Title

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Journal

Academic radiology, 22(4)

ISSN

1076-6332

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Publication Date

2015-04-01

DOI

10.1016/j.acra.2014.11.005

Peer reviewed

Interpretive Versus Noninterpretive Content in Top-Selling Radiology Textbooks:

What Are We Teaching Medical Students?

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Rationale and Objectives: There are little data as to whether appropriate, cost effective, and safe ordering of imaging examinations are adequately taught in US medical school curricula. We sought to determine the proportion of noninterpretive content (such as appropriate ordering) versus interpretive content (such as reading a chest x-ray) in the top-selling medical student radiology textbooks.

Materials and Methods: We performed an online search to identify a ranked list of the six top-selling general radiology textbooks for medical students. Each textbook was reviewed including content in the text, tables, images, figures, appendices, practice questions, question explanations, and glossaries. Individual pages of text and individual images were semiquantitatively scored on a six-level scale as to the percentage of material that was interpretive versus noninterpretive. The predominant imaging modality addressed in each was also recorded. Descriptive statistical analysis was performed.

Results: All six books had more interpretive content. On average, 1.4 pages of text focused on interpretation for every one page focused on noninterpretive content. Seventeen images/figures were dedicated to interpretive skills for every one focused on noninterpretive skills. In all books, the largest proportion of text and image content was dedicated to plain films (51.2%), with computed tomography (CT) a distant second (16%). The content on radiographs (3.1:1) and CT (1.6:1) was more interpretive than not.

Conclusions: The current six top-selling medical student radiology textbooks contain a preponderance of material teaching image interpretation compared to material teaching noninterpretive skills, such as appropriate imaging examination selection, rational utilization, and patient safety.

Key Words: Medical student; radiology textbooks; interpretive content; noninterpretive content; appropriate utilization.

There is a growing emphasis in medical practice on the safe, cost effective, and appropriate ordering of radiology studies. Although this trend will reduce health care costs, it more importantly will improve patient care.

The efforts made toward improving ordering practices have largely been directed toward those already ordering imaging studies, namely practicing medical providers. Educational initiatives including the "Choosing Wisely" (1) and "Image Gently" (2) campaigns direct referring physicians to imaging options that are safer, involve lower radiation, and highlight clinical scenarios where imaging may be unnecessary. Additionally, the American College of Radiology (ACR) "Appropriateness Criteria" is available as a free, evidence-based, online resource designed to help ordering physicians choose the best imaging examination (3). These resources add transparency and are highly educational but are underused by students. One recent single-institution study that found the vast majority of senior medical students (96%) were not previously aware of the ACR Appropriateness Criteria; however, once introduced, almost all students found the resource useful (94%) and planned to use it in clinical practice (89%) (4). Undergraduate medical educators have also been quick to point out that teaching good imaging practices early on is far more effective than correcting ordering habits after they have formed (5).

Unfortunately, there are several obstacles that limit our ability to teach medical students about appropriate imaging examination utilization. First, there is very limited formal radiology content built into US medical school curricula (5). For example, the Liaison Committee on Medical Education states that "Educational opportunities must be available … in the disciplines that support general medical practice

Acad Radiol 2015; 22:520–526

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http://dx.doi.org/10.1016/j.acra.2014.11.005

(eg, diagnostic imaging …)" (6). Additionally, many medical student radiology courses across the country focus more on interpretive skills than on appropriate utilization and safety. One of the most common formats for "educational opportunities" in radiology are the fourth-year elective clerkships in the reading room where students may spend most of the day observing case interpretation (5,7).

The vast majority of medical students will go into fields other than radiology (8) and will not be interpreting imaging examinations on their own. To train the next generation of referring providers, undergraduate medical curricula must not only include "sufficient" imaging educational content but must also include the "right" educational content. That educational content should emphasize the appropriate, safe, rational, and cost-effective ordering of imaging studies as part of the overall diagnostic workup of patients (5,9,10).

Surveys regarding the amount of radiology content offered in modern curricula have already been published (5). Published data on the proportions of interpretive versus utilization-focused (or "noninterpretive") material, however, are lacking. Although quantitatively evaluating the full 4-year curricula at all US medical schools would prove quite challenging, popular textbooks offer us a window into the educational content currently being offered. Textbooks are often the backbone of radiology courses, and in some cases, act as supplements voluntarily selected by the students themselves. We, therefore, sought to rigorously evaluate and quantify the proportion of interpretive versus noninterpretive content in the top-selling medical student radiology textbooks. Our hypothesis was that a large majority of textbook content would be focused on interpretive skills.

MATERIALS AND METHODS

Textbook Selection

To identify the most popular general radiology textbooks currently offered for medical student use, we performed an online search at the single largest book retailer in the United States, Amazon.com (11,12). The search was conducted in the medical books category, using the terms "medical student, radiology." Both hardcopy and digital books were included. Of the titles generated, only the following were included: 1) general radiology textbooks (subspecialty specific texts on topics such as "chest radiology" and anatomy atlases were excluded), 2) books published after 2000 (most recent edition), and 3) books described as being appropriate for medical student use in the online description.

The books identified by the aforementioned search and inclusion/exclusion criteria were sorted by sales rank. Amazon.com sales ranks update hourly, and there are no published summary or cumulative sales ranks for individual book titles available to the public through Amazon or any other nonindustry source (13). To determine the constancy of these rankings, the hourly sales ranks were tracked twice a day for a 2-week period in January 2014.

We identified a ranked list of top-selling general radiology textbooks using the aforementioned criteria. We intended to review between five and 10 textbooks at the study onset, depending on the results of the rank list. Over the 2-week period of sales tracking, none of the top six books dropped out of the top six sales ranking spots, although there was some movement within the top six spots. Books ranked seventh and below did not maintain a consistent sales rank position over the 2-week period. Therefore, the top-selling six books were selected for this analysis. To focus on content offered by radiology resources as a whole (rather than critique-specific textbooks), the titles will remain blinded in this article.

Data Extraction

All textbooks were reviewed by a single author (—). All text, tables, images, figures, appendices, practice questions, question explanations, and glossaries were analyzed. Table of contents, indexes, prefaces, bibliographies, and suggested reading lists were not analyzed. Text and image content were evaluated separately. Four textbooks were evaluated in hardcopy format, and two were evaluated as e-books (a popular and less-expensive format available through our university library).

Interpretive Versus Noninterpretive Text

"Text content" was defined as any material in the main text, tables, appendices, practice questions, review questions, question answers, and glossaries.

We initially considered evaluating the text content in each book on a per-page basis. However, there was tremendous variability of text density among the different pages in any individual book and between the different hardcopy books; also, there was no universal formatting for page breaks in the digital books. Therefore, before beginning the analysis, we determined that the average hardcopy textbook page in our cohort contained four paragraphs of text; so, we therefore evaluated all paper and electronic textbook text in four paragraph blocks, which we referred to as "pages" for the sake of simplicity and convention. Twelve lines of material in tables were counted as one paragraph, as did one review question with its answer choices (conversions that were determined by comparing the length of tables, questions, and paragraphs in our hardcopy textbooks).

Individual "pages" of text were semiquantitatively scored as to the percentage of the material that was interpretive versus noninterpretive. Each page was scored on the following scale:

1) <5% or less discussion of interpretive skills
2) 5%–24%
3) 25%–49%
4) 50%–74%
5) 75%–94%
6) 95%–100% discussion of interpretive skills.

To sum the total number of "pages" of interpretive versus noninterpretive content throughout a book, each "page" was multiplied by the midvalue in the score range. So one page scored as 5%–24% interpretive (midvalue = 14.5%) was considered to be 0.145 pages interpretive and 0.855 pages noninterpretive. All the interpretive and noninterpretive page fractions were then added together to determine the total number of "pages" of interpretive and noninterpretive content.

Interpretive text was defined as follows: 1) any discussion of imaging findings, 2) the differential for an imaging finding, 3) how to review/alter/view images to make a diagnosis, 4) how to evaluate quality of images, and 5) questions asking the reader to make a diagnosis based solely on an imaging finding. Aspects of protocoling were also considered interpretive, if they contained a level of detail that would only be relevant to a radiologist, such as a specific time delay after contrast injection.

Noninterpretive text was, by default, all other content. For the sake of explicitness, however, we defined this category as follows: 1) any discussions of anatomy, 2) pathophysiology, 3) clinical symptoms, 4) indications for imaging, 5) use of imaging to guide clinical management, and 6) basic descriptions of how each modality works. Although detailed discussions of protocoling were considered interpretive as previously described, tips for ordering the correct protocol or a discussion of what type of protocol is needed to make a diagnosis (information relevant to an ordering provider) was considered noninterpretive.

Interpretive Versus Noninterpretive Image Content

Images and figures were evaluated as discrete units. Although paper books can have large and small images, e-books tend to have equal-sized images, usually presented as thumbnails that can be enlarged. Analyzing image content across all six books on a per-image basis was considered most reasonable and relevant.

Images were also initially evaluated on a six-level scale as to their interpretive versus noninterpretive content, although only nine of 3195 images (<0.3%) were considered to have both types of content in the image and/or caption. Therefore, we herein reported all images as being 100% interpretive or 100% noninterpretive.

Interpretive images and figures were defined as follows: 1) images demonstrating findings or where the caption discusses a differential, 2) images describing how to determine normal anatomy in a given imaging modality or how to determine quality of image and factors that affect quality, 3) images demonstrating pathology, 4) diagrams of imaging findings or drawings meant to represent imaging findings, and 5) images of how to place patients in imaging equipment if provided in detail that would only be relevant to a radiologist.

Noninterpretive images and figures were, by default, all other imaging content. For the sake of explicitness, however, we defined this category as follows: 1) anatomy figures not intended to guide film interpretation, 2) images of pathology slides, 3) diagrams depicting pathophysiology of a disease, and 4) images of equipment or patients to demonstrate the basics of how images are produced.

Subject Matter

Each text "page" and each image were also scored as to the predominant subject matter addressed. Categories considered included the following: 1) x-rays (including discussions of fluoroscopy and angiography), 2) computed tomography (CT), 3) magnetic resonance (MR), 4) nuclear medicine, 5) ultrasound, 6) "multiple modalities" (when there was no predominant modality discussed on an individual page), and 7) "other" (when no particular imaging modality was addressed, such as disease pathology or anatomy). The number of text "pages" for each category was summed and the proportion of each content type was calculated. The same calculation was performed for the image content. The percentages of text- and image-based content for each category (ie, CT) were then averaged for the entire sample of textbooks as a whole. Subsequently, the text pages and images regarding each content type were cross-referenced to the interpretive versus noninterpretive score for each page and image, to determine the proportion of each content type that was either interpretive or noninterpretive.

Statistical Analysis

Descriptive statistics, including ratios and proportions, were calculated using the Stata software package, version 12.0 (Stata Corporation, College Station, TX).

RESULTS

In total, 1931.75 pages of text and 3195 individual images were evaluated between the four hardcopy and two digital books. The data from individual books are presented in no specific order and without identifiers, given that our intent was to evaluate the content available as a whole, rather than assess specific individual texts.

Interpretive Versus Noninterpretive Text and Images

The books on average had more interpretive text than noninterpretive text (1.4:1; Table 1). Five of the books had more interpretive text than noninterpretive text (ranging from 1.5:1 to 1.9:1), and one book had less (0.9:1). In all books, the vast majority of the images were interpretive (17:1; Table 2).

Subject Matter

In all six books, the largest proportion of text and image content was dedicated to plain film radiographs (51.2%), with CT

TABLE 1. Summed Number of Book "Pages" Containing Interpretive Versus Noninterpretive Content

Textbook	Interpretive Text Content (Pages)	Noninterpretive Text Content (Pages)	Ratio of Interpretive to Noninterpretive Content
Book 1	271.5	157.5	1.7:1
Book 2	56.5	29.0	1.9:1
Book 3	129.0	83.0	1.6:1
Book 4	279.0	184.5	1.5:1
Book 5	202.5	127.0	1.6:1
Book 6	189.5	223.0	0.9:1
Total	1128.0	804.0	1.4:1

TABLE 2. Summed Number of Images and Figures Depicting Interpretive Versus Noninterpretive Content

Textbook	Interpretive Image Content (No. of Images)	Noninterpretive Image Content (No. of Images)	Ratio of Interpretive to Noninterpretive Content
Book 1	505	7	72:1
Book 2	166	28	6:1
Book 3	548	10	55:1
Book 4	831	116	7:1
Book 5	806	17	47:1
Book 6	156	5	31:1
Total	3012	183	17:1

a distant second (16%; Table 3). Relatively little content was dedicated to MR, ultrasound, and nuclear medicine (together 10.3%). The text content on radiographs (3.1:1) and CT (1.6:1) was more interpretive in nature. The MR, ultrasound, and nuclear medicine content were all slightly more noninterpretive in focus (0.7:1, 0.7:1, and 0.3:1, respectively). The image-based content remained heavily skewed toward interpretation across all modalities.

DISCUSSION

More than 5000 discrete images and blocks of text were individually evaluated in the six most frequently purchased medical student radiology textbooks. We rigorously evaluated the amount of interpretive versus noninterpretive content contained within each of these resources both individually and together. When considering text and figure content together, our results showed that all six textbooks were weighted toward teaching medical students interpretive content over noninterpretive content.

Although textbooks and educational curricula focusing on interpretation of imaging studies are foundational to teaching radiology residents, it remains unclear how much of this material is appropriate for general medical students. According to recent National Resident Matching Program (NRMP) data, fewer than 5% of graduating US medical students pursue careers in radiology (8). Particularly as radiology struggles to maintain (or grow) the limited amount of teaching time we have in modern curricula, a focus on appropriate utilization may be more useful for the majority of students who will not be pursuing radiology as a career. A clear and sophisticated understanding of which imaging tests are most appropriate (4) and safest (14) under a variety of clinical circumstances is among the most valuable information we can convey to benefit the largest number of students.

Although teaching noninterpretive skills is clearly important, radiology curricula in medical school still often disproportionally emphasize film interpretation, likely for the following reasons:

1) It is the format of most pre-existing educational materials and lectures
2) It is the format of most commercially available radiology educational resources (most intended for training residents and practicing radiologists)
3) It is the way we, as radiologists, are used to teaching radiology (to residents), and it is the way we were taught
4) Interpretive skills are a form of "problem solving," which is intellectually attractive.

Certainly, some limited "familiarity" with how radiologists read cases is necessary for all doctors, much like all doctors have seen surgeons perform operations and have looked through a microscope alongside a pathologist. However, there are dangers with overemphasizing image interpretation skills as a medical student skill set. Such an approach can instill a false sense of competence, particularly if they achieve some success by correctly identifying obvious abnormalities on specifically selected films. In some studies, >50% of family physicians take their own x-rays, yet when overread by radiologists, discordance rates of >12% are noted (15,16). When considering that the majority of x-rays in a family practice setting will be normal, this discordance rate probably underestimates the true incompetence.

Of the interpretive content, the subject matter most relevant to nonradiologists is probably plain film, because physicians will often make basic preliminary assessments using this modality (eg, line placements, feeding tube placements, and fluid status) (17–19). Furthermore, students are eager to gain this type of skill set (18). Our study demonstrated that the largest percentage of the interpretive content was indeed focused on plains films. In fact, within our textbook cohort, far more emphasis was placed on plain film interpretation than teaching of any other aspect of radiology. Although we agree that teaching basic plain film interpretation skills is important (and these skills are better taught by radiologists than nonimaging experts on the wards), when any basic interpretation is taught, it is our opinion that students must be made aware of their limitations (20,21). Even simple interpretive content appropriate for students (ie, line placements on chest x-ray) should be presented with a wide

TABLE 3. Percentage of Book Pages Dedicated to Radiologic Modalities

	X-Rays (%)	CT (%)	MR (%)	US (%)	Nuc Med (%)	Multiple (%)	Other (%)
Book 1	50.8	15.3	4.7	5.3	0.3	18.3	5.4
Book 2	73.9	12.7	0	0	0	0.7	12.8
Book 3	54.9	6.7	2.2	3.1	1.2	21.5	10.3
Book 4	45.8	17.3	4.8	6.7	2.6	15.8	7.0
Book 5	42.3	17.1	13.2	2.3	1.9	21.5	4.2
Book 6	39.6	27.0	8.8	3.6	1.1	14.6	5.3
Mean	51.2	16.0	5.6	3.5	1.2	15.4	7.5

CT, computed tomography; MR, magnetic resonance; Nuc Med, nuclear medicine; US, ultrasound.
Percentage represents the combined average of both text and image content.

range of examples that include findings both within and beyond their abilities, and highlight circumstances which would require a radiologist's help.

If interpretation is made to seem easy, it devalues the role and extensive training of radiologists. If 4+ years of dedicated imaging training followed by a rigorous certification is in the best interests of patients, why are we teaching students to do what we do without that level of training and certification? How will students look to radiologists as skilled consultants, if our job is overly simplified in introductory textbooks and they are subsequently encouraged to interpret films on their own?

CT was the second most commonly presented modality, and again, the majority of the content was geared toward teaching students how to interpret the studies. There is actually little need for nonradiologists to interpret CT scans independently, and there are likewise little data to suggest they are able to do so successfully even after advanced training in their fields (22,23). However, CT is one of the most commonly "ordered" imaging examinations in the United States with >76 million scans performed in 2013 (24). It is associated with more risks than many imaging examinations because of the involved radiation, and in some cases, intravenous contrast administration. And, it is well known that practicing physicians and trainees routinely order CT scan inappropriately. One study that attempted to quantify the incidence of inappropriate ordering retrospectively analyzed CT scans ordered by primary care physicians and found that 27% of all CT scans were performed for inappropriate indications according to the ACR Appropriateness Criteria guidelines (25). Given our limited time in modern medical curricula, can we afford to teach students the CT appearance of a specific liver tumor when so few practicing physicians understand when they should order a CT?

Of note, a surprisingly small amount of content in the textbooks addressed some other advanced imaging modalities, including MR, ultrasound, and nuclear medicine studies. Although it is likely appropriate to de-emphasize any interpretive information regarding these modalities, students and ordering physicians do need to be familiar with these examinations and the spectrum of indications and contraindications. Although the limited content on these subject areas was indeed slightly skewed toward noninterpretive skills, the overall proportion of information was very small, especially compared to the relatively very large amount of material focused on plain film and CT interpretation. Perhaps, the pervasive lack of understanding of these advanced modalities is at least partially attributable to insufficient information in our medical student curricula and textbooks.

When improper utilization of imaging does occur, it results in inefficient resource allocation, wasted medical dollars without net benefit, needless risks to patients (including radiation exposure and contrast administration), and poor physician productivity (hours lost correcting errors triggered by incorrect examination ordering). The extent of this problem has been well documented, and some technology-based solutions are being developed, including physician order entry programs for imaging studies with integrated clinical decision support systems (26,27). However, despite any evolving improvements to our ordering and technological support systems, it is still crucial that referring physicians understand the basics of optimal examination utilization and ordering. Stressing the importance of education, Naeger et al. (28) wrote "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."

Further development of resources, either textbook or other formats, which support this type of practical noninterpretive learning would no doubt help educators better incorporate this content into their curricula. A better balance can likely be achieved between teaching the interpretive skills that students and clerkship directors desire and teaching these other critical skill sets relevant for ordering providers. Some digital resources for medical students such as the "Core Radiology Course" (29) do emphasize examination selection and appropriateness in addition to the basic interpretive skills. However, there are overall few resources geared toward teaching noninterpretive skills to medical students leaving individual institutions in many instances to create materials on their own to address important topics such as radiation safety and contrast safety.

As medical schools across the country continue to overhaul their curricula, radiologists have an excellent opportunity to become more involved in medical student education. In a recent national survey of Radiology Department Chairs and Medical School Deans, there was a broad call for

developing and distributing a nationally recognized imaging curriculum with widely distributed resources that emphasize material about imaging safety, appropriateness, and utilization (5). Thus, stressing these noninterpretive skills can help persuade medical school leadership to include more radiology content in medical school curricula as a path to optimizing patient outcomes. As we consider curricular revisions, we also need to collectively examine what environment and circumstances are ideal to most effectively convey these concepts. Reading room electives are valuable to students interested in pursuing radiology as a career given the exposure to daily practice patterns; however, they are "not nearly" as high yield for teaching future ordering providers (7). Information about proper utilization can often be taught more effectively in a classroom or small group setting, which makes it well suited for vertical integration throughout a 4-year curriculum, another innovation desired by a majority of medical school deans (5). However, regardless of where in a curriculum this content is taught, it is critical that it is presented by imaging experts and not limited to anecdotal experiences on the wards.

Our study has several limitations. Most notably, we selected the textbook sample using sales statistics from the single largest US bookseller, rather than all booksellers. Cumulative US sales statistics are not available to the public, however. Furthermore, the way in which these books are used may not accurately reflect curricula, an implication we have made. Some books may be used as a self-study aid or ordered by nonstudents. Even when textbooks are assigned, they may not reflect modifications implemented by a course director. Additionally, many course directors or supervising physicians on service may not assign textbooks at all, or even if they do, students may not use them. Although we considered surveying radiology course directors about their individual curricula, self reporting of an estimated percentage of interpretive versus noninterpretive content would be highly subjective, and there was no way to perform a more rigorous and reliable "scored" review of such diffuse materials across the country. Another factor, textbook authors and textbook publishers may have intentionally skewed content toward interpretation to broaden the books appeal, beyond students, to junior residents. In fact, none of the book titles specifically referenced "medical students," likely reflective of such marketing considerations. Despite these limitations, the content within these textbooks, written by esteemed radiologist educators and marketed to medical students online, can be assumed to be at least partially reflective of what is presently being taught. Finally, the textbooks were only reviewed by a single reader (who was unblinded to the study hypothesis). Any content deemed difficult to categorize was addressed by consensus amongst three authors, and the majority of the scoring was noncontroversial. This high-volume review required several months time. Given the straightforward nature of most of the scoring, double scoring did not seem justified.

In summary, we found that the top-selling medical student radiology textbooks contained a clear preferential focus on material teaching image interpretation over noninterpretive skills, such as appropriate and rational imaging examination selection, utilization, and patient safety. Until we have nationally recognized imaging curriculum that emphasizes information relevant to future ordering providers, our findings underscore the importance of including alternate sources of this critical information in medical school curricula.

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