.9.6 Hyperthermia

Hyperthermia competencies (elective) include the following:

- 1) discusses how hyperthermia may complement radiotherapy;
- 2) describes sites that may benefit most from hyperthermia;
- 3) describes different hyperthermia techniques (e.g., local, regional, whole-body hyperthermia);
- 4) discusses heating techniques available for hyperthermia;
- 5) describes the treatment planning process and thermometry verification;

- 6) discusses the potential difficulties and side effects of hyperthermia;
- 7) describes hyperthermia models used to predict and calculate heat transfer;
- 8) describes invasive and non-invasive thermometry techniques; and
- 9) describes QA tests for hyperthermia and their recommended frequency.

4.5.9.7 High Intensity Focused Ultrasound (HIFU)

HIFU competencies (elective) include the following:

- 1) compares and contrasts conventional hyperthermia and HIFU;
- 2) describes the process of operation of HIFU;
- 3) discusses sites that may benefit most from HIFU;
- 4) describes the treatment planning process for HIFU;
- 5) describes the differences between MR- and US-guided focused US therapy;
- 6) discusses the available thermometry verification techniques; and
- 7) describes quality assurance tests for HIFU and their recommended frequency.

4.5.9.8 Proton Therapy

Proton therapy competencies (elective) include the following:

- 1) Selection
 - a. demonstrates an understanding of the theory of operation of proton accelerators currently used in radiation oncology treatment (e.g., synchrotrons and cyclotrons) and their limitations;
 - b. demonstrates an understanding of the major subsystems and components of proton accelerators (e.g., synchrotrons and cyclotrons);
 - c. demonstrates an understanding of the various beam line delivery systems used for treatment (e.g., fixed and gantry) and their components;
 - d. demonstrates an understanding of proton delivery technologies (e.g., passive scattering and pencil beam scanning), including their limitations;
 - e. demonstrates an understanding of the main mechanical and architectural requirements for a building or vault to safely install a new proton accelerator;
 - f. demonstrates an understanding of workflow in single- and multi-room proton facilities; and
 - g. demonstrates an understanding of the underlying principles that guide design of performance tests for a proton accelerator.

2) Calibration

- a. demonstrates an understanding of the instrumentation and dosimetry protocols (e.g., theory of operation, limitations) employed in the calibrating of megavoltage proton treatment beams;
- b. demonstrates an understanding of how stopping power uncertainty impacts beam calibration and reference conditions;
- c. demonstrates an understanding of the dosimetry correction factors used for proton calibration measurements;
- d. competently calibrates proton beams using a recognized national or international protocol (e.g., International Atomic Energy Organization [IAEA] TRS-398);
- e. demonstrates an understanding of the differences between various beams (i.e., scattered, uniform scanning, and pencil beam); and
- f. demonstrates an understanding of the ramifications of proton beam current and dose.

3) QA

- a. demonstrates an understanding of the pertinent recommendations for quality assurance of proton units used in radiation therapy;
- b. competently performs routine (daily/weekly/monthly/annual) QA tests of proton treatment units;
- c. competently analyzes routine QA tests for proton treatment units;
- d. demonstrates an understanding of the basis for accepted tolerances for routine QA tests and related required action should any of the checks fall out of tolerance; and
- e. demonstrates an understanding of the imaging components used for patient positioning and treatment verification.

4) Treatment planning

- a. generates treatment plans for all of the following sites and compares resulting plans with those generated using other modalities (e.g., photons, electrons):
 - i. brain,
 - ii. breast,
 - iii. prostate,
 - iv. lung,
 - v. abdomen,
 - vi. gastrointestinal system, and
 - vii. craniospinal.

GUIDELINES FOR RADIATION ONCOLOGY PHYSICS RESIDENCY TRAINING PROGRAMS

- b. understands beam properties
 - i. demonstrates an understanding of proton interactions with media;
 - ii. demonstrates an understanding of proton percent depth dose in tissue and other media and proton ranges for different energies (e.g., stopping and scattering power, range);
 - iii. demonstrates an understanding of the potential uncertainties of dose deposition in proton radiotherapy;
 - iv. demonstrates an understanding of flatness and symmetry requirements for proton beams; and
 - v. discusses the uncertainties related to proton therapy (e.g., in terms of physics, biology, machine, and patient setup accuracy) and how they may be detected and mitigated during the planning and delivery process.
 - c. understands beam modifiers
 - i. demonstrates an understanding of the design and use of tissue compensators;
 - ii. demonstrates an understanding of common patient positioning and immobilization devices;
 - iii. demonstrates an understanding of the differences in the ICRU structures (e.g., CTV, PTV [as per ICRU 50, 62, and 78]) of proton and photon beams (e.g., dependency on beam orientation and range uncertainty); and
 - iv. demonstrates an understanding of how a commercial treatment planning system's computer algorithm calculates dose and monitor units for proton therapy.
- 5) Radiobiology
- a. discusses the impact of dose and fractionation for normal and tumor tissues and
 - b. demonstrates an understanding of the impact of beam quality (e.g., LET) on the RBE of different forms of ionizing radiation (e.g., electrons, photons, charged particles).
- 6) Radiation safety
- a. demonstrates an understanding of the nuances in the structural and shielding requirements for proton beam facilities and
 - b. demonstrates an understanding of neutron activation in proton beam in terms of both safety and utilization for imaging.

4.5.9.9 *Microspheres*

Microspheres competencies (elective) include the following:

- 1) demonstrates an understanding of how microspheres are radio-labeled;
- 2) compares and contrasts the use and delivery of commercially available microspheres;
- 3) discusses personal protection techniques (i.e., time, distance, and shielding) and safe handling of microspheres;
- 4) discusses the process by which microspheres are calibrated;
- 5) discusses the process by which measurement equipment (i.e., a dose calibrator) is calibrated;
- 6) discusses and, if possible, performs an assay for microspheres;
- 7) discusses issues related to long-term storage or disposal of waste; and
- 8) discusses the operation and appropriateness of different survey instruments (i.e., GM counters, ionization chambers, and scintillation counters).

4.5.9.10 *Electronic Brachytherapy*

Electronic brachytherapy competencies (elective) include the following:

- 1) discusses the process of calibrating electronic sources prior to treatment;
- 2) discusses the process by which measurement equipment is calibrated;
- 3) discusses personal protection techniques (i.e., time, distance, and shielding) during treatments;
- 4) discusses federal or state/provincial regulatory issues related to the use of electronic brachytherapy; and
- 5) discusses the operation and appropriateness of different survey instruments.

APPENDIX A

SAMPLE EVALUATIONS

PLEASE NOTE: The forms shown below are intended to be samples to assist program directors in continually improving their residency programs. The forms have emerged from multiple residency programs and should be modified to fit the needs of individual residency programs. There are currently no standardized criteria/scales for evaluating staff and residents.

The evaluation forms include the following:

Resident Evaluation Form

Staff Evaluation Form

Program Evaluation Form

Resident Evaluation

Resident Name

Date

Evaluated Rotation

Faculty Reviewer

Rotation Assessment

Yes No

Has the resident completed the competencies outlined for this rotation?

Has the resident completed the assigned readings for this rotation?

Was the resident sufficiently engaged in this rotation?

Did the resident routinely interact with her/his mentors for this rotation?

Oral Assessment

High Pass

Pass

Conditional Pass

Fail

--	--	--	--

Comments:

Signed,

Faculty Name Signature

Faculty Name Signature

I have read the above evaluation outlined by the faculty members involved in my end of rotation evaluation.

I believe the evaluation is an accurate representation of my oral review.

I believe the evaluation is an inaccurate representation of my oral review.

Comments:

Resident Signature

Date

Staff Evaluation

Rotation

Dates

Mentor/s

Sufficient time was allotted to this rotation: Yes No

Evaluation scale for the following questions:

1=Poor 2=Fair 3=Good 4=Very Good 5=Excellent

- | | 1 | 2 | 3 | 4 | 5 |
|--|--------------------------|--------------------------|--------------------------|--------------------------|--------------------------|
| 1. The rotation achieved the outlined objectives. | <input type="checkbox"/> |
| 2. The faculty mentor(s) actively and effectively participated in the rotation training. | <input type="checkbox"/> |
| 3. The faculty mentor(s) invited questions and discussion. | <input type="checkbox"/> |
| 4. The faculty mentor(s) treated me professionally. | <input type="checkbox"/> |
| 5. The faculty mentor(s) teach(es) effectively. | <input type="checkbox"/> |

Comments:

What are the strengths of this rotation (including faculty)?

What are the weaknesses of this rotation (including faculty)?

General comments:

Program Evaluation

Evaluation Topics	Graduating Residents Use this column	Non-graduating Residents Use this column
	Level of satisfaction: 1 = not satisfied 5 = very satisfied	Reason for leaving: 1 = not important 5 = very important
1. Workplace evaluation		
a. Orientation/training	1 2 3 4 5	1 2 3 4 5
b. Professional development	1 2 3 4 5	1 2 3 4 5
c. Teamwork	1 2 3 4 5	1 2 3 4 5
d. Relations with colleagues	1 2 3 4 5	1 2 3 4 5
e. Relations with supervisor	1 2 3 4 5	1 2 3 4 5
f. Relations with medical staff	1 2 3 4 5	1 2 3 4 5
g. Adequate job autonomy	1 2 3 4 5	1 2 3 4 5
h. Workplace stress	1 2 3 4 5	1 2 3 4 5
i. Challenges at work	1 2 3 4 5	1 2 3 4 5
j. Opportunities for career growth	1 2 3 4 5	1 2 3 4 5
k. Use of my skills or experience	1 2 3 4 5	1 2 3 4 5
l. Barriers in the workplace	1 2 3 4 5	1 2 3 4 5
2. Residency Director's support		
a. Supported my professional growth	1 2 3 4 5	1 2 3 4 5
b. Was open to ideas and concerns	1 2 3 4 5	1 2 3 4 5
c. Gave feedback in a constructive and caring manner	1 2 3 4 5	1 2 3 4 5
d. Kept me informed about issues important to my job	1 2 3 4 5	1 2 3 4 5
e. Gave me ideas about how to do a better job	1 2 3 4 5	1 2 3 4 5
f. Listened to my concerns and took action to improve things	1 2 3 4 5	1 2 3 4 5
g. Was accessible if needed	1 2 3 4 5	1 2 3 4 5
h. Overall, I was satisfied	1 2 3 4 5	1 2 3 4 5

3. Would you recommend this physics residency program? Yes No

Continued

4. As you think about your work environment, what has contributed the most to your satisfaction?

5. If you could change one thing about your work environment, what would it be?

— THANK YOU FOR COMPLETING THIS SURVEY —

APPENDIX B

SAMPLE CLINICAL OBJECTIVE TEMPLATES

PLEASE NOTE: The forms below are intended to be samples to assist program directors in the continual improvement of their residency programs. The forms have emerged from multiple residency programs and should be modified to fit the needs of individual residency programs. There are currently no standardized criteria/scales for evaluating resident performance during clinical rotations.

The clinical objective forms include the following:

Medical Physics Residents in Imaging Evaluation Form

Medical Physics Residents in Nuclear Medicine Form

Medical Physics Residents in Radiation Oncology Form

**IMAGING PHYSICS RESIDENCY PROGRAM
FACULTY EVALUATION OF RESIDENT**

RESIDENT'S NAME:				
Rotation name:	COMPUTED TOMOGRAPHY			
Inclusive dates of rotation:				
Faculty name:				
Evaluation criteria	Not Competent	Marginally Competent	Fully Competent	Explanatory Notes
Patient care and procedural skills	<i>(Residents should provide information that is appropriate, accurate, and relevant to diagnosis of health problems.)</i>			
1. Performs annual compliance testing of a computed tomography scanner				
2. Performs acceptance testing of a computed tomography scanner				
3. Performs daily quality control tests of a computed tomography scanner				
4. Determines CTDI for computed tomographic examinations				
5. Estimates patient ionizing radiation dose and risk for computed tomographic examinations				
6. Estimates ionizing radiation dose to conceptus and risk for computed tomographic examinations				
7. Calculates and evaluates shielding for a computed tomography scanner room				
8. Uses information technology to retrieve and store patient demographic, examination, and image information				
Medical knowledge	<i>(Residents should be knowledgeable, scholarly, and committed to lifelong learning.)</i>			
9. Explains the complete computed tomographic imaging chain from production of x-rays to image reconstruction				
10. Explains the physical meaning of Hounsfield units				
11. Explains how specific aspects of imaging protocol affect patient dose and diagnostic benefits of examination				
12. Uses information technology to investigate clinical, technical, and regulatory questions				

Continued

Practice-based learning and improvement	<i>(Residents should investigate and evaluate patient care practices, appraise and assimilate scientific evidence, and improve patient care practices.)</i>			
13. Analyzes test results and recognizes unexpected findings, including image artifacts				
14. Investigates equipment performance and image quality problems				
15. Recognizes and corrects personal errors				
Interpersonal and communication skills	<i>(Residents should demonstrate effective information exchange with physicians, technologists, service personnel, and professional associates.)</i>			
16. Works effectively with others as a member or leader of a health care team				
17. Produces written reports that are accurate, concise, and grammatically correct				
18. Presents technical information effectively to other residents, technologists, faculty, and other health care professionals				
19. Listens effectively				
Professionalism	<i>(Residents should carry out responsibilities, adhere to ethical principles, and show sensitivity to a diverse patient population.)</i>			
20. Shows a responsiveness to the needs of patients that supersede self-interest				
21. Respects patient privacy and confidentiality				
22. Is committed to excellence and ongoing professional development				
Systems-based practice	<i>(Residents should be aware of the system of health care and effectively call on system resources in order to provide optimal care.)</i>			
23. Partners with managers and providers to assess, coordinate, and improve health care				
24. Understands how his/her professional practices affect other health care professionals				
25. Utilizes system resources effectively to provide optimal care				

**NUCLEAR MEDICINE RESIDENCY PROGRAM
FACULTY EVALUATION OF RESIDENT**

RESIDENT'S NAME:				
Rotation name:	NUCLEAR MEDICINE AND PET			
Inclusive dates of rotation:				
Faculty name:				
Evaluation criteria	Not Competent	Marginally Competent	Fully Competent	Explanatory Notes
Patient care and procedural skills	<i>(Residents should provide information that is appropriate, accurate, and relevant to diagnosis of health problems.)</i>			
1. Performs acceptance testing (including SPECT) of a nuclear medicine camera				
2. Performs annual testing (including SPECT) of a nuclear medicine camera				
3. Perform acceptance testing of a PET or PET/CT scanner				
4. Performs annual testing of a PET or PET/CT scanner				
5. Performs quality control (QC) tests on nuclear medicine imaging systems, dose calibrators, and counting systems				
6. Monitors QC program for all imaging and non-imaging equipment				
7. Estimates patient radiation dose and risk from nuclear medicine examinations				
8. Estimates radiation dose to fetus and risk from nuclear medicine examinations				
9. Calculates shielding for a PET facility				
10. Uses information technology to retrieve and store patient demographic, examination, and image information				
11. Performs release calculations for patients receiving radionuclide therapies				
Medical knowledge	<i>(Residents should be knowledgeable, scholarly, and committed to lifelong learning.)</i>			
12. Explains the complete nuclear medicine imaging chain, including image formation and image reconstruction				
13. Understands the use and characteristics of radionuclides for nuclear medicine imaging				

Continued

14. Explains how uptake and clearance of radiopharmaceuticals affects patient dose and diagnostic benefits of examination				
15. Uses information technology to investigate clinical, technical, and regulatory questions				
Practice-based learning and improvement	<i>(Residents should investigate and evaluate patient care practices, appraise and assimilate scientific evidence, and improve patient care practices.)</i>			
16. Analyzes results of testing and recognizes unexpected findings				
17. Investigates equipment performance and image quality problems				
18. Recognizes and corrects personal errors				
Interpersonal and communication skills	<i>(Residents should demonstrate effective information exchange with physicians, technologists, service personnel, and professional associates.)</i>			
19. Works effectively with others as a member or leader of a health care team				
20. Produces written reports that are accurate, concise, and grammatically correct				
21. Presents technical information effectively to other residents, technologists, faculty, and other health care professionals				
22. Listens effectively				
Professionalism	<i>(Residents should carry out responsibilities, adhere to ethical principles, and show sensitivity to a diverse patient population.)</i>			
23. Shows a responsiveness to the needs of patients that supersede self-interest				
24. Respects patient privacy and confidentiality				
25. Is committed to excellence and ongoing professional development				
Systems-based practice	<i>(Residents should be aware of the system of health care and effectively call on system resources in order to provide optimal care.)</i>			
26. Partners with managers and providers to assess, coordinate, and improve health care				
27. Understands how his/her professional practices affect other health care professionals				
28. Utilizes system resources effectively to provide optimal care				

**RADIATION ONCOLOGY RESIDENCY PROGRAM
FACULTY EVALUATION OF RESIDENT**

RESIDENT'S NAME:	
Rotation staff member/advisor(s):	
Rotation duration:	
Rotation dates:	

A medical physics resident in radiation oncology will be expected to demonstrate the following competencies associated with brachytherapy and radiation safety. Listed below are the minimum standards.

Contents Outline

Knowledge Factors

- List of reading assignments
- Regulations
- General Brachytherapy
- HDR Brachytherapy
- LDR I-125 Eyeplaques
- Shielding
- Others

Practical Factors

- Handling radioactive material (receiving packages)
- HDR
- LDR Eyeplaques
- LDR microspheres
- Treatment Planning – clinical and test cases

Case Participation

- HDR (Cylinder [standard or multi-channel], Ring and Tandem, Tandem and Ovoids)
- Microspheres
- Others

Knowledge Factors – List of reading assignments

1. Title 10 of the Code of Federal Regulations (parts 19, 20, and 35). <http://www.nrc.gov/reading-rm/doc-collections/cfr/>.
2. State regulations http://www.aapm.org/government_affairs/licensure/default.asp.
3. AAPM Task Group #43U, “Dosimetry of interstitial brachytherapy sources.”
4. AAPM Task Group #56, “Code of practice for brachytherapy physics.”
5. AAPM Task Group #59, “HDR brachytherapy treatment delivery.”
6. AAPM Task Group #64, “Permanent prostate seed implant brachytherapy.”
7. AAPM Task Group #129, “Dosimetry of I-125 and Pd-103 COMS eye plaques for intraocular tumors.”
8. AAPM Task Group #137, “AAPM recommendations on dose prescription and reporting methods for permanent interstitial brachytherapy for prostate cancer.”
9. AAPM Report 98, “Third-party brachytherapy source calibrations and physicist responsibilities.”
10. AAPM Task Group #138, “A dosimetric uncertainty analysis for photon-emitting brachytherapy sources.”
11. AAPM Task Group #144, “Recommendations of the AAPM on dosimetry, imaging, and quality assurance procedures for Y-90 microsphere brachytherapy in the treatment of hepatic malignancies.”
12. AAPM Task Group #186, “Model-based dose calculation methods in brachytherapy beyond the TG-43 formalism.”
13. *ICRU Report 38*, “Dose and volume specification for reporting intracavitary therapy in gynecology.”
14. *NCRP Report No. 155*, “Management of Radionuclide Therapy Patients.”
15. ABS recommendations – <http://www.american-brachytherapy.org/guidelines/index.cfm>.
16. Haie-Meder, C. *et al.* “Recommendations from Gynaecological (GYN) GEC-ESTRO Working Group (I): Concepts and terms in 3D image

Continued

based 3D treatment planning in cervix cancer brachytherapy with emphasis on MRI assessment of GTV and CTV.” *Radiother. Oncol.* 74:235–45 (2005).

17. Potter, R. *et al.* “Recommendations from gynecological (GYN) GEC ESTRO working group (II): Concepts and terms in 3D image-based treatment planning in cervix cancer brachytherapy – 3D dose volume parameters and aspects of 3D image-based anatomy, radiation physics, radiobiology.” *Radiother. Oncol.* 78:67–77 (2006).
18. Hellebust, T.P. *et al.*, “Recommendations from Gynaecological (GYN) GEC-ESTRO Working Group: Considerations and pitfalls in commissioning and applicator reconstruction in 3D image-based treatment planning of cervix cancer brachytherapy.” *Radiother. Oncol.* 96:153–60 (2010).
19. Van Dyk, J., ed. *The Modern Technology of Radiation Oncology: A Compendium for Medical Physicists and Radiation Oncologists*. Madison, WI: Medical Physics Publishing, 1999.
20. Thomadsen, B.R., M. Rivard, W. Butler, ed. *Brachytherapy Physics*, 2nd ed. AAPM 2005 Summer School Proceedings. Madison, WI: Medical Physics Publishing, 2005.

Knowledge Factors – Regulations

Read and demonstrate an understanding of 10CFR19.

<i>Signature/Date</i>	
-----------------------	--

Read and demonstrate an understanding of 10CFR20.

<i>Signature/Date</i>	
-----------------------	--

Read and demonstrate an understanding of 10CFR35.

<i>Signature/Date</i>	
-----------------------	--

Read and demonstrate an understanding of state regulations.

<i>Signature/Date</i>	
-----------------------	--

Knowledge Factors – Handling Radioactive Sources

Read and demonstrate an understanding of NCRP 155.

<i>Signature/Date</i>	
-----------------------	--

Read and demonstrate an understanding of AAPM Report 98.

<i>Signature/Date</i>	
-----------------------	--

Knowledge Factors – General Brachytherapy

Read and demonstrate an understanding of AAPM TG-43U report.

<i>Signature/Date</i>	
-----------------------	--

Perform TG-43 calculations for a single-, double-, and triple-source plan.

<i>Signature/Date</i>	
<i>Signature/Date</i>	
<i>Signature/Date</i>	

Read and demonstrate an understanding of the AAPM TG-186 report.

<i>Signature/Date</i>	
-----------------------	--

Read and demonstrate an understanding of the AAPM TG-56 report.

<i>Signature/Date</i>	
-----------------------	--

Read and demonstrate an understanding of the AAPM TG-59 report.

<i>Signature/Date</i>	
-----------------------	--

Read and demonstrate an understanding of the GEC-ESTRO recommendations for volume-based treatment planning for cervical cancer.

<i>Signature/Date</i>	
-----------------------	--

List from memory the mean energy and half-life for Ra-226, Cs-137, Ir-192, Y-90, Pd-103, Cs-131, and I-125.

<i>Signature/Date</i>	
-----------------------	--

Demonstrate an understanding of GYN and GU anatomy.

<i>Signature/Date</i>	
<i>Signature/Date</i>	

Demonstrate an understanding of cervical and endometrial cancer.

<i>Signature/Date</i>	
-----------------------	--

Demonstrate an understanding of prostate cancer.

Signature/Date	
----------------	--

Knowledge Factors – HDR Brachytherapy

Complete annual HDR emergency in-service training.

Signature/Date	
----------------	--

Discuss dose limits for HDR GYN planning.

Signature/Date	
----------------	--

Discuss dose limits for HDR prostate planning.

Signature/Date	
----------------	--

Knowledge Factors – Eyeplaque

Read and discuss COMS protocol.

Signature/Date	
----------------	--

Read and demonstrate an understanding of AAPM TG-129 report.

Signature/Date	
----------------	--

Knowledge Factors – Others

Read and discuss the AAPM TG-64 report (Prostate LDR).

Signature/Date	
----------------	--

Read and discuss the AAPM TG-137 report (Prostate LDR).

Signature/Date	
----------------	--

Discuss dose limits for LDR prostate planning.

Signature/Date	
----------------	--

Read and discuss the AAPM TG-144 report.

Signature/Date	
----------------	--

Read and discuss the ICRU-38 report (LDR GYN).

Signature/Date	
----------------	--

Read and discuss J. Van Dyk’s chapter on IORT (#17).

Signature/Date	
----------------	--

Practical Factors – General Brachytherapy

Complete radiation safety training.

Signature/Date	
----------------	--

Practical Factors – Handling Radioactive Sources

Receive and check in radioactive sources into inventory.

Signature/Date	
----------------	--

Perform hot lab survey and quarterly inventory.

Signature/Date	
----------------	--

Complete source room competency.

Signature/Date	
----------------	--

Complete and demonstrate an understanding of radioactive material packaging and transportation.

Signature/Date	
----------------	--

Practical Factors – HDR

Observe morning QA.

Signature/Date	
----------------	--

Signature/Date	
----------------	--

Signature/Date	
----------------	--

Perform morning QA independently.

Signature/Date	
----------------	--

Participate in source exchange QA.

Signature/Date	
----------------	--

Perform monthly QA.

Signature/Date	
----------------	--

Perform annual QA.

Signature/Date	
----------------	--

Perform patient survey before and after the HDR treatment.

Signature/Date	
----------------	--

Plan HDR vaginal cylinder case.

Signature/Date	
----------------	--

Plan HDR ring and tandem or ring and ovoids case.

Signature/Date	
----------------	--

Plan HDR multi-channel cylinder case.

Signature/Date	
----------------	--

Perform 2nd check for the plan.

Signature/Date	
----------------	--

Export plan to the treatment console.

Signature/Date	
----------------	--

Practical Factors – LDR Eye Plaque

Generate an eye plaque treatment plan.

Signature/Date	
----------------	--

Place an order for eye plaque seeds.

Signature/Date	
----------------	--

Assay eye plaque I-125 seeds.

Signature/Date	
----------------	--

Construct or discuss the construction of an eye plaque.

Signature/Date	
----------------	--

Observe and discuss eye plaque procedure.

Signature/Date	
----------------	--

Perform a post-implant survey.

Signature/Date	
----------------	--

Perform a post-removal survey.

Signature/Date	
----------------	--

Perform billing for eye plaque treatment.

Signature/Date	
----------------	--

Practical Factors – LDR Microsphere

Calculate activity required for microsphere treatment.

Signature/Date	
----------------	--

Assay microsphere vials before and after the infusion.

Signature/Date	
----------------	--

Place an order for microspheres.

Signature/Date	
----------------	--

BRACHYTHERAPY CASE PARTICIPATION

Document participation in planning, checking, delivering, and administrative paperwork of the following implants:

HDR Cylinder (Single- or Multi-channel)

	Date	Supervisor	Note
1			
2			
3			
4			
5			

HDR Tandem and Ring/Split Ring/Ovoids

	Date	Supervisor	Note
1			
2			
3			
4			
5			

HDR Interstitial (Prostate or Gynecologic)

	Date	Supervisor	Note
1			
2			
3			
4			
5			

LDR Eye Plaque

	Date	Supervisor	Note
1			
2			
3			
4			
5			

LDR Microsphere

	Date	Supervisor	Note
1			
2			
3			
4			
5			

Others

	Date	Supervisor	Note
1			
2			
3			
4			
5			

APPENDIX C

COMBINING IMAGING AND NUCLEAR MEDICINE RESIDENCIES

INTRODUCTION

This appendix describes those competencies common to imaging and nuclear medicine residency programs, competencies in the imaging residency to be augmented for nuclear medicine physics, and competencies unique to nuclear medicine physics that must be completed to provide a combined imaging and nuclear medicine physics residency. At the completion of the combined residency program, the resident shall demonstrate competency in all of the subjects in chapters 2 and 3.

COMMON COMPETENCIES

General competencies associated with the working environment (Section 1.8) and overall adjustment to the residency environment is common to both imaging and nuclear medicine physics residency programs. The total time devoted to mastering the competencies in B.1–B.3 would be equivalent to a 24-month nuclear medicine residency.

B.1 Competencies Completely Covered in Imaging Physics

The following competencies are covered under the imaging physics residency program and also fulfill the competency requirements for a nuclear medicine physics program, either completely or with only very minor augmentation:

Hard-copy and image displays (Section 2.5.2)

Computed tomography (Section 2.5.4)

Magnetic resonance imaging (Section 2.5.7)

Imaging informatics (Section 2.5.9)

B.2 Competencies Requiring Augmentation for Nuclear Medicine Physics

The following imaging competencies shall be augmented to address specific nuclear medicine physics competency requirements:

Nuclear medicine (Section 2.5.8)

Safety (Section 2.5.10)

The competencies listed in B.1 and B.2 are equivalent to 12 months of clinical training/experience.

B.3 Competencies Unique to Nuclear Medicine Physics

The following competencies unique to Nuclear Medicine Physics shall be addressed and completed:

Gamma Camera with/without SPECT (Section 3.5.1)

Positron emission tomography (Section 3.5.2)

Non-imaging equipment (Section 3.5.4)

Patient dosimetry (Section 3.5.6)

Radiopharmacy (Section 3.5.8)

Clinical studies (Section 3.5.9)

Radionuclide therapy (Section 3.5.10)

CONCLUSION

Imaging physics residency program staff are encouraged to explore options for providing a combined imaging and nuclear medicine physics residency. This may be accomplished in an additional year (following the completion of an imaging residency) using faculty from the residency program who meet the personnel requirements described in Section 1.3.4. Alternatively, this additional year of nuclear medicine training may be provided at another facility with adjunct faculty and facilities that meet the residency program requirements described in Section 1.3. This arrangement would be governed by an affiliation agreement that specifies that residency program staff are responsible for ensuring that all program requirements are met. In either case, the program faculty shall include at least one nuclear medical physicist certified by an appropriate certifying board and a nuclear medical physician certified by the ABR or its equivalent, depending on the subfield of medical physics in which the program specializes. The ratio of full-time nuclear medical physicists participating in medical physics resident training to residents enrolled in the additional year of nuclear medicine physics should be at least 1:1.

EPILOGUE

This report represents the recommended design of a residency program based on the collective wisdom and experience of many clinical medical physicists, the majority of whom are residency program directors. The goal of a clinical medical physics residency program is to train medical physicists to a level of knowledge and competence that permits them to practice independently in one of the three main branches of medical physics. It is probable that any professional medical physicist will take several years beyond the residency training to attain all the knowledge listed in this document or to be competent in all the activities listed in this document.

We strongly believe in a structured, formal training model for clinical residencies, and we strongly encourage the development of residency programs in facilities that meet the set of minimum requirements and have the will to meet the goal of independent practice for its graduates. The recommendations of this report suggest that these minimums can also be obtained through collaboration agreements between two or more facilities.

ACRONYMS

AAPM	American Association of Physicists in Medicine
ABMS	American Board of Medical Specialties
ABR	American Board of Radiology
ABRF	American Board of Radiology Foundation
ACGME	Accreditation Council for Graduate Medical Education
ACR	American College of Radiology
ADCL	Accredited Dosimetry Calibration Laboratory
ALARA	As Low as Reasonably Achievable
ART	Adaptive Radiation Therapy
ASTRO	American Society for Radiation Oncology
BED	Biological Equivalent Dose
CAD	Computer-aided Detection
CAMPEP	Commission on Accreditation of Medical Physics Educational Programs
CBCT	Cone-beam Computed Tomography
CCPM	Canadian College of Physicists in Medicine
CNSC	Canadian Nuclear Safety Commission
COMP	Canadian Organization of Medical Physicists
CQI	Continuous Quality Improvement
CRCPD	Conference of Radiation Control Program Directors
CT	Computed Tomography
CTDI	Computed Tomography Dose Index
CTV	Clinical Target Volume
DICOM	Digital Imaging and Communication in Medicine
DICOM-RT	Digital Imaging and Communication in Medicine in Radiation Therapy
Dmax	Depth at maximum dose
DMLC	Dynamic Multileaf Collimator
DOT	Department of Transportation
DRR	Digitally Reconstructed Radiograph
DVH	Dose Volume Histogram

EPID	Electronic Portal Imaging Device
ESTRO	European Society for Radiotherapy and Oncology
EUD	Equivalent Uniform Dose
FDA	Food and Drug Administration
FMEA	Failure Mode and Effect Analysis
GEC	Groupe Européen de Curiethérapie
gEUD	Generalized Equivalent Uniform Dose
GM	Geiger–Müller (counter)
GTV	Gross Tumor Volume
GYN	Gynecologic
HEBD	High-energy Brachytherapy Dosimetry
HIPAA	Health Insurance Portability and Accountability Act
HIFU	High-intensity Focused Ultrasound
HDR	High Dose Rate
HL7	Health Level 7
HVAC	Heating, Ventilation, and Air Conditioning
HVS	Human Visual System
IAEA	International Atomic Energy Association
ICRP	International Commission on Radiological Protection
ICRU	International Commission on Radiation Units and Measurements
IEC	International Electrotechnical Commission
IHE	Integrating the Healthcare Enterprise
IHE-RO	Integrating the Healthcare Enterprise Radiation Oncology
IMAT	Intensity-modulated Arc Therapy
IMRT	Intensity-modulated Radiation Therapy
IORT	Intraoperative Radiation Therapy
ITV	Internal Target Volume
LEBD	Low-energy Brachytherapy Dosimetry
LET	Linear Energy Transfer
Linac	Linear accelerator
LDR	Low Dose Rate
LNT	Linear No-threshold

MIP	Maximum Intensity Projection
MIRD	Medical Internal Radiation Dose
MLC	Multileaf Collimator
MOSFET	Metal Oxide Semiconductor Field-effect Transistor
MR	Magnetic Resonance
MRI	Magnetic Resonance Imaging
MQSA	Mammography Quality Standards Act
MU	Monitor Unit
NCRP	National Council on Radiation Protection and Measurement
NEMA	National Electrical Manufacturers Association
NIST	National Institute of Standards and Technology
NRC	Nuclear Regulatory Commission
NTCP	Normal Tissue Complication Probability
OAR	Off-axis Ratio
OSLD	Optically Stimulated Luminescence Dosimeter
PACS	Picture Archiving and Communication Systems
PET	Positron Emission Tomography
PRV	Planning Organ at Risk Volume
PTV	Planning Target Volume
QA	Quality Assurance
QC	Quality Control
QMP	Qualified Medical Physicist
RAL	Remote Afterloader
RBE	Relative Biological Effectiveness
RF	Radiofrequency
RFP	Request for Proposal
RIS	Radiology Information Systems
ROI	Region of Interest
RSNA	Radiological Society of North America
RSO	Radiation Safety Officer

SAD	Source-to-axis Distance
SBRT	Stereotactic Body Radiation Therapy
SIIM	Society for Imaging Informatics in Medicine
SMLC	Segmental Multileaf Collimator
SNM	Society of Nuclear Medicine
SPECT	Single-photon Emission Computed Tomography
SPIE	International Society for Optics and Photonics
SRS	Stereotactic Radiosurgery
SSD	Source-to-Skin Distance
TAR	Tissue Air Ratio
TBI	Total Body (photon) Irradiation
TCP	Tumor Control Probability
TJC	The Joint Commission
TLD	Thermoluminescence Dosimeter
TMR	Tissue Maximum Ratio
TPR	Tissue Phantom Ratio
TSET	Total Skin Electron Therapy
US	Ultrasound
VMAT	Volumetric Modulated Arc Therapy

BIBLIOGRAPHY

1. American Association of Physicists in Medicine. Retrieved April 17, 2012, from www.aapm.org.
2. AAPM Report No. 90, *Essentials and Guidelines for Hospital-Based Medical Physics Residency Training Programs*. Retrieved from www.aapm.org/pubs/reports, 2006.
3. Commission on Accreditation of Medical Physics Education Programs Inc., *Guidelines for Accreditation of Residency Education Programs in Medical Physics*. Retrieved April 24, 2012, from <http://www.campep.org/resguidelines.pdf>, 2009.
4. AAPM Task Group 133, *Alternative Clinical Training Pathways for Medical Physicists*. Retrieved from www.aapm.org/pubs/reports, 2008.
5. Accredited Council for Graduate Medical Education, *Common Program Requirements*. Retrieved May 24, 2012 from http://www.acgme.org/acWebsite/dutyHours/dh_dutyhoursCommonPR07012007.pdf, 2011.
6. ABR/ACR/RSNA/AAPM/ASTRO/ARR/ARS, *Online Modules on Ethics and Professionalism*. Retrieved May 31, 2012, from <http://www.aapm.org/education/onlinemodules.asp>.
7. Accreditation Council for Graduate Medical Education, *ACGME Core Curriculum*. Retrieved April 24, 2012, from http://www.acgme.org/acwebsite/RRC_280/280_corecomp.asp.
8. American Board of Medical Specialties, *MOC Competencies and Criteria*. Retrieved May 26, 2012, from www.abms.org/Maintenance_of_Certification/MOC_competencies.aspx.
9. Thomas, S.R., W.R. Hendee, and B.R. Paliwal. The American Board of Radiology Maintenance of Certification (MOC) Program in Radiologic Physics. *Medical Physics* 32 (1): 263–267 (2005).
10. Nasca, T.J., I. Philibert, T. Brigham, and T.C. Flynn. The Next GME Accreditation System—Rationale and Benefits. *The New England Journal of Medicine* 366: 1051–1056 (2012).
11. AAPM Report No. 197, *Academic Program Recommendations for Graduate Degrees in Medical Physics*. Retrieved from www.aapm.org/pubs/reports, 2009.
12. AAPM Report No. 197S. *The Essential Medical Physics Didactic Elements for Physicists Entering the Profession through an Alternative Pathway: A Recommendation from the AAPM Working Group on the Review of Reports 44 & 79*. Retrieved from www.aapm.org/pubs/reports, 2011.
13. American Association of Physicists in Medicine, *Safety in Radiation Therapy – A Call to Action*. Retrieved June 21, 2012, from www.aapm.org/meetings/2010SRT/.
14. American Society for Radiation Oncology, *Patient Safety*. Retrieved June 21, 2012, from www.astro.org/Clinical-Practice/Patient-Safety/Index.aspx.
15. United States Department of Health & Human Services, *Patient Safety & Medical Errors*. Retrieved June 21, 2012, from www.ahrq.gov/qual/patientsafety.htm.
16. International Atomic Energy Agency, *Radiation Protection of Patients (RPOP)*. Retrieved June 21, 2012, from <https://rpop.iaea.org/RPOP/RPoP/Content/index.htm>.
17. American Board of Radiology Foundation, *Ethics and Professionalism Modules*. Retrieved June 19, 2012, from <http://ep.rsna.org/default.asp>.
18. Centers for Medicare & Medicaid Services, Medicare Benefit Policy Manual, Chapter 6 – Hospital Services Covered Under Part B. Retrieved June 21, 2012 from <http://www.cms.gov/Regulations-and-Guidance/Guidance/Manuals/downloads/bp102c06.pdf>, 2011.
19. Code of Federal Regulations, 42 CFR 410.32 – Diagnostic x-ray tests, diagnostic laboratory tests, and other diagnostic tests: Conditions, Department of Health and Human Services, Washington, DC, 2000.

RELEVANT PUBLISHED GUIDELINES AND REPORTS

As new professional guidelines, task group reports, and white papers are continually published and updated, the work group recommends that individuals review the most current reports. These documents may be retrieved from the following websites:

AAPM Medical Physics Practice Guidelines: <http://www.aapm.org/pubs/MPPG/>

AAPM reports: <https://www.aapm.org/pubs/reports/>

ACR practice guidelines and technical standards: <http://www.acr.org/Quality-Safety/Standards-Guidelines>

ASTRO white papers: <https://www.astro.org/Clinical-Practice/White-Papers/Index.aspx>

CNSC acts and regulations: <http://www.cnsccsn.gc.ca/eng/lawsregs/actsregulations/index.cfm>

CRCPD suggested state regulations: www.crcpd.org/ssrcr.aspx

ICRP publications: <http://www.icrp.org/publications.asp>

ICRU reports: <http://www.icru.org/>

NRC NUREG-Series publications: www.nrc.gov/reading-rm/doc-collections/nuregs/

NRC regulations: www.nrc.gov/reading-rm/doc-collections/cfr/

NCRP reports: <http://www.ncrppublications.org/Reports/>

State regulations and licensure: https://www.aapm.org/government_affairs/licensure/default.asp