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The American Society for Radiation Oncology's 2015 Core Physics Curriculum for Radiation Oncology Residents

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ABSTRACT

Purpose: The American Society for Radiation Oncology (ASTRO) published its first physics education curriculum for radiation oncology residents in 2004. This curriculum was updated in 2007 and 2010. The newly established ASTRO Physics Core Curriculum Subcommittee (PCCSC) began the most recent update of this curriculum in 2014.

Methods and Materials: The ASTRO PCCSC is composed of physicists and physicians from various academic institutions with radiation oncology residency education programs. Members of the committee also have associations with the American Association of Physicists in Medicine (AAPM), American College of Radiology (ACR), and/or American Board of Radiology (ABR). A survey was sent to members of the PCCSC to gather information for modifying the curriculum. Using the survey results, members of the PCCSC reviewed and updated existing sections and created new sections in the detailed curriculum document. We also endeavored to provide additional clinical context to the curricular material through the creation of practical clinical experiences. Finally, we reviewed the ABR blueprint of examination topics for correlation with this curriculum.

Results: The new curriculum represents 56 hours of resident physics didactic education, including a 4-hour initial orientation. The committee recommends that residents complete this curriculum at least twice during their residency education. In addition to this core curriculum, a set of practical clinical physics modules and treatment planning modules are included and are recommended as a supplement to the didactic training material. Major changes to the curriculum include the addition of Basic Physics and Stereotactic Radiosurgery/Stereotactic Body Radiotherapy sections, and the elimination of the sections titled Radiopharmaceutical Physics and Dosimetry and Hyperthermia. Minor changes include the addition of Volumetric Arc Therapy (VMAT), a Simulation and Treatment Verification section, and an optional Research and Development in Radiation Oncology section; changing Radiation Incidents and Bioterrorism Response Training to Incidents and Safety; and updating the references. The new curriculum was approved by the ASTRO board in October 2015. To assure that the physics component of the ABR radiation oncology initial certification (IC) examination remains consistent with this curriculum and to provide resident examination feedback for consideration during future updates of the curriculum, a feedback loop has been established with the ABR.

Conclusions: The ASTRO physics core curriculum for radiation oncology residents has been updated in an effort to identify the most important physics topics for preparing residents for careers in radiation oncology, to reflect changes in technology and practice since the publication of previous recommended curricula, and to provide practical training modules in clinical radiation oncology physics and treatment planning. The PCCSC is committed to keeping the curriculum current through periodic review and updating. An annual meeting between

the ASTRO PCCSC and ABR will take place to review resident feedback from the physics component of the ABR radiation oncology IC examination and to assure that the ABR examination blueprint remains consistent with this curriculum.

1. INTRODUCTION

In 2002, an ad hoc Committee on Physics Teaching to Medical Residents was organized by the Radiation Physics Committee of the American Society for Radiation Oncology (ASTRO). The ad hoc committee's main objective was to develop a core curriculum for physics teaching within radiation oncology residency programs to improve consistency in radiation oncology physics teaching, intensity, and subject matter. The outcome of this effort was the first ASTRO radiation oncology resident physics core curriculum which was published in 2004[1]. A second goal of the ad hoc committee was to assure periodic review and revision of the curriculum and this resulted in 2 subsequent published core curricula[2,3].

In 2009, ASTRO created the Physics Core Curriculum Subcommittee (PCCSC) with the mission of "making recommendations for physics curriculum based on resident career needs, communicate with the American Board of Radiology (ABR) so that they may use these recommendations to update exams, and move to centralized web-based teaching aids." The 2015 curriculum represents the efforts of this subcommittee to meet the first 2 of these 3 aims and becomes the fourth in a series of core physics curricula for radiation oncology residents. This curriculum includes updates to the specification, content, and organization of the subjects. In addition, detailed appendices that include specific topics and references have been completely revised.

A significant effort was made to incorporate modern technology and techniques while still preserving the most important basic physics components of the curriculum. While technology changes rapidly, basic physics does not, and a foundation in basic physical principles will prepare the resident to understand new technology. Indeed, the primary objective of physics training for radiation oncology residents is to produce better practitioners by providing a solid understanding of the physical principles and technical details involved in the process of radiotherapy. This requires presentation of the technical elements of safe and effective application of technology and procedures used for radiotherapy, but also requires residents to grasp many basic physics concepts in order to understand the essential details behind the material being taught. A thorough understanding of the material is more useful in confronting a previously un-encountered problem than is the mere memorization of information. Educators of radiation oncology residents bear the difficult responsibility of imparting both of these important aspects - providing the relevant technical information and cultivating critical thinking skills.

The role of basic physics and biology education in preparing medical residents for future scientific research and innovation in our profession should not be underestimated. We currently enjoy an abundance of outstanding medical school graduates interested in entering the radiation oncology profession, many of them with a strong technological and/or physical science background. Indeed, in 2014, more applicants with PhDs in addition to their medical degree were matched to residencies in radiation oncology than any other specialty (National Resident Matching Program: Charting Outcomes in the Match - **www.nrmp.org/wp-content/uploads/2014/09/Charting-Outcomes-2014-Final.pdf**). Teaching residents both the basic science and technical details supporting the physics and biology of radiotherapy helps the residents to become better clinicians and to ask the right questions that can lead to scientific inquiry. As leaders in our profession have previously asserted, it is critical that we adequately prepare the next generation of clinician scientists if we are to contribute substantially to the future of cancer research and innovation[4,5]. The more we help residents understand how the fundamentals of medical physics pertain to the current state of radiation oncology, the more likely they are to find ways to improve upon it.

Within the context described above, the purpose of this paper is to describe the process of revising the ASTRO physics curriculum for radiation oncology residents and present the resulting recommended curriculum.

2. METHODS AND MATERIALS

The PCCSC is composed of physicists and physicians from various academic institutions with radiation oncology residency education programs. Members of the committee also have associations with the American Association of Physicists in Medicine (AAPM), American College of Radiology (ACR), and/or ABR. In preparation for the review of the curriculum by the PCCSC, a survey tool was developed and sent to all committee members with questions regarding the suitability of existing subjects, potential modification or elimination of current subjects, and addition of new subjects to the ASTRO core curriculum as well as the existence of a laboratory component in the physics curriculum at their institutions.

Because curricular recommendations do not always match current practice, the survey asked committee members not only how many hours they spend on each topic in their own institution's curricula but also how many hours they think are necessary to adequately cover the topic. Eight of eleven committee members completed the survey, providing data for curriculum hours as well as recommendations for particular subjects to be added or eliminated from the existing curriculum. Those subjects were then discussed among the full PCCSC in delineating the final curriculum.

Once the updated subject list was determined, individual members volunteered to review/create the outline and references for the detailed appendices. One member was appointed to modify the content of each existing section and 2 to 3 members were assigned to create each new section. A series of monthly meetings including all PCCSC members followed to review each modified and new section. Suggested references were also modified or created for each section and reviewed by the entire PCCSC. Finally, a set of practical, hands-on radiation oncology clinical physics and treatment planning modules were created as supplements to the didactic training material.

The ASTRO PCCSC is committed to assuring that this proposed curriculum remains relevant until the next published curriculum, that it remains consistent with the ABR physics blueprint, and that it provides an effective study framework for residents preparing for the physics board examination. As such, we intend to continue to discuss the curriculum during regular meetings of the PCCSC and have established an annual feedback loop with the ABR to assure both that this curriculum remains consistent with the ABR blueprint and that we consider feedback from examinees who have taken the physics component of the ABR initial certification (IC) examination. The ABR produces a "blueprint" of physics topics from which questions for the physics component of the ABR IC examination are drawn and which is also provided to candidates as a study guide at **http://www.theabr.org/ic-ro-study-phys**. This blueprint was updated in 2015 and an additional aspect of this feedback process was the independent review of the ASTRO curriculum and the

ABR blueprint by both the PCCSC and an ABR trustee for assurance of correlation. Since the content for the Radiation Oncology In-Training (TXIT™) examination is based on this ABR study guide, we should also expect continued consistency between the TXIT™ exam and this curriculum[6].

3. RESULTS

The revised curriculum represents 56 hours of resident physics didactic education, including a 4 hour initial orientation. Specific topics are listed in Table 1, along with the associated section(s) of the ABR blueprint. The total recommended curriculum has been reduced by 4 hours from the 2010 curriculum. In addition to this core curriculum, a set of practical clinical physics modules and treatment planning modules are also included and are recommended as a supplement to the didactic training material (see Table 2). Major changes to the curriculum structure include the addition of a basic physics section, the removal of stereotactic radiosurgery and stereotactic body radiotherapy from the Special Procedures section and creation of an independent 2 hour section for both topics, and the removal of the Radiopharmaceutical Physics and Dosimetry and Hyperthermia sections. Also, minor changes and additions to existing sections are included, such as the addition of a subsection on Volumetric Arc Therapy (VMAT), a Simulation and Treatment Verification section, and an optional Research and Development in Radiation Oncology section. Finally, the Radiation Incidents and Bioterrorism Response Training section was changed to Incidents and Safety. While Table 1 lists the section titles and recommended hours for the curriculum and Table 2 provides the module titles for the practical components, the recommended details of the curriculum are provided in the appendices [link to appendices]. Appendix 1 provides the recommended details of the curriculum, Appendix 2 provides recommended references for teaching material, Appendix 3 provides a glossary of acronyms, Appendix 4 provides a set of practical clinical radiation oncology physics modules, and Appendix 5 provides a set of practical modules for radiotherapy treatment planning.

On the survey, the number of actual and recommended hours for each subject was fairly consistent for each respondent, with deviations typically only where newer procedures or technology require expanded content within the curriculum or where older procedures were being phased out. The number of recommended hours for each subject was also fairly consistent among respondents and an average value for each topic served as the starting point for committee discussion to determine the final recommended number of hours for each topic. The total didactic curriculum hours among respondents ranged from 40 to 70 hours with a mean (SD) of 52.5 (8.8) hours, which agrees fairly well with the final recommendation of 56 hours.

The survey responses also showed that the number of times residents were required to complete this curriculum varied among institutions but it was common for residents to complete the curriculum more than once. Four of eight respondents required residents to take the full curriculum twice, two required it 3 times, and the remaining two either gave residents the option to take it a second time or required residents to do so if their TXIT™ scores were below a specified cutoff. The committee recommends that residents complete this curriculum at least twice during their residency education. However, this recommendation does not apply to the practical clinical radiation oncology physics and treatment planning components.

Seven of eight committee members responding to the survey reported that their institutions had a laboratory or clinical rotation component; however, the total reported hours within this component varied from 4 to 60 with a mean of 12 hours. In addition, the laboratory component was not mandatory at four of these institutions and these lab components varied significantly in content. Written descriptions of these rotations included the following components: clinical dosimetry (treatment planning), treatment calculations, linear accelerator design and function, radiation detectors, treatment unit calibration, observation of quality assurance for special procedures, safety/emergency training, and involvement in or observation of quality assurance tests and other physics activities.

The PCCSC recommends that the radiation oncology residency physics education curriculum contain a laboratory / clinical component that supplements the didactic material presented in the courses. A set of example laboratory exercises is provided in Appendix 4 as a guideline for developing practical experiences to help residents solidify didactic concepts. Ideally, each module of the practical clinical radiation oncology physics component will be performed after completing the associated didactic material. The PCCSC also recommends a radiotherapy treatment planning component and a comprehensive set of treatment planning modules is provided in Appendix 5 as a template for such a component. We anticipate that the practical treatment planning component will be completed either during a designated treatment planning rotation within the residency curriculum or gradually throughout the residency program and integrated with the disease-site specific clinical rotations. While Appendix 5 provides only a set of recommended treatment sites and teaching points, examples of detailed treatment planning exercises exist elsewhere, for example by Golden *et al.*[7]

Resident feedback from the medical physics component of the ABR IC examination will be reviewed annually by the chair of the ABR Resident Physics Test Assembly Committee and the chair of the ASTRO PCCSC. This review will help shape future curricula by providing insight into the examinees' perceptions of their relative level of preparation for various topics as well as core skills and familiarity with particular procedures and technologies. The first review was completed in October 2015. The most common request from examinees was a desire for increased clinical applicability of examination material. We hope that the revisions within this curriculum and the addition of the practical, hands-on clinical components will help improve the link between didactic material and practical application both in education programs and examination content.

4. DISCUSSION

The updated curriculum was completed and approved by the ASTRO Board of Directors in October 2015. We have made an effort to include in this curriculum not only information about new technology and techniques but also basic science instruction that provides a solid foundation in radiological physics. Technology and techniques in radiation oncology change very rapidly; therefore, it is important that this curriculum be updated regularly and that individual residency programs perform annual review and continuous quality improvement. Such annual program reviews should include participation from all physics educators as well as the residency program director and have suitable resident representation. The content, philosophy, and goals of resident physics education should be reviewed with an eye toward identifying the concepts critical to improving clinical practice and preparing residents to be clinician scientists. In addition, every attempt should be made to incorporate physics principles into clinical rotations to assure that the relationship between the didactic material and its clinical application is clear.

The updated curriculum presented here can be used as a guide in the development of didactic radiation oncology resident physics education. Additionally, we recommend incorporation of clinical physics and/or laboratory experiences as well as treatment planning experience in order to provide practical, hands-on experience in the application of the didactic concepts. We anticipate that the addition of these practical experiences will not only improve understanding of core concepts and their clinical applications, but will also offer educators a platform to re-evaluate current teaching practices in an effort to enhance the resident education process. It is our hope that by supplementing lectures with other educational experiences, residents will gain reinforced understanding and improved retention of the material in this curriculum. While we make no effort in this document to address 'how' to teach, many valuable resources are available to educators. Several relevant examples can be found in the Educator Resources section of the AAPM Medical Physicists as Educators website (**wikifull.aapm.org/index.php/MPESC**). Instead of restating this pedagogic information, our goal here is to provide a clear and concise framework of 'what' to teach.

The revised curriculum is the culmination of the efforts of a number of radiation oncology resident educators to identify the most important radiation oncology physics topics. As a result, it should remain consistent with the physics component of the American Board of Radiology (ABR) IC examination and other preparatory examinations for radiation oncology residents. While the ABR blueprint provides a list of topics for study, the list provided in Appendix 1 of this curriculum is much more detailed and we hope that it will serve as a reference to both instructors and residents. This comprehensive list covers all topics that we expect to appear on the ABR examination and may also provide guidance to the authors of the TXIT and RAPHEX exams. We anticipate continued collaboration between the PCCSC and the ABR in maintaining independent but consistent curricula. While we have not made a specific recommendation for any individual textbook for the didactic course, we have identified a number of general radiation oncology physics reference texts useful for educating radiation oncology residents as well as specific references for each section of the curriculum. These are found in the detailed curriculum available at [link to appendices]

CONCLUSIONS

The ASTRO physics core curriculum has been updated by the ASTRO PCCSC to identify the most important physics topics for preparing residents for a career in radiation oncology and to reflect changes in technology and practice since the publication of previous recommended curricula. We anticipate that physics educators will use this curriculum to structure or modify their resident physics education courses and that the ABR, TXIT™, and Raphex exams will remain consistent with this curriculum. A feedback loop has been established to assure that the blueprint used to create the physics component of the ABR IC examination will remain consistent with the ASTRO physics core curriculum and that both the ABR and ASTRO PCCSC will review and consider residents' post-examination feedback during future updates of the curriculum. We also invite resident physics instructors to contribute to the continued development of this curriculum by emailing feedback to **research@astro.org**. The curriculum will be updated again in three years and we anticipate the development of centralized Web-based teaching aids to supplement this curriculum in order to further improve the quality and standardization of physics education for radiation oncology residents.

REFERENCES

Table 1. Recommended topics, hours of instruction, and corresponding 2015 ABR blueprint sections for the American Society for Radiation Oncology's 2015 core physics curriculum for radiation oncology residents.

Chapter	Title	Hours	Correlated ABR blueprint sections
0	Orientation	4	None
1	Basic Physics	1	I.1, III.1-2
2	Atomic and Nuclear Structure	2	I.2-4, II.1-6
3	Production of Kilovoltage X-ray Beams	2	III.3, IV.4, VII.1.a, VII.2
4	Production of Megavoltage X-Ray Beams	3*	IV.1,3
5	Radiation Interactions	3	III.4-5, V.1-6, VII.1
6	Radiation Quantities and Units	1	VI.1,2,4,5
7	Radiation Measurement and Calibration	3*	VI.6-8,10-12, 14
8	Photon Beam Characteristics and Dosimetry	7*	XII.1,4,6, VIII, IX
9	Electron Beam Characteristics and Dosimetry	2*	X.1-11
10	Imaging Fundamentals	4	XI
11	Simulation and Treatment Verification	2*	XII.3; XIV
12	Informatics	1	XVII
13	Intensity Modulated Radiation Therapy (IMRT)	3*	XIII.1-3
14	Prescribing, Reporting, and Evaluating Radiotherapy Treatment Plans	1	XII.2, 5
15	Special Procedures	2	X.12, XII.8, XV.8
16	Brachytherapy	6*	II.5,XV.1-7, 9-10, XVI.3-4
17	Quality Assurance	2*	XX.4
18	Radiation Protection and Shielding	2*	VI.3, XVI.1-2,5-6
19	Safety and Incidents	1	XX.2.a,b,d
20	Particle Therapy	2	IV.2, XVIII.1-5
21	Stereotactic Radiosurgery / Stereotactic Body Radiotherapy (SRS/SBRT)	2	XII.7
22	Research and Development in Radiation Oncology Physics (Optional)	1#	None

* Indicates subject matter that should be complemented with a physics clinical/laboratory rotation.
# Optional section.

Table 2. Recommended practical clinical radiation oncology physics and treatment planning supplements to the American Society for Radiation Oncology's 2015 core physics curriculum for radiation oncology residents.

Practical Component	**Modules**	
Clinical Radiation Oncology Physics	1	Introductory laboratory / linac primer
	2	External beam therapy with photons and electrons - Absolute dosimetry for machine calibration
	3	External beam therapy with photons and electrons - Relative dosimetry for beam model characterization
	4	External beam therapy with photons and electrons - *In vivo* dosimetry and delivery verification
	5	Brachytherapy
	6	Radiation Protection and Shielding
Radiotherapy Treatment Planning	1	Central Nervous System
	2	Head & Neck
	3	Thorax
	4	Breast
	5	Abdomen / Pelvis
	6	Other (optional)