

EFFECTIVE PHYSICS EDUCATION FOR OPTIMIZING CT IMAGE QUALITY AND DOSE MANAGEMENT *WITH OPEN ACCESS RESOURCES*

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Abstract: The most effective optimization of CT image quality and related radiation dose management requires a clinical imaging staff with knowledge of the physics principles that apply to the imaging process. This knowledge can be developed through a combination of learning activities, including classroom discussions, but a critical requirement is guided learning activities associated with the clinical imaging procedures. A program is described for including physics education within clinical activities, especially for trainees, and online open access resources are provided to enhance the process.

Keywords: Computed Tomography, Physics Education, Image Quality, Radiation Dose Management.

INTRODUCTION

Computed tomography (CT) is now one of the most effective and valuable imaging methods for medical diagnosis and guiding therapeutic procedures. With the continuing advances in technology there is the capability to produce images with characteristics that can be optimized for a wide range of clinical purposes. Also, there is the need to manage the radiation dose for each patient and balance it with respect to the image quality requirements. This is achieved by adjusting the protocol factors for each procedure. Developing an optimized protocol requires knowledge of the clinical requirements, the design and functional characteristics of the equipment, and especially the physical principles and physics that is the foundation of the CT imaging process. There is a significant challenge in providing the medical professionals who have responsibility for and who conduct CT procedures with the appropriate knowledge of physics that can be applied to enhance the effectiveness and safety of CT. A model of a collaborative approach to providing this education, on a global basis, is described along with the online resources that are open access and can be used in any CT program.

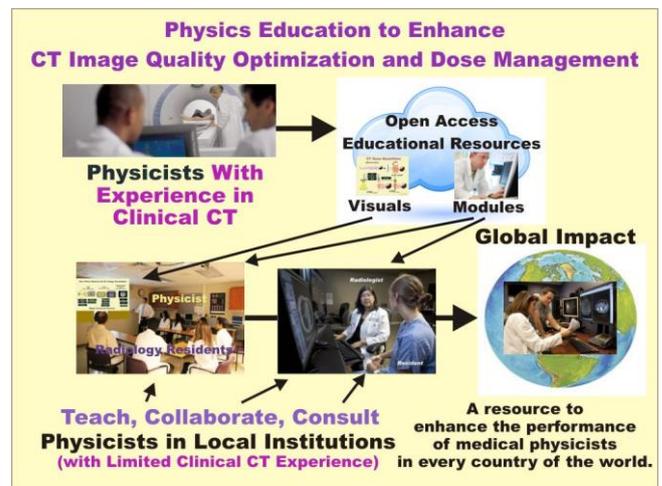


Figure 1. The model of a program to provide physics education to support clinical CT procedures.

CONTROLLING THE CT PROCEDURE

There are two major factors that can be controlled in each CT procedure as illustrated in Figure 1. One is the characteristics and quality of the image and the other is the radiation dose delivered to the patient. The direct control of these by the medical staff is through the adjustment of the imaging protocol which is the complex combination of quite a few individual protocol factors.

A. Technology. The imaging capabilities and ability to manage radiation dose that are available in a specific clinic depend on the design characteristics of the CT equipment. With the continuing development and innovations there is generally the opportunity to produce higher quality images and to do it with a reduced radiation dose to the patient. However, this can only be achieved if the staff is capable of developing and using protocols that are optimized for each.

B. Science. Physics is the fundamental science of CT. The imaging process and the design of the technology are based on physics principles. That is the knowledge used by physicists and engineers in the

continuing development of CT technology. However, of equal significance is the knowledge of physics required by the medical professionals who conduct imaging procedures. This is the knowledge that must be applied in the intelligent selection, adjustment, and optimization of imaging protocols.

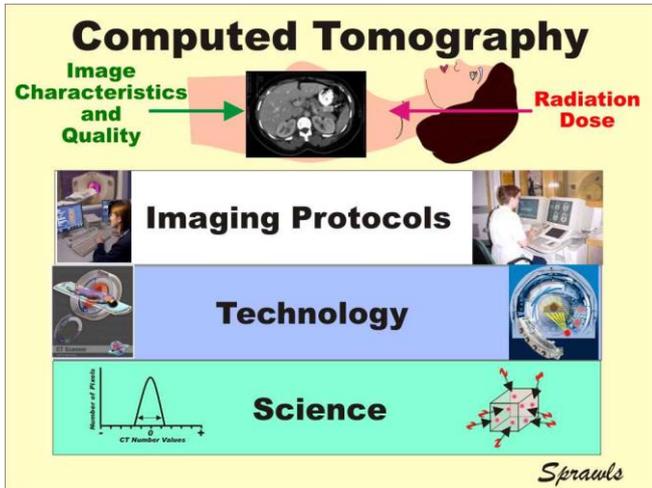


Figure 2. The major factors that determine image quality and dose to the patient.

PHYSICS KNOWLEDGE STRUCTURES

Knowledge of physics is actually a mental representation of various components of the physical universe, depending on the specific areas of study and experience, medical physics being the one that is our interest at this time. Physics knowledge structures consist of a complex combination of elements including images, words, and mathematical quantities. The organization of these elements contributes to a higher level of knowledge in the form of principles, concepts, and the ability to analyze conditions and apply the knowledge to innovate and produce solutions to a variety of questions or problems.

A. Appropriate Knowledge Structures. The physics knowledge structure that is appropriate for an individual depends on the work or functions that they are to perform. The knowledge structure needed by physicists and engineers who develop CT technology, new methods and procedures, and evaluate quality and performance is very different from that needed by the medical imaging staff conducting clinical procedures.

B. Physicists and Engineers: They need a strong quantitative (mathematical) understanding of both the physics and technology in order to innovate, develop, and analyze new possibilities. This also applies to the clinical medical physicist who evaluates image quality, system performance, and plays a major role in radiation dose

management. This knowledge comes from physics and engineering study, typically at the graduate level, and practical and applied experience.

C. Medical Imaging Professionals: This is the team of professionals who have responsibility for and conduct the CT imaging procedures. They include radiologists, trainees (residents and fellows), and technologists who operate the equipment. They need a physics knowledge structure that applies to their functions. It needs to give them insight into and an understanding of the CT process with which they can interact. To a great extent it needs to make what is generally an “invisible world” visible so that useful knowledge structures can be formed and used.

VISUALIZATION

A major factor in providing effective medical physics education, especially for medical imaging professionals, is to enable them to visualize the imaging process and especially the relationships among the various components and elements. This helps form mental knowledge structures of the CT process that go beyond just seeing the equipment and the images. Here we have two examples.

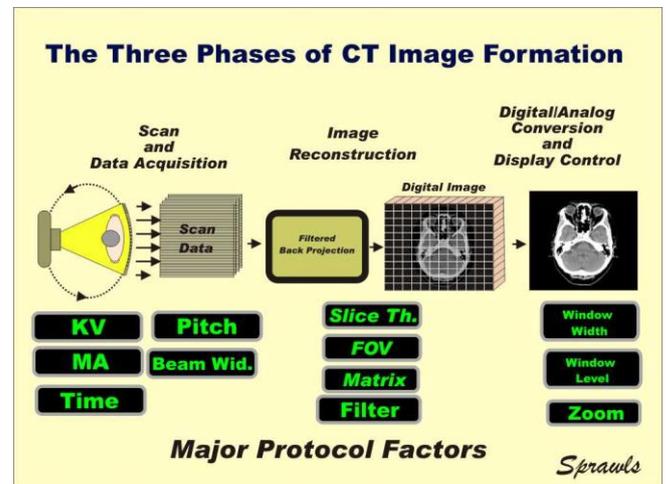


Figure 3. The three phases of the CT imaging process and the major protocol factors associated with each.

This visual provides a comprehensive view of the CT process and shows where it is possible to interact and control the characteristics and quality of the images. This is the type of knowledge that cannot be conveyed by words alone or mathematical equations.

One of the most difficult topics for many to understand is the different quantities that are used to express radiation dose, their relationships, and the factors that control them. That is all brought together in this one visual.

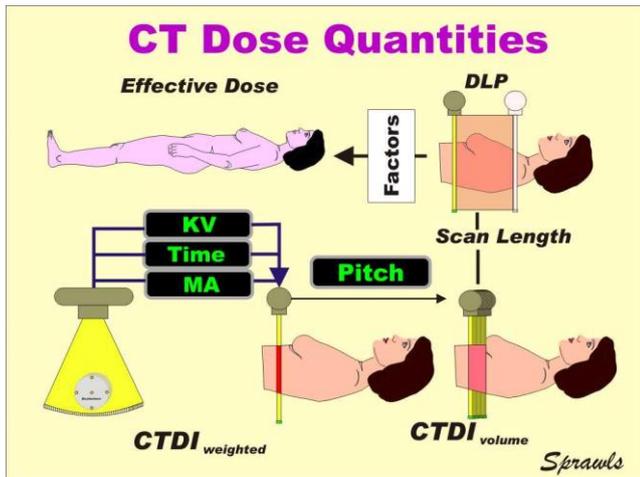


Figure 4. The relationship of the various radiation dose quantities used in CT.

LEARNING AND TEACHING PHYSICS

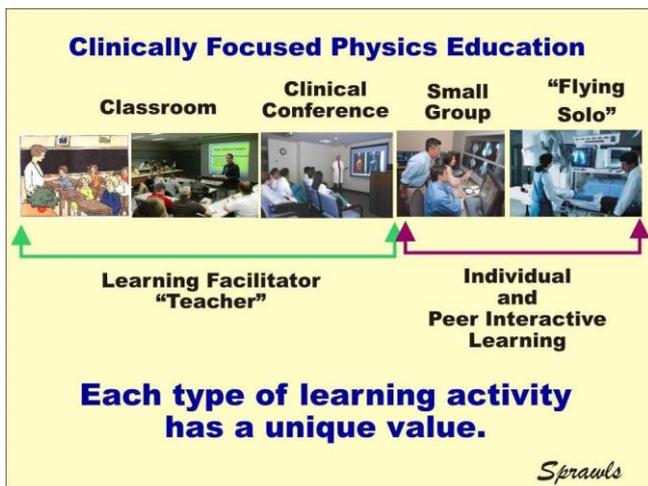


Figure 5. The series of learning activities that contributes to physics knowledge that can be applied to clinical imaging.

Knowledge of physics, and especially medical physics, is developed through a series of learning activities ranging from classroom to direct clinical experience as shown here.

A major objective of medical physics education for medical imaging professionals is to enable them to apply physics principles in the control and optimization of the imaging process, such as CT. The different types of learning activities have their advantages and values but also their limitations and challenges. The goal is to provide a combination of activities that produce the desired results.

A. Classroom and Conference Presentation.

Both of these obstacles can be overcome to a great extent by the use of the web-based resources provided here. These are visuals for classroom/conference presentations and discussions (Ref. 1) and a module (Ref. 2) to support both classroom learning and as a review and reference during clinical activities.

The Visuals can be used by medical physicists, even without significant CT experience, to conduct classes and conference discussions on the physics that is the foundation of CT. They are used in the context of *Collaborative Teaching* where the physicist conducting the class or conference discussion uses his knowledge and experience in general and radiation physics in combination with the Visuals prepared by a collaborator, in this case the author, who has extensive experience in the physics of clinical CT. A significant value of the visuals is that they provide a highly-effective connection between the classroom and the clinical CT process. It enables the learners to develop mental knowledge structures that will support their clinical activities, specifically analyzing images and optimizing procedures.

The online module can be assigned to the learners, rather than a traditional textbook, for additional study, review, and reference.

LEARNING PHYSICS IN THE CLINIC

The clinical environment where the learner is actually participating in CT procedures provides an excellent opportunity for learning physics. The great advantage of this, compared to the traditional classroom is that there is direct observation and interaction with the equipment, the images, and the procedures. Here the learning experience can be directed by the experienced clinical radiology faculty. The online module is used as a review as the learner begins a clinical CT rotation and as a reference as questions come up and during discussions with the clinical faculty.

While it is important to produce images of superior quality, it is also important for trainees to understand the cost of radiation dose when evaluating CT images. Despite the increased focus on radiation dose, few radiologists routinely examine the CT dose report on every patient, especially when the images are of good quality. It is important that radiology trainees be aware of the principle of As Low As Reasonably Achievable (ALARA). While images should be of diagnostic quality, some noise should be expected for most exams if the radiation dose is considered. Discussing the dose report routinely raises awareness of CT dose and its relationship to image quality and also reinforces concepts of CTDI_{vol}, DLP, and effective dose with the increasing complexity of newer scanners.



Figure 6. Advantages of physics education in the CT clinic.

A The Need for Clinically Focused Physics Education.

It is also essential to understand how to implement dose saving techniques including automatic tube current, tube potential selection, and iterative reconstruction. Adjusting these parameters can be confusing, particularly when dealing with multiple scanner platforms which employ different quality reference standards. Also, while these techniques can be of great benefit when used properly, radiologists and technologists need to be aware of the pitfalls. For instance, as tube current modulation is based on the scout image, the tube current will be defaulted to the maximum if the patient is scanned beyond the region included on the scout.

In the age of digital imaging, radiologists have less contact with technologists and imaging equipment in daily practice. Reviewing physics in the clinical setting can help trainees learn to rectify suboptimal images and become more aware of radiation dose. Discussing real life examples reinforces these concepts and makes them less abstract.

B Providing Clinically Focused Physics Education.

Suboptimal images present an opportunity to discuss imaging parameters (tube current, tube potential, rotation speed, and pitch) as it relates to image quality and dose specific for that patient. This can be especially instructive when there is a prior comparison exam using a different technique. Trainees can also be shown the effects of poor patient positioning, which can result in suboptimal image quality and higher dose to the patient. The presence of artifacts may prompt a discussion on the purpose of daily and periodic quality control. Radiologists need to be able to distinguish between equipment artifacts, noise, a poorly positioned patient, and operator error. The objective, for a trainee, should be to provide a comprehensive physics learning experience during a clinical rotation. This begins with the study of the online module followed by a discussion with a physicist if available, reviewing and answering questions as needed.

As clinical cases are interpreted the radiologist can address image quality and procedure issues and ask questions of the trainee. This is a more effective learning experience if a plan is followed that includes specific topics to discuss and related questions. The plan can be developed as a collaborative effort between the radiologist and physicist. The objective for the clinical staff is to review and enrich their knowledge of physics as it applies to CT by studying the online module in the context of continuing education.

CONCLUSION

The optimization of CT imaging procedures to produce maximum image quality and clinical information along with effective dose management requires knowledge of applied physics principles by the medical professionals with responsibility for the CT procedures. The development of an effective educational program needs to combine the advantages and values of different types of learning activities with a special emphasis on “clinically-focused” activities where the trainee/learner is actively involved with the imaging process. Medical physicists affiliated with radiology educational programs and clinical CT activities can contribute to the process by using open access resources for both classroom and in-the-clinic learning activities. The two authors, one a physicist (PS) and one a radiologist (P-ATG) are finding this collaborative and clinically-focused educational model to be very effective especially for radiology resident and fellow training. It has added a new dimension to more traditional medical physics education.

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