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Authors

Naeger, David M
Webb, Emily M
Zimmerman, Leslie
et al.

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Strategies for Incorporating Radiology into Early Medical School Curricula

David M. Naeger, MD^a, Emily M. Webb, MD^a, Leslie Zimmerman, MD^b,
Brett M. Elicker, MD^a

Clinically oriented material is being incorporated increasingly early into medical school curricula. Traditional models of incorporating radiology early on, mainly as an adjunct to pathology or anatomy instruction, are not focused on learning important aspects of clinical radiology. Medical students can be better served by an integrated curriculum that focuses on appropriate ordering of radiology studies, an intuitive understanding of imaging modalities, and understanding the patient experience.

Key Words: Education, medical students, integrated curricula

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INTRODUCTION

Radiology is central to the practice of modern medicine. Despite its pivotal role, formal radiology education is often limited in scope, or sometimes nonexistent, in medical school curricula. When included, radiology is often used more as an instructional aid in anatomy and pathology courses, or is offered only to seniors as a stand-alone elective without any integration into the remainder of the curriculum.

There are many potential benefits of early exposure to radiology during medical school. It allows students to gain familiarity and begin to recognize radiology as an essential component of medicine alongside other key clinical fields. Students with early exposure to radiology in an integrated curriculum are also more likely to take a radiology elective later in their studies [1]. Most graduating medical students do not become radiologists, but rather go in to a variety of primary care fields and subspecialties, eventually becoming our referring clinicians. Having a better understanding of medical imaging will produce more informed clinicians and hopefully translate to improved exam ordering and patient care. For students who are considering radiology as a career choice, early exposure allows for more time to explore their options and assess the fit.

Although many radiologists would agree that early exposure is desirable, *how* to teach this specialized, highly clinical field to a preclinical audience proves far less straightforward. Which topics should be taught? What are reasonable learning objectives? What is the optimal setting and teaching method? We seek to review strategies for incorporating radiology education early in medical school curricula.

THE OLD PARADIGM

At schools where radiology content is taught in the preclinical years, the material is often used to supplement the teaching of anatomy and/or pathology. Many anatomy labs have “radiology stations” at which radiologic images of a portion of the body are reviewed as an adjunct to the dissection. In pathology labs, radiology may be shown as a correlate to the gross pathology specimens and serve to emphasize how such diseases might be viewed in living patients, particularly in regards to oncology.

Although both types of offerings provide some exposure to radiologic modalities and imaging indications, these sessions are focused on learning the relevant anatomy and pathology, not clinical radiology. This construct does not communicate the underlying technology behind image acquisition and, more importantly, it does not communicate the full role of imaging in clinical practice.

Historically, limited early radiology exposure seemed appropriate, given the smaller clinical role of imaging many decades ago, as well as the prevailing structure of medical school curricula in which clinical topics were strictly excluded from the first 2 years. This curricular paradigm is changing, however, and so must our involvement and ideas about appropriate radiology education in early medical school curricula.

^aDepartment of Radiology and Biomedical Imaging, University of California, San Francisco, California.

^bDivision of Pulmonary and Critical Care Medicine, University of California, San Francisco, California.

Corresponding author and reprints: Emily M. Webb, MD, Department of Radiology and Biomedical Imaging, 505 Parnassus Ave., M-391, Box 0628, San Francisco, CA 94143-0628; e-mail: emily.webb@ucsf.edu.

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THE NEW PARADIGM

Medical school curricula are evolving toward more integrated models [2]. Beginning with the introduction of case-based learning scenarios focused on clinical vignettes [3], schools have found that students are more motivated and engaged when the clinical utility of basic science content is evident [4]. As curricular reform has resulted in greater degrees of integration and problem-based learning, graduates demonstrate improved clinical skills and feel better prepared for clinical practice when compared with students from more traditional school models [5,6]. Integrated curricula review the basics of diseases alongside information regarding laboratory work-up, pharmacologic treatment, and the basics of medical and surgical management. Often, high-level epidemiological and socioeconomic analyses are also discussed. How can such a breadth of information be reviewed *without* including discussion of one of medicine's best diagnostic tools: medical imaging? These new curricula offer an opportunity to present clinical radiology during these early (formerly, "preclinical") years.

In this type of curricular model, it is especially important to consider the learner's stage of sophistication. First- and second-year students often have a more cursory understanding of clinical issues, which can limit their appreciation for the nuances of appropriate use of imaging and consultation. However, the basic principles can be introduced, ideally alongside relevant content from other disciplines, providing a solid foundation for more sophisticated learning in later clinical rotations. A logistic advantage to this approach is that a dedicated hour of radiology lecture need not be added to the students' already busy classroom schedule. Securing classroom time with the students is always challenging and competitive given the broad and complex scheduling demands across a curriculum. Rather, radiology can be integrated into already existing sessions, complementing the existing material, and simultaneously introducing concepts of medical imaging. For example, in an integrated curriculum, a single first-year lab session might describe a clinical case of a patient with ischemic heart disease and then review the relevant cardiac histology, gross and cytopathology, and the appearance of cardiomegaly on chest x-ray. More advanced details regarding appropriate use of chest x-rays in clinical practice, and the spectrum of abnormalities that can be diagnosed, can be perfected later as students gain more firsthand clinical experience.

HOW TO TEACH IT: GUIDING PRINCIPLES

Focus on Indications, Not Interpretation

Resident education is almost exclusively focused on image interpretation. The methods of acquisition, techniques for image evaluation, and mastery of differentials are all aimed at the same goal: deriving clinically useful information from medical imaging. Medical student

education is *not* (or should not be) focused on imaging interpretation. Fewer than 5% of medical students become radiologists [7], with the remainder entering into fields that often utilize radiology in the care of patients. Therefore, most students will not be performing sophisticated image interpretation as practicing physicians, and those who do will have the duration of residency to master the material. All graduating students, future imagers and nonimagers alike, will enter into internships and become referring physicians, and most will continue to order imaging throughout their residency and subsequent practice. Understanding the role of imaging, its indications, and the nuances of appropriate ordering is an almost universally required skill set.

Improper ordering of imaging exams is a pervasive problem. In recognition, the ACR has recently begun a Choosing Wisely[®], an educational campaign that emphasizes appropriate indications for imaging. Materials often highlight clinical scenarios where imaging is actually unnecessary [8]. Improper utilization leads to poor resource allocation, wasted medical dollars, needless radiation exposure to patients, and countless hours of lost physician time trying to contact ordering physicians and correct errors during exam protocoling. Indeed, the medical literature has documented the extent of this problem, and technological solutions are being developed, including electronic physician order entry systems for radiologic exams with integrated clinical decision support [9,10]. The need for these electronic resources speaks to the complexity and clinical sophistication often needed in determining the best imaging exam in any given clinical scenario. However, even in an era of evolving technological support, it is still critical that physicians learn the basics of proper exam utilization and ordering. After all, it will always be the physician who decides when to request a study and who must subsequently decide whether to accept or reject the decision support suggestions.

Highlight What We Do, Not How to Do It

Medical students, similar to the general public, typically have a poor understanding of the role of radiologists in medical practice. Simplifying 4 years of residency and many years of honing our craft into a few short didactic image interpretation sessions is unlikely to adequately emphasize the expertise necessary for performing sophisticated interpretations. When medical students visit the operating room, the surgeon demonstrates the many years of training needed to practice. Radiologists should do the same.

For example, in reviewing pneumothoraces on chest x-ray, it seems intuitive that we should teach the basics of finding a pneumothorax (eg, "see the pleural line? That indicates a pneumothorax"). The truth is that finding the pleural line can be trickier than it appears on example cases, and there are myriad additional signs to look for. Therefore, when teaching this, we could focus the instruction on examples of what is done by an experienced reader (eg, "This is an example of the x-ray

demonstrating a pneumothorax. Radiologists look for a pleural line, which is the most common finding; however, there are numerous potential other findings as well. Sometimes the signs are present but much more subtle than this, and there are mimics as well. You may be asked to evaluate the size or existence of a pneumothorax as an intern or resident, but remember it can sometimes be very difficult and that is why you have trained imaging experts available to you 24 hours a day.”

Focus on Intuitive Understanding Over Detailed Memorization

An intuitive understanding of each modality will serve medical students well as they attempt to master the full breadth of a medical school curriculum. Understanding the use of sound reflection in ultrasound helps students understand the modality’s limitations, for example, poor imaging at depth. It also highlights the absence of ionizing radiation. Nonintuitive information (for example, understanding how fat looks in breast ultrasound compared to abdominal ultrasound) will be difficult to remember and is of low utility.

As an additional example, “high-resolution” chest CT is an inherently confusing term to those who are unfamiliar. The name suggests improved technology or a “better” test and the differences in technique require fairly high-level understanding of scan protocols. Ignoring the protocol and focusing on the technique’s strength (evaluating lung parenchyma for subtle findings of interstitial lung disease) and weaknesses (finding pulmonary nodules or evaluating soft tissue) are more clinically useful teaching points.

Focus Narrowly

Early in medical school, every single medical specialty’s material is covered to a cursory degree. To practice cardiology, one requires 3 years of internal medicine residency training and 3 years of cardiology fellowship; the cardiology reviewed during medical school, however, may comprise only a few weeks to months of instruction. Although one could theoretically review everything in radiology cursorily, choosing high-yield topics to cover in a moderate depth is usually favored. Hysterosalpingograms play a limited role in the evaluation of a limited patient population referred primarily by one specialty. Understanding PET/CT’s role in oncology, however, will be important for many types of physicians, including primary care, oncology, surgery, and pathology, to name only a few. Topics that broadly teach the strengths and weakness of imaging (and specific modalities), as well as the integration of imaging with clinical information, may succeed in conveying broad messages to medical students while focusing on a single narrow scope.

Teach the Patient Perspective

Although it seems obvious, medical students should graduate with knowledge of what their patients will experience. On wards, students inherently learn at least a portion of the patient perspective of being admitted and

hospitalized. Seeing a patient in clinic gives some perspective on what it is like to visit an outpatient office. Without seeing a mammogram suite, however, young referring physicians have no idea what their patients will experience. Some students graduate without seeing the size of a standard MRI bore or hearing a MR scanner in action. Patients expect their physicians to know something about the experience of undergoing a test, and ordering physicians are the first in line to answer patient questions. We can teach this by including pictures of equipment, giving tours, and putting together demonstrations. We can also verbally describe the patient experience or invite patients themselves into the classroom to talk about their experiences.

TOPICS & LEARNING OBJECTIVES

The Alliance of Medical Student Educators in Radiology has published a national radiology curriculum, including suggested learning objectives [11]. This compendium includes a listing of information that may be suitable for more junior medical students. Examples of topics and learning objectives suggested by the curriculum that fit with the guiding principles listed above are presented in [Table 1](#).

The sequence of topics presented in an integrated medical curriculum is often unique to the school and dependent upon the specifics of material presented by other departments. It is difficult to suggest any single “correct” formula, beyond the previously discussed guiding principles. An example of chest radiology topics presented across our 4-year integrated curriculum is presented in [Table 2](#).

Table 1. Examples of selected Alliance of Medical Student Educators in Radiology (AMSER) learning objectives that meet our guiding principles for inclusion of radiology content early in medical school curricula

AMSER Learning Objective	Guiding Principle
Construct the appropriate imaging algorithm for common diagnostic scenarios	Focus on indications, not interpretation
List clinical scenarios in which radiology is particularly important in diagnosis, management, and delivery of patient care	Highlight what we do, not how to do it
Discuss challenges specific to imaging children and how these may affect choice of imaging modality	Focus on intuitive understanding of modalities and technology
Discuss current recommendations for screening mammography	Focus narrowly
Describe what a patient experiences during a gastrointestinal fluoroscopic procedure	Teach the patient perspective
This list is drawn from a comprehensive list that can be found online [11].	

Table 2. Example of thoracic imaging topics and settings included throughout a 4-year curriculum and relevant Alliance of Medical Student Educators in Radiology (AMSER) learning objectives

Session Title	Setting	AMSER Learning Objectives
Year 1		
"Introduction to Radiology and Imaging Modalities"	Large group lecture and e-learning	Categorize different tissues from most to least opaque on x-ray including bone, soft tissue, air, metal, and fat
"How to Read a Chest X-ray"	Large group lecture	Identify the different CXR views and describe when they are helpful, as well as the limitations of each
Live "Cardiac Ultrasound" anatomy lab breakout session	Small group	Explain why ultrasound is a good modality for assessing vascular structures
"Imaging of the Heart"	Large group lecture	Compare and contrast the benefits and limitations of different radiologic modalities including plain film, CT, ultrasound, MR, nuclear medicine
Radiology pathology lab: "Response of the Heart to Injury"	Small group	Recognize normal anatomic structures of the chest on imaging exams and become familiar with the range of normal appearances
Radiology pathology lab: "Cardiac Ischemia"	Small group	Differentiate between pulmonary vascular congestion, interstitial pulmonary edema, and alveolar edema on CXR
Radiology pathology lab: "Valvular Heart Disease"	Small group	Discuss the criteria for diagnosis of cardiomegaly on CXR
"Imaging of Respiratory Diseases"	Large group lecture	Recognize a pleural effusion at CXR on supine, upright, and decubitus films
Radiology pathology lab: "Respiratory System"	Small group	Identify consolidation on CXR and formulate a differential diagnosis for the appearance
Radiology pathology lab: "Obstructive and Restrictive Lung Disease"	Small group	List different types of pathologies that can produce an "opacity" on CXR

(continued)

Table 2. Continued

Session Title	Setting	AMSER Learning Objectives
Year 2		
"Mock Thoracic Tumor Board"	Mock tumor board	List clinical scenarios in which radiology is particularly important in diagnosis, management, and/or delivery of patient care
"Role of Imaging in the Management of Cancer Patients"	Large group lecture and e-learning	Compare the relative radiation dose delivered by different imaging modalities and contrast these with annual rates of background radiation exposure
Problem-based learning session: "Lung Cancer Patient Case"	Small group	List several clinical scenarios in which imaging of the chest can be used to guide procedures
Year 3		
"CXR Technique and Evaluating CXR Quality"	Large group lecture	Employ a systematic search pattern for interpreting CXR
"Intro to Lines and Tubes on Chest X-ray"	Large group lecture	Recognize the correct positioning of feeding tubes, venous lines, and endotracheal tubes on CXR
"Logistics of Ordering Radiology Studies and Preparing Your Patient"	Large group lecture	Summarize the categories of critical information that must be included on an imaging exam requisition
"Expert Panel: CT Screening in Smokers"	Clinical conference	Compare the conspicuity of chest masses on CXR and CT
Year 4		
Diagnostic radiology elective	Small groups, lectures, and e-learning	Construct the appropriate imaging algorithm for common diagnostic scenarios, including suspected pneumonia, suspected pulmonary embolism, solitary pulmonary nodule, lung cancer staging, screening for metastasis, and suspected aortic dissection
Reading room-based elective	Clinical clerkship, lectures, and e-learning	Choose an appropriate imaging protocol (noncontrast CT vs contrast-enhanced CT vs multiphase CT) for common cardi thoracic indications

(continued)

Table 2. Continued

Session Title	Setting	AMSER Learning Objectives
End of medical school Capstone course: "Advanced Lines and Tubes on CXR"	Large group lecture	Recognize the correct and incorrect positioning of feeding tubes, venous lines, and endotracheal tubes on CXR

CXR = chest x-ray.

SETTINGS

Lectures

The most common educational format in most medical schools is the group lecture. Increasingly, however, schools are turning to alternative, more interactive formats. This is not because lecturing is ineffective. Indeed, many authors have demonstrated at least equivalent outcomes when traditional lecturing was compared with more novel formats [12,13]. Rather, the declining popularity of formal lectures is being driven more by technology, allowing for remote "attendance" of lectures, including watching recorded lectures at a later time. Online lectures have been found to be similarly effective to live lectures [14]. Using face-to-face classroom time for more interactive teaching formats offers an adjunct method of learning and instruction, which cannot be easily replicated online.

Small Groups

Problem-based learning sessions and other small group sessions are quickly becoming the norm rather than the exception in medical school classrooms across the country. Seventy percent of US medical schools include small group sessions in their curriculum, typically centered around a patient case. A minority of programs describe their entire curriculum as problem based [15]. Problem-based learning is popular among students and teachers, who describe the format as "more interactive and engaging" [16,17]. However, the effectiveness overall remains unclear, with multiple authors reporting little to no difference in student retention compared with more traditional learning formats [18,19]. Despite the ongoing debate as to how problem-based learning could be best utilized within medical school curricula, it does have some clear advantages as a method for introducing radiology into a preclinical curriculum [20]. First, inclusion of radiology content in a patient case alongside clinical and basic science material from other disciplines directly demonstrates the role of imaging in medical practice more than a stand-alone radiology lecture may. This setting is also ideal for teaching students to critically think through an imaging algorithm, weighing relative risks versus benefits, and relative strengths versus weaknesses, of different modalities in answering a

particular question. It allows them an opportunity to practice the exact skill set we most want to impart, and in doing so, students often understand for the first time why having an understanding of medical imaging will be so important in their future clinical practice. Small groups also allow an opportunity to view images and explore questions of utilization with much more direct and immediate feedback. Small groups are also ideal for tours and demonstrations of imaging equipment.

Mock Tumor Boards and Clinical Conferences

Mock tumor boards and clinical conferences are a popular format. These forums demonstrate the varied roles of subspecialists in patient care and the level of interdisciplinary coordination and teamwork required to manage complex cases. The radiology of these sessions can focus on the indications for various studies in the work up and management of various tumors and the experience of patients. Mock tumor boards are also inherently narrow in focus and highlight the contribution of well-trained imaging specialists.

Computer-based Simulations and E-Learning

Radiology can also be effectively taught in multiple digital or e-learning formats. Online independent learning modules are certainly considered more innovative [12,21,22] than printed textbooks. These resources allow more opportunity for active learning by providing an interactive experience with a case-based or problem-based format [3]. The material in radiology lends itself particularly well to these types of multimedia materials, given the central importance of images [20]. In some instances, the imaging *necessitates* a nonstatic presentation, for example, cines in some ultrasound and cardiac MRI studies. Even with static images, interactive feedback is a helpful format in mastering learned skills like image viewing.

Ultimately a combination of these formats is probably most common and may be the most effective.

CONCLUSIONS

The movement towards integrated medical school curricula is resulting in the inclusion of clinical information increasingly early in the students' education. Given the central role of imaging in clinical medicine, radiology is being invited to contribute to students' preclinical education to an increasing degree. The selection of material and an appropriate presentation format is essential for maintaining student interest and meeting reasonable educational goals. We outline a series of guiding principles, which can help radiology educators present information in a level-appropriate manner. We have also reviewed an examples topic list culled from the well-established Alliance of Medical Student Educators in Radiology medical school curriculum, and finally, we briefly reviewed the settings in which radiology may be asked to contribute educational content.

TAKE-HOME POINTS

- Radiology is central to clinical medicine. As more clinically relevant material is incorporated into early medical school curricula, radiology is often asked, or given the opportunity, to contribute content.
- Introducing radiology early in curricula can help prepare students for a career of appropriate ordering, while also allowing students inclined towards the specialty the opportunity to fully explore their career options.
- Focusing educational content on imaging indications, an intuitive understanding of imaging modalities, and the patient experience can help maintain student interest, as well as meet the educational goals of modern medical students.

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