Book Review
Radiological Physics Taught Through Cases

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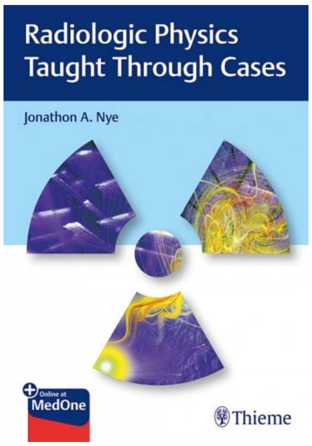

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Published in 2020 by Thieme Publishers New York, this book provides a novel approach to exposing diagnostic radiology residents to physics of radiology in 154 pages with 231 illustrations. It should be noted that the expected audience for this book are radiologists-in-training and not necessarily physics or medical physics students. This book is organized in 7 chapters, authored by different physicists, and each chapter is subdivided into 10 sections followed by some review questions in section 11 of each chapter. In the preface, Professor Nye correctly asserts that the many approaches used to teach physics of radiology to residents often fall short of covering the fundamental physics necessary to teach the physics of the different modalities in sufficient detail. As such, the typical once or twice a month lectures each concentrating on a different modality, cram a tour-de-force presentation of the factors responsible for image creation and display, without really concentrating on interpreting images. This book adopts an example-based approach, primarily focusing on artifacts observed in images and explaining their causes. They provide references to guide the reader to texts where the physics and mathematics of image formation are discussed. Each section starts with a case presented, followed by the findings, a discussion of the findings, and the section is concluded by a summary (referred to as "Resolution.")

In this review, we will look at each chapter, give a summative narrative of the coverage keeping the intended audience in mind, and share a few important topics, which might find their way into the next edition of this book. We have extensive teaching experience and draw upon our own experiences both in teaching and practice.

Chapter 1: Fluoroscopy by Rebecca Milman Marsh and Michael Silosky.
Fluoroscopy with its uses in IRs, Cath Labs, portable C-arms and O-arms, CT Fluoroscopy, Digital Subtraction Angiography (DSA), Cone Beam Tomography and some combinations of these procedures have become an ever more present modality of X-ray imaging in hospitals and operating rooms. While the cases presented here deal with different fluoroscopy modalities, the underlying theme is a comparative evaluation of the dose -- Peak Skin Dose (PSD), Dose Area Product (DAP), Kerma Area Product (KAP), Dose Length Product (DLP) -- in the different fluoroscopy procedures (DSA, CINE, HDR Fluoroscopy, CBCT, etc). In one case, they show how motion artifact can render DSA images less useful. They share cautionary remarks on use of lead shielding, anti-scatter grids, and high dose rate image acquisition modalities.

The approach is highly engaging and keeps the audience's attention. A section on strategies to reduce dose to the physicians and staff, a discussion of frames per second and pulses per second, dose rate versus field size, and proper uses of low dose and high dose rate modes could be useful.

Chapter 2: Mammography by Ingrid S. Reiser.
With the refinement of digital detector technologies, mammography has made significant advances. Dr. Reiser describes this modality as the unique modality that is "dedicated to and optimized for a single anatomy." This chapter primarily deals with presenting cases where artifacts are seen due to patient positioning, patient motion, detector or detector-row dropout, other detector artifacts showing as micro-calcifications, imperfection in compression paddles, and other artifacts due to presence of heart-assist devices. There is also a section on the selection of technique factors in light of patient thickness to reduce Average Glandular Dose (AGD) and optimize image contrast.

While the emphasis on artifacts in mammograms cannot be overstated, it would have been nice to add a section discussing typical dose levels in mammography, resolution and low-contrast detectability levels, statistics on specificity (False-Positive and True-Negative), and perhaps a whole section on tomosynthesis would be helpful. The latter is clearly a lead-in to the next chapter.

Chapter 3: Computed Tomography by Karen L. Brown and Jason R. Gold.
Computed tomography calculates the attenuation coefficient μ of each voxel in a patient relative to that of water, μ_w. The CT number of each pixel in Hounsfield unit is defined as CT # (HU) = 1000 x (μ - μ_w) /μ_w. This number associated to each pixel in the image provides a gray level that is adjusted by the window width and level on the monitor. In this chapter the authors describe the ring, beam hardening, partial volume, and metal and motion artifacts and provide typical images showing these artifacts. In addition, in treating dose in CT (CT Dose Index ($CTDI_{vol}$)) and Dose-Length Product (DLP)) they provide a nice discussion of the effect of kV on image quality and dose, relationship of $CTDI_{vol}$ and patient size, and image quality variation with slice thickness and reconstruction filter.

While the discussion is quite complete, a brief discussion of the geometry of CT machines, helical versus axial reconstruction methods, and a brief discussion of dual energy CT units can be added.

Chapter 4: Magnetic Resonance Imaging by Puneet Sharma.
Magnetic Resonance imaging is a (relatively) newer mode of imaging that is revolutionizing diagnostic radiology due to its ability to provide unparalleled contrast between different tissue types. With the rapid development of new reception technologies, pulse-echo sequences and pre- and post-processing techniques leading to better signal-to-noise ratio and reduced scanning times, this modality will largely replace many other radiographic exams. The artifacts demonstrated in the case-by-case studies here include motion artifacts (ghosting), high signal intensity artifact leading to "pile-up" affecting visualization of surrounding structures, aliasing leading to extra anatomy superimposed on the primary anatomy, edge ripple (Gibbs phenomenon) that can be "presumed to be motion" artifacts, chemical shift artifact leading to dark etching between soft tissue and fat interfaces, effect of field inhomogeneity or poor shimming within FOV on fat suppression protocols, signal-to-noise variation in FOV and flow-related contrast issues.

While there is a masterful choice of artifacts demonstrated here, the complicated discussion of pulse-echo sequences, k-space filling of signals, T1, T2, T2* and proton density weightings, frequency and phase encoding, and discrete Fourier transform cut-off leading to aliasing artifacts will certainly leave the audience gasping for air. With the prevalence of contrast studies, chemical shifts, spin echo versus gradient echo sequences, some additional comments on their specific uses could direct the reader to further sources.

Chapter 5: Nuclear Medicine by Jonathon A. Nye, James R. Galt and John N. Aarsvold.
Nuclear medicine differs from other modes of radiology in that planar projections and tomographic images are constructed from radionuclides administered to patients. Data collection is "photon starved" leading to substantially lower signal to noise ratio, grainy images, and considerations such as geometry, energy gating, collimation, detector inhomogeneity and many other factors leading to degradation of image contrast and spatial resolution. Due to the above factors many forms of artifacts may arise here. The authors demonstrate artifacts due to geometry, positron range in FDG imaging (PET), patient motion, attenuation correction errors, images formed from incorrect choice of collimators, poor camera positioning relative to the patient, and improper reconstruction parameters and energy discrimination. There are also two sections outlining how parallel processing is used and how smoothing is used to improve contrast through a reduction in statistical noise.

The choice of artifacts here are comprehensive and include 2D and 3D nuclear medicine imaging including gamma cameras (single-head and multi-head), SPECT and PET cameras. The discussion of data acquisition and image formation are quite brief. A discussion of dose and data acquisition time may be useful in rationalizing the question of data starvation. Some discussion of typical expected resolution could also be helpful.

Chapter 6: Ultrasound Imaging by Zheng Feng Lu.
Due to its low cost and safety, ultrasound imaging is used extensively in radiology. In this section the author summarizes the myriad of issues that can lead to artifacts or incorrect measurements of distances in B-mode ultrasound images. These are errors arising from a "constant speed of sound" assumption, artifacts due to transducer element dropout, effect of controls (transmit power, gain, time gain compensation, dynamic range) on appearance of images, reverberation artifacts, range ambiguity and shadowing, and doppler imaging aliasing. The author also adds a brief section on harmonic imaging and its advantages and differences in the appearance of images based on monitor luminance.

The discussion here is quite complete. If we had to add something, we would provide some quantitative information and how the artifacts could degrade that information. Some of this could include a brief discussion of signal-to-noise, typical tissue attenuation coefficients as a function of frequency, resolution versus depth, low contrast detectability and acceptable levels of screen luminance.

Chapter 7: Image Processing by Jonathon A. Nye and Randahl C. Palmer.
In this chapter, which departs both in format and intent from the other chapters, the authors discuss a few image processing techniques used to either highlight specific features in images (edge filters, bandpass filters, maximum intensity projection for PET), and a few multi-modalities

(fused imaging) to enhance specificity and sensitivity to specific features/pathologies.

In conclusion, this book presents a novel and highly useful model to excite radiologists-in-training to caveats of different modalities of diagnostic imaging and to alert them to artifacts that may arise and their causes. The discussion is tailored to cover the most important issues in a very limited time, perhaps at the cost of covering more physics, instrumentation, image acquisition and formation concepts. The list of 20 or so review questions at the end of each section is a wonderful resource for both the teachers and students. We definitely recommend this text for teaching the residents in diagnostic radiology.

P.S. As a final remark, we would like to add that like most fields, radiological physics has become full of acronyms. The author(s) are well-served by posting a page online or adding an index of acronyms to each chapter (or to the entire book) to identify these acronyms and make the task of the reader browsing through the book easier.

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