RADIOGRAPHY IN THE DIGITAL AGE

RADIOGRAPHY IN THE DIGITAL AGE

Physics—Exposure—Radiation Biology

By

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Dedication

To Jason and Stephanie,
Melissa and Tim,
Chad and Sarah,
Tiffani and Nate,
Brandon, and Tyson,
a most remarkable family,
and to my cherished wife, Margaret,
who made it possible for them all
to come into my life.

PREFACE

The advent of digital radiographic imaging has radically changed many paradigms in radiography education. In order to bring the material we present completely up-to-date, and in the final analysis to fully serve our students, much more is needed than simply adding two or three chapters on digital imaging to our textbooks.

First, the entire emphasis of the *foundational* physics our students learn must be adjusted in order to properly support the specific information on digital imaging that will follow. For example, a better basic understanding of waves, frequency, amplitude and interference is needed so that students can later grasp the concepts of spatial frequency processing to enhance image sharpness. A more thorough coverage of the basic construction and interpretation of graphs prepares the student for histograms and look-up tables. Lasers are also more thoroughly discussed here, since they have not only medical applications, but are such an integral part of computer technology and optical disc storage.

Second, there has been a paradigm shift in our use of image terminology. Perhaps the most disconcerting example is that we can no longer describe the direct effects of kVp upon image contrast; rather, we can only describe the effects of kVp upon the subject contrast in the remnant beam signal reaching the image detector, a signal whose contrast will then be drastically manipulated by digital processing techniques. Considerable confusion continues to surround the subject of scatter radiation and its effects on the imaging chain. Great care is needed in choosing appropriate terminology, accurate descriptions and lucid illustrations for this material.

The elimination of much obsolete and extraneous material is long overdue. Our students need to know the electrical physics which directly bear upon the production of x-rays in the x-ray tube—they do not need to solve parallel and series circuit problems in their daily practice of radiography, nor do they need to be spending time solving problems on velocity.

A large amount of new information on digital processing is being introduced into our curriculum. Room must be made for this critical material, and since it has been some time since the fields of CT and MRI have established their own certification exams, these are appropriate chapters to eliminate. We *do* want our graduates to be able to answer basic questions from patients about *any* of the specialized imaging fields. In this textbook, this information is embedded within chapters where it fits perfectly—MRI is briefly overviewed when *radio* waves are discussed under basic physics, sonography is also discussed under the general heading of *waves*, and CT is described along with attenuation coefficients under digital imaging.

It is time to bring our teaching of image display systems up to date by presenting the basics of LCD screens and the basics of quality control for electronic images. These have been addressed in this work, as part of *eleven full chapters* dealing specifically with digital and electronic imaging concepts.

If you agree with this educational philosophy, you will find this textbook of great use. The basic layout is as follows: In Part I, *The Physics of Radiography*, ten chapters are devoted to laying a firm foundation of math and basic physics skills. The descriptions of atomic structure and bonding go into a little more depth than previous textbooks have done. A focus is maintained on *energy* physics rather than mechanical physics. The nature of electromagnetic waves is more carefully and thoroughly discussed than most textbooks provide. Chapters on electricity are limited to only those concepts which bear directly upon the production of x-rays in the x-ray tube.

Part 2, *Production of the Radiographic Image*, presents a full discussion of the x-ray beam and its interactions within the patient, the production and characteristics of subject contrast within the remnant beam, and the proper use of radiographic technique. This is conventional information, but the terminology and descriptions used have been adapted with great care to the digital environment. Part 3, *Digital Radiography*, includes eight chapters covering the physics of digital image capture, extensive information on digital processing techniques, and the practical application issues of both CR and DR.

Part 4, *Special Imaging Methods*, includes chapters on mobile radiography, digital fluoroscopy and an extensive chapter on quality control which includes the electronic digital image. Finally, Part 5 consists of five chapters on *Radiation Biology and Protection*, including an unflinching look at current issues and practical applications.

For a textbook to retain enduring value and usefulness, professional feedback is always needed. I invite colleagues who have adopted the text to provide continuing input so that improvements might be made in the accuracy of the information as well as the presentation of the material. My personal contact information is available in the *Instructor and Laboratory Manual* on disc.

The *Instructor and Laboratory Manual* includes the answer key for all chapter review questions and a bank of over 1450 multiple choice questions for instructors' use. It also includes laboratory exercises, including 14 that demonstrate the applications of CR equipment for use in class. The manual is available only on disc from Charles C Thomas Publisher, Ltd.

This is intended to be a textbook written "by technologists for technologists," with proper focus and scope for the practice of radiography in this digital age. It is sincerely hoped that it will make a substantial contribution not only to the practice of radiography and to patient care, but to the satisfaction and fulfillment of radiographers in their career as well.

Q.B.C.

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Some material was adopted and adapted from contributing authors to my textbook, *Practical Radiographic Imaging*, (previously *Fuchs's Radiographic Exposure, Processing and Quality Control*). They include Robert DeAngelis, BSRT in Rutland, Vermont, Robert Parelli, MA, RT(R) in Cypress, California, and Euclid Seeram, RTR, MSc, in Burnaby, British Columbia, Canada. Their contributions are still greatly valued.

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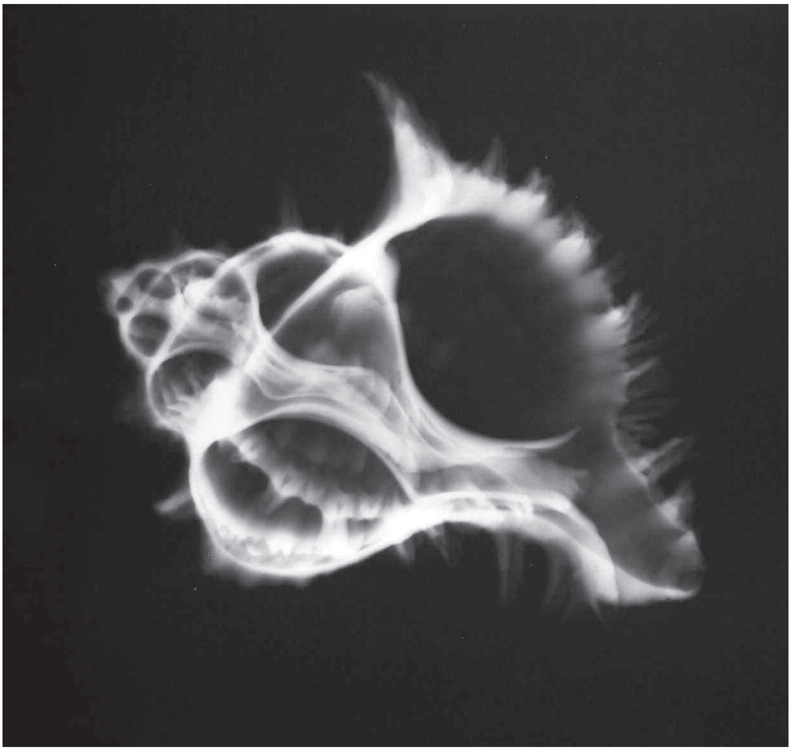
RADIOGRAPHY IN THE DIGITAL AGE

Part I

THE PHYSICS OF RADIOGRAPHY



Radiograph of a conch seashell.

Chapter 1

INTRODUCTION TO RADIOGRAPHIC SCIENCE

THE SCIENTIFIC APPROACH

Radiography is a branch of the modern *science* of medicine. Science is objective, observable, demonstrable knowledge. Try to imagine your doctor engaging in practices that were not grounded in scientific knowledge! What is it that sets science apart from art, philosophy, religion and other human endeavors? There are actually several foundational principles to scientific method. It is worthwhile to give a brief overview of them. They include:

Parsimony: The attempt to simplify concepts and formulas, to economize explanations; the philosophy that simple explanations are more likely to be true than elaborate, complex ones.

Reproducibility: The requirement that proofs (experiments) can be duplicated by different people at different times and in different locations with precisely the same results.

Falsifiability: The requirement that any theory or hypothesis can logically and logistically be proven *false*. Anything that cannot be proven false is not science, but belongs in another realm of human experience.

Observation: The requirement that experiments and their results can be directly observed with the human senses.

Measurability: The requirement that results can be quantified mathematically and measured.

As a fun practice exercise, consider the following three statements. Which one is scientific?

1. *The moon is made of green cheese.*
2. *Intelligent life likely exists elsewhere in the universe.*
3. *Albert Einstein was the greatest physicist in the twentieth century.*

The most scientific statement is No. 1. Even though it may not be a true statement, it is nonetheless a statement that can be (and has been) proven false with modern travel technology, it is simple, and experiments proving that moon rocks do not consist of green cheese can be reproduced by anyone, anywhere on earth with the same, observable, measurable results. Statement No. 2 may be true or false, but *cannot be proven false*, because to do so would require us to explore every planet in the entire universe, documenting that we have looked in every crevice and under every rock. It may be classified as a philosophical statement, but not as a scientific one. Statement No. 3 is, of course, a simple matter of personal opinion that depends upon how one defines the word "greatest." It is a historical statement that defies standardized measurement or observation.

Perhaps the strongest aspect of the scientific method is that when it is used properly, it is *self-correcting*. That is, when a theory is found to be wrong, that field of science is expected to be capable of transcending all politics, prejudice, tradition and financial gain in order to establish the new truth that will replace it. Sometimes this process is painful to the scientific community, and it has been known to take years to complete. But, at least it presupposes a collective willingness to accept the *possibility* that a previous position may have been wrong, something one rarely sees in nonscientific endeavors.

This principle of *self-correction* is nicely illustrated in the story of Henri Becquerel and the discovery of natural radioactivity, related in the next section. Also demonstrated in both his story and that of Wilhelm Roentgen, the discoverer of x-rays, is the fact that many scientific truths are discovered by accident. Nonetheless, it is *because* scientific method is being followed, not in spite of it, that they have occurred, and *through* scientific method that they come to be fully understood.

How does this scientific approach apply to radiography, specifically? Even though some aspects of radiography, such as positioning, are sometimes thought of as an art, the end result is an image that contains a quantifiable amount of diagnostically useful details, a measurable amount of information. Image qualities such as contrast, brightness, noise, sharpness and distortion can all be mathematically measured. Even the usefulness of different approaches to positioning are subject to measurement through repeat rate analysis. In choosing good radiographic practices, rather than relying on the subjective assertion from a cohort that, "It works for me," important matters can be objectively resolved by simply monitoring the repeats taken by those using the method compared to those using another method. By using good sampling (several radiographers using one method and several using another over a period of weeks), reliable conclusions can be drawn.

The standard of practice for all radiographers is to use good common sense, sound judgment, logical consistency and objective knowledge in providing the best possible care for their patients.

A BRIEF HISTORY OF X-RAYS

It is fascinating to note that manmade radiation was invented *before* natural radioactivity was discovered. If this seems backward, it is partly because x-rays were discovered by accident. In the late 1800s, Wilhelm Conrad Roentgen (Fig. 1-1) was conducting experiments in his laboratory at Wurzburg University in Germany. It had been discovered that a beam of electricity (glowing a beautiful blue in a darkened room) could be caused to stream across a glass tube. With strong enough voltage, the electricity could be caused to "jump" from a negatively-charged *cathode* wire across the gap toward a positively-charged *anode* plate, although most of it actually struck the glass behind. Since they were emitted from the cathode, these streams of electricity were dubbed *cathode rays*.

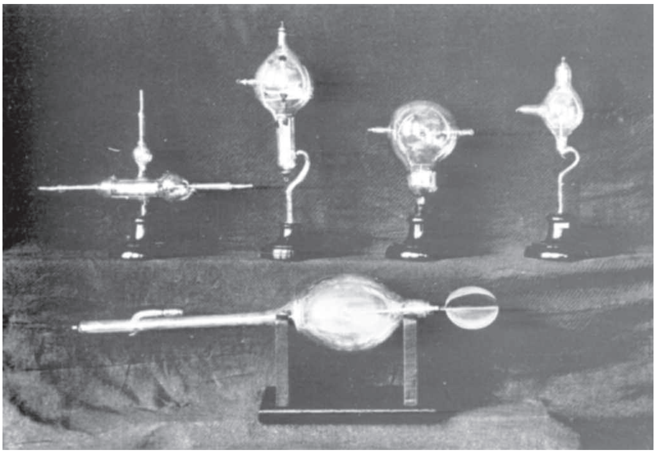
Several researchers were studying the characteristics of cathode rays. These glass tubes, known as Crookes tubes, came in many configurations. Figure 1-2 shows several that Roentgen actually used in his experiments. If most of the air was vacuumed out of the tube, the cathode rays became invisible. (It was later understood that they were in fact the electrons from the current in the cathode, far too small for the human eye to see, and that the blue glow was the effect from the ionization of the air around them.)

Other researchers had noticed that the glass at the anode end of the tube would fluoresce with a greenish glow when the cathode rays were flowing. They began experimenting with placing fluorescent materials in the path of the beam. They learned how to deflect the beam at right angles with a plate so it could exit the tube through a window of thin aluminum. In this way, cards or plates coated with different materials could simply be placed alongside the tube, in the path of the electron beam, to see how they fluoresced. Researchers learned to surround the tube with black cardboard so as to not confuse any light that might be generated within the tube with the fluorescence of the material outside the tube.

Figure 1-1

Wilhelm Conrad Roentgen, discoverer of x-rays.

Figure 1-2



Photograph of Crookes tubes employed by Roentgen in his experiments on cathode rays, which led to the discovery of x-rays. (From Quinn B. Carroll, *Practical Radiographic Imaging*, 8th ed. Springfield, IL: Charles C Thomas Publisher, Ltd., 2007. Reprinted by permission.)