Hands-on Physics Education of Residents in Diagnostic Radiology

Jie Zhang, PhD, Peter A. Hardy, PhD, David J. DiSantis, MD, M. Elizabeth Oates, MD

Rationale and Objectives: The American Board of Radiology Core Examination integrates assessment of physics knowledge into its overall testing of clinical radiology, with an emphasis on understanding image quality and artifacts, radiation dose, and patient safety for each modality or subspecialty organ system. Accordingly, achieving a holistic approach to physics education of radiology residents is a huge challenge. The traditional teaching of radiological physics—simply through didactic lectures—was not designed for such a holistic approach. Admittedly, time constraints and clinical demands can make incorporation of physics teaching into clinical practice problematic. We created and implemented a week-long, intensive physics rotation for fledgling radiology residents and evaluated its effectiveness.

Materials and Methods: The dedicated physics rotation is held for 1 week during the first month of radiology residency. It comprises three components: introductory lectures, hands-on practical clinical physics operations, and observation of clinical image production. A brief introduction of the physics pertinent to each modality is given at the beginning of each session. Hands-on experimental demonstrations are emphasized, receiving the greatest allotment of time. The residents perform experiments such as measuring radiation dose, studying the relationship between patient dose and clinical practice (eg, fluoroscopy technique), investigating the influence of acquisition parameters (kV, mAs) on radiographs, and evaluating image quality using computed tomography, magnetic resonance imaging, ultrasound, and gamma camera/single-photon emission computed tomography/positron emission tomography phantoms. Quantitative assessment of the effectiveness of the rotation is based on an examination that tests the residents' grasp of basic medical physics concepts along with written course evaluations provided by each resident.

Results: The pre- and post-rotation tests show that after the physics rotation, the average correct score of 25 questions improved from 13.6 ± 2.4 to 19 ± 1.2. The survey shows that the physics rotation during the first week of residency is favored by all residents and that 1 week's duration is appropriate. All residents are of the opinion that the intensive workshop would benefit them in upcoming clinical rotations. Residents acknowledge becoming more comfortable regarding the use of radiation and providing counsel regarding radiation during pregnancy.

Conclusions: An immersive, short-duration, clinically oriented physics rotation is well received by new or less experienced radiology trainees, correlates basic physics concepts with their relevance to clinical imaging, and more closely parallels expectations of the American Board of Radiology Core Examination.

Key Words: Physics teaching; hands-on; residents; diagnostic radiology; education.

INTRODUCTION

In 2013, the American Board of Radiology (ABR) replaced the separate written, physics, and oral examinations in diagnostic radiology with the new ABR Core and Certifying Examinations. The ABR Core Examination is intended to validate the candidate's basic knowledge, skills, and understanding of the entire field of diagnostic radiology, including physics, whereas the certifying examination is intended to validate if the candidate has acquired and is able to apply the requisite knowledge, skills, and understanding for practice (1).

Acad Radiol 2017; ■:■■–■■

From the Department of Radiology, University of Kentucky, 800 Rose Street, Room HX 311A, Lexington, KY 40536-0293 (J.Z., P.A.H., M.E.O.); Department of Radiology, Mayo Clinic, Jacksonville, Florida (D.DS.). Received December 1, 2016; revised January 17, 2017; accepted January 18, 2017. The content of this paper is solely the responsibility of the authors and does not necessarily represent any official views from the American Board of Radiology (ABR) or Radiological Society of North America (RSNA). **Address correspondence to:** J.Z. e-mail: jnzh222@uky.edu

http://dx.doi.org/10.1016/j.acra.2017.01.015

The ABR Core Examination weaves physics into its sections dealing with imaging modalities and subspecialty organ systems, and shifts the focus from rote knowledge of physics concepts to purposeful application of physics knowledge to solve clinical problems. The content stresses medical physics of practical use to the radiologist. With the integration of clinically relevant physics into the new ABR Core Examination, radiology residency programs are faced with the challenge of how radiological physics should best be taught. In the new ABR Core Examination, the items avoid esoteric minutiae, but instead target practical problems such as radiation dose reduction and image artifact mitigation. Traditional physics teaching to radiology residents through dedicated lectures may not meet these requirements. The Radiological Society of North America/American Association of Physicists in Medicine (RSNA/AAPM) Physics Modules, with their sets of animations and simulations, mitigate this problem to some extent, but do not go far enough in giving the resident an appreciation of the technology they will use in their career.

It is therefore the right time to create a curriculum that not only engages the learner, but also is viewed as eminently practical. We believe that residents trained in a way to understand medical physics concepts at a deeper level will be better prepared to practice effectively and conduct research which will continue to advance the science of radiology.

RATIONALE FOR THE PROGRAM

Although much has changed in the scope and complexity of the practice of radiology, little has changed in the physics education of radiology residents. Despite research documenting the relatively low retention rate, didactic lectures remain a mainstay in most departments. For introductory physics classes, several investigators discovered that, even when lectures are delivered by experts, the students retain as little as 10%–20% of the material (2–5). One can reasonably assume that the situation is equally dismal for medical physics lectures delivered to radiology residents who often view learning physics as an unwelcome distraction from their true goal—learning to interpret clinical images. Yet, developing a more-than-cursory understanding of the physical principles that underpin medical imaging is crucial to being a good radiologist. Only by understanding how the imaging technology works can a radiologist understand what has gone wrong when artifacts appear or when imaging equipment malfunctions.

Because clinical imaging is grounded in technology, it forms the core of the curriculum. It should be taught systematically and evaluated rigorously. Because it is generally impractical to incorporate physics teaching into daily clinical practice at the workstation, a dedicated systematic hands-on physics rotation offers a time-efficient alternative, addressing this knowledge void and bridging the gap between our current educational programs and evolving need for practical knowledge of physics concepts.

Residents who may have limited physics background may likely have negative stereotypes of physics and question whether they fit into a physics class. With this mind-set, they will likely develop a feedback loop of negative feelings and results. A hands-on education with active participation can function as a "psychological intervention" (6), which helps convert a negative interpretation into a positive or at least a neutral interpretation that leads to a sense of belonging in the classroom and greater success.

IMPLEMENTATION OF THE PROGRAM

Curriculum

We have developed a series of hands-on laboratory operations illustrating and elucidating the fundamentals of imaging physics, instrumentation, and radiation safety, while highlighting their applicability to the daily practice of clinical radiology. The current curriculum includes 32 laboratory operations, covering X-ray tube function, X-ray projection imaging, fluoroscopy, computed tomography (CT), ultrasound, magnetic resonance imaging (MRI), and gamma camera/single-photon emission computed tomography (SPECT)/positron emission tomography (PET) (Table 1).

TABLE 1. Curriculum and Schedule for Hands-on Physics Education of Residents in Radiology

X-ray tubes (day 1: 8:00 AM to 12:00 noon)
X-ray tube disassembly and assembly
Effects of mAs and kV on X-ray quantity and quality
Half value layer
Heel effect and its clinical concerns
X-ray projection imaging (day 1: 1:00 PM to 5:00 PM)
Effect of kV and mAs on image quality and radiation exposure
Effect of field size and grid on image quality and radiation exposure
Effect of focal-spot size and object-to-image detector distance on image blur and magnification
Automatic exposure control (AEC) and its appropriate use
Mammography and tomosynthesis
Fluoroscopy (day 2: 8:00 AM to 12:00 noon)
Effect of acquisition modes on image quality and radiation exposure
Fluoroscopy dose metrics and measurement
Strategies to reduce patient and personnel dose
Computed tomography (day 2: 1:00 PM to 5:00 PM)
CT dose index and dose-length product
Selection of CT acquisition parameters
Tube current modulation and automatic kV adjustment
Evaluation of CT image reconstruction algorithms and image quality
Magnetic resonance imaging (day 3: 8:00 AM to 5:00 PM)
Components of the MR imager: magnet, gradients, RF coils, and room shielding
MR safety
Effects of Gd-based contrast agents on MR image
Effects of TE, TR on image contrast
Gamma camera/SPECT/PET (day 4: 8:00 AM to 5:00 PM)
Survey meters: calibration and application
Dose calibrator
Testing parameters for gamma camera
Evaluation of SPECT system using phantom
Evaluation of PET system using phantom
Ultrasound (day 5: 8:00 AM to 12:00 noon)
Ultrasound image creation, effect of frequency, focal depth on image appearance
Doppler ultrasound: basic principle, angular dependence, artifacts
Shear wave elastography, basic physics, measuring tissue stiffness
Radiation safety/wrap up (day 5: 1:00 PM to 5:00 PM)

CT, computed tomography; Gd, gadolinium; MR, magnetic resonance; PET, positron emission tomography; SPECT, single-photon emission computed tomography.

Each laboratory operation includes a specific objective, description of procedures, results, discussion points, and review questions. Table 2 shows an example of laboratory operations. Some laboratory operations are further divided into sub-operations; for example, the laboratory operation "effect of