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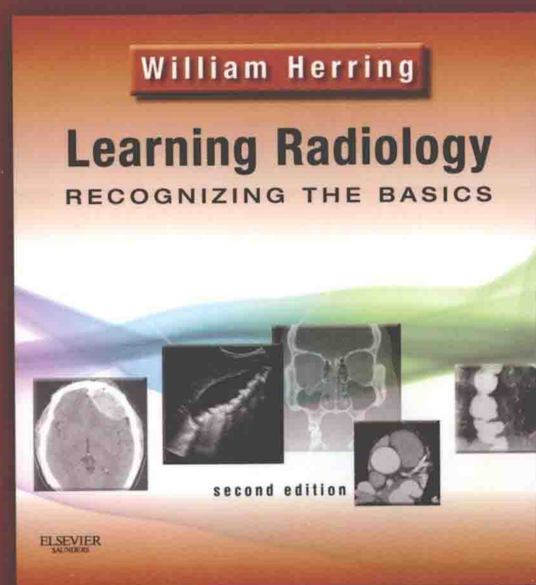
Learning Radiology

RECOGNIZING THE BASICS

影像诊断学基础教程

（第 2 版）

William Herring



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影像诊断学基础教程

（第2版）

Learning Radiology

Recognizing the Basics

（Second Edition）

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影像诊断学基础教程

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Learning Radiology

Recognizing the Basics

（Second Edition）

To my wife, Patricia,

and our family

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Chapter 20, Magnetic Resonance Imaging

Preface to the First Edition

If you're the kind of person, like I am, who reads the preface after you've read the book, I hope you enjoyed it. If you're the kind of person who reads the preface before reading the book, then you're in for a real treat.

Suppose for a moment that you wanted to know what kind of bird with a red beak just landed on your windowsill (don't ask why). You could get a book on birds that listed all of them alphabetically from albatross to woodpecker and spend time looking at hundreds of bird pictures. Or you could get a book that lists birds by the colors of their beaks and thumb through a much shorter list to find that it was a cardinal.

This is a red-beak book. Where possible, groups of diseases are first described by the way they *look* rather than by what they're *called*. Imaging diagnoses frequently, but not always, rest on a recognition of a reproducible visual picture of that abnormality. That is called the *pattern recognition approach* to identifying abnormalities, and the more experience you have and more proficient you become at looking at imaging studies, the more comfortable and confident you'll be with that approach.

Before diagnostic images can help you decide what disease the patient may have, you must first be able to differentiate between what is normal and what is not. That isn't as easy as it may sound. Recognizing the difference between normal and abnormal probably takes as much, if not more, practice than deciding what disease the person has.

In fact, it takes so much practice, some people—I believe they are called *radiologists*—have actually been known to spend their entire life doing it. You won't be a radiologist after you've completed this book, but you should be able to recognize abnormalities and interpret images better. By so doing, perhaps you can participate in the care of patients with more assurance and confidence.

In this text, you'll spend time in each section learning how to recognize what is normal so that you can differentiate between such things as a skin fold and a pneumothorax or so that you can recognize whether that fuzzy white stuff at the lung bases is pneumonia or the patient simply hasn't taken a deep breath.

Where pattern recognition doesn't work, we'll try whenever possible to give you a logical *approach* to reaching a diagnosis based on simple yet effective decision trees. These will be little decision trees—saplings with only a few branches—so that they are relatively easy to remember.

By learning an approach, you'll have a method you can apply to similar problems again and again. Have you ever heard the saying "Give a man a fish; you have fed him for today. Teach a man to fish, and you have fed him for a lifetime"? Learning an imaging approach is like learning how to fish, except a lot less smelly. An approach will enable you to apply a rational solution to diagnostic imaging problems.

This text was written, in part, to make complementary use of the medium for which radiologic images are ideally suited: the computer screen. The web is ideal for accessing and displaying images, but many people do not want to read large volumes of text from their computer screens. So we've joined the text in the printed book with photos, quizzes, and tutorials available online at StudentConsult.com in a series of *web enhancements* that accompany every chapter.

This text is not intended to be encyclopedic. There are many wonderful radiology reference texts available, some of which contain thousands of pages and weigh slightly less than a Volkswagen. This text is oriented more towards students, interns, and residents or residents-to-be.

Not every imaging modality is covered equally in this book, and some are not covered at all. This book emphasizes conventional radiography because that is the type of study most patients have first and because the same imaging principles that apply to recognizing the diagnosis on conventional radiographs can be applied to making the diagnosis on more complex modalities.

With a better appreciation and understanding of why images look the way they do, you'll soon be recognizing abnormalities and making diagnoses that will impress your mentors and peers and astound your friends and relatives.

Let's get started.

William Herring, MD

Preface to the Second Edition

This second edition of *Learning Radiology: Recognizing the Basics* includes numerous changes and additions. There are additional chapters, over a hundred new photos, reorganization of key material throughout the text, and an increased emphasis on the cross-sectional imaging modalities of computed tomography (CT), magnetic resonance imaging (MRI), and ultrasound.

Two entirely new chapters have been added to help you understand the basic principles and fundamental observations of ultrasound and MRI. Trauma has moved to its own chapter, bringing together related material to provide cohesive coverage of this important subject. A new and helpful appendix has been added, which lists the most appropriate imaging study to order for each of a myriad of clinical scenarios. This information should prove indispensable on clinical rounds.

Many chapters have been reorganized. The chapter on Recognizing Adult Heart Disease has been restructured to include relevant material featuring CT and MRI. The chapters on Diseases of the Chest and Diseases of the GI and Urinary Tracts have been updated with increased emphasis on CT, ultrasound, and MRI. The chapters on Recognizing Arthritis and Common Causes of Neck and Back Pain incorporate more MRI imaging. The chapter on Recognizing Bowel Obstruction and Ileus now includes additional CT imaging.

There are enhancements to the printed text again available to registered users on the StudentConsult.com website, including access to the full text and all of its photos. Also available on the website are 24 interactive modules to help you learn radiologic anatomy. An algorithm for diagnosing adult heart disease using conventional radiography is available online. A new section on nuclear medicine has also been added to StudentConsult.com.

The first edition suggested that you'd soon be recognizing abnormalities and making diagnoses that would impress your mentors and peers and astonish your friends and relatives. With this edition, you hold the potential to be even more astounding.

Prepare to amaze.

William Herring, MD

Acknowledgments

First, I am grateful to the many thousands of you whom I have never met but who found a website called Learning Radiology helpful, and made it so popular it played a role leading to the first edition of this book, which was so popular that it led to this second edition.

For their help and suggestions, I would like to thank my colleague Mindy Horrow, MD, who read and critiqued several chapters with her usual expert eye and fine mind, and Thomas Reilly, MD, one of our radiology residents, who made invaluable suggestions about how the first edition could be changed. Daniel Kowal, MD, a radiologist who graduated from our program, did an absolutely wonderful job in simplifying the complexities of MRI for a great new chapter he wrote for this edition.

I want to thank Shuchi Rodgers, MD, Jenifer Slone, MD, Susan Summerton, MD, Mindy Horrow, MD, Morrie Kricun, MD, Huyen Tran, MD, Joanne Lee, MD, Jeffrey Weinstein, MD, and Michael Chen, MD for supplying additional photos for this edition. Thanks to Ryan Smith, MD for reviewing the StudentConsult chapter on nuclear medicine.

I certainly want to recognize and again thank Jim Merritt and Andrea Vosburgh from Elsevier for their continued support and assistance.

I also want to acknowledge the hundreds of radiology residents and medical students who, over the years, have provided me with an audience of motivated learners without whom no teacher could teach.

Finally, I want to thank my wonderful wife, Pat, who has encouraged me throughout the project, and my family.

Contents

Chapter 1

Recognizing Anything: An Introduction to Imaging Modalities

Up for a challenge? Look at these four images (Fig. 1-1). Each is diagnostic. How many can you recognize? "None" would be a good start. The answers are at the end of this book, both literally and figuratively. Literally, because the answers **really** are at the end of this book—on the last printed page, to be exact. Figuratively, because you will learn about each of these modalities, about these four diseases and many others, about how to approach imaging studies, and much more as you complete this text.

LET THERE BE LIGHT ... AND DARK, AND SHADES OF GRAY

- Once upon a time, not too long ago, radiographic images lived on the medium of film. In some places, film is still used, but it is becoming much less common.
- Images were produced by a combination of x-rays and light striking a piece of photographic film, which in turn produced a latent image that was subsequently processed in a darkroom filled with chemicals and then, literally, hung up to dry.
  - When an immediate reading was requested, the films were interpreted while still dripping with chemicals, and the term **wet reading** for a "stat" interpretation was born.
  - Films were viewed on lighted view boxes (almost always backward or upside-down if the film placement was being done as part of a movie or TV show).
- This workflow lasted for decades, but it had two major drawbacks:
  - It required lots of physical storage space for the growing number of films.
  - The radiographic film itself could only be in one place at one time, which was not necessarily where it might be needed to help in the care of the patient.
- And so **digital radiography** came to be, in which the photographic film was replaced by a **photosensitive cassette or plate** that could be processed by an electronic reader so that the image could be stored digitally.
  - Countless images could be stored in the space of one spinning hard disk on a computer server.
  - Even more importantly, the images could be viewed by anyone with the right to do so, anywhere in the world, at any time.
- The studies were maintained on computer servers on which the images could be archived, communicated, and stored. This was and is called **PACS**, a **Picture Archiving, Communications, and Storage** system.
- Using PACS systems, all sorts of images can be stored and retrieved, including **conventional radiographs (CR)**, **computed tomographic scans (CT)**, **ultrasound images (US)**, and **magnetic resonance imaging studies (MRI)**.
- Let's look briefly at each of these modalities.

CONVENTIONAL RADIOGRAPHY (PLAIN FILMS)

- Images produced through the use of ionizing radiation, i.e., x-rays, but without added contrast material like barium or iodine, are called ***conventional radiographs*** or, more often, "plain films."
- These images are relatively inexpensive to produce, can be obtained almost anywhere using portable or mobile machines, and are still the most widely obtained imaging studies.
- They require a source to produce the x-rays (the "x-ray machine"), a method to record the image (a film, cassette, or plate) and a way to process the recorded image (either using chemicals or a digital reader).
- Common uses for conventional radiography include the ubiquitous chest x-ray, plain films of the abdomen, and virtually every initial image of the skeletal system to exclude fractures or arthritis.
- Ionizing radiation in large doses, substantially higher than any medical radiographic procedure, is known to produce cell mutations that can lead to many forms of cancer or anomalies. Public health data on lower levels of radiation vary as to their assessment of risk, but it is generally held that only medically necessary diagnostic examinations should be performed and that studies using x-rays should be avoided during potentially teratogenic times, such as pregnancy.

COMPUTED TOMOGRAPHY (CT OR CAT SCANS)

- CT scanners, first introduced in the 1970s, brought a quantum leap to medical imaging.
- Using a gantry with a rotating x-ray beam and multiple detectors in various arrays (which themselves are rotating continuously around the patient) along with sophisticated computer algorithms to process the data, a large number of two-dimensional, slicelike images could be formatted in multiple imaging planes.
- CT scans can also be **"windowed"** (see Chapter 11) in a way that optimizes the visibility of different types of pathology after they are obtained, a benefit called **postprocessing** that digital imaging, in general, markedly advanced.

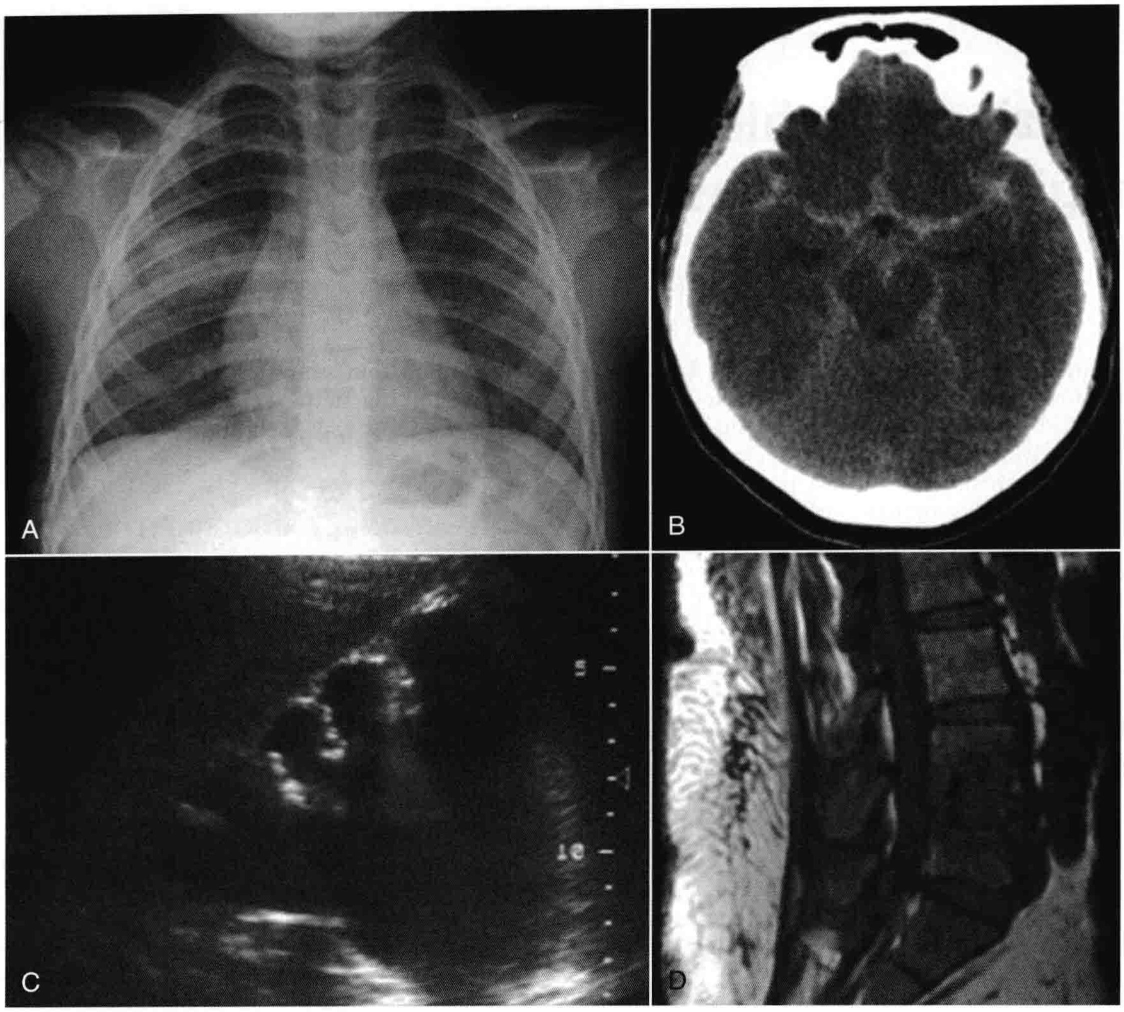

Figure 1-1 **Images of four different patients with four different diseases, each in a different imaging modality.** How many do you know? The answers are on the last printed page of this text.

Postprocessing allows for additional manipulation of the raw data to best demonstrate the abnormality without repeating a study and reexposing the patient.

- Producing CT images requires an expensive scanner, a space dedicated to its installation, and sophisticated computer processing power.
- CT scans, though, are the cornerstone of cross-sectional imaging and are widely available, although not as yet truly portable. CT scanners are more expensive to acquire and operate than conventional radiographic units and, like them, still utilize ionizing radiation (x-rays) to produce their images.

ULTRASOUND (US)

- Ultrasound utilizes acoustical energy above the audible frequency of human hearing to produce images, instead of using x-rays as both conventional radiography and CT scans do.
- It employs a **transducer,** which both produces the ultrasonic signal and records it. The signal is processed for its characteristics by an onboard computer. Ultrasound images are recorded digitally and are easily stored in a PACS system.
- Ultrasound scanners are relatively inexpensive compared to CT and MRI scanners. They are widely available and can be made portable to the point of being handheld.
- Because ultrasound utilizes no ionizing radiation, it is particularly useful in imaging women of child-bearing age, pregnant women, and children.
- Ultrasound is especially useful in imaging soft tissues and for delineating solid from cystic structures. It is also widely used for image-guided biopsies and is a noninvasive means of studying blood flow.
- Ultrasound is generally considered to be a very safe imaging modality without any known major side effects when used at medically diagnostic levels.

MAGNETIC RESONANCE IMAGING (MRI)

- Magnetic resonance imaging utilizes the potential energy stored in the body's **hydrogen atoms.** The atoms are manipulated by very strong magnetic fields and radiofrequency pulses to produce enough localizing and tissue-specific energy to allow highly sophisticated computer programs to generate 2- or 3-dimensional images (see Chapter 20).

- MRI scanners are not as widely available as CT scanners; they are expensive to acquire and require careful site construction to operate properly. In general, they also have a relatively high, ongoing operating cost.
- However, they utilize no ionizing radiation and produce much higher contrast between different types of soft tissues than can CT.
- MRI is widely used in neurologic imaging and is particularly sensitive in imaging soft tissues like muscles, tendons, and ligaments.
- Safety issues are associated with the extremely strong magnetic fields of an MRI scanner, both for objects within the body (e.g., pacemakers) and for ferromagnetic projectiles in the MRI scanner environment (e.g., metal oxygen tanks). There are also known side effects from the radiofrequency waves such scanners produce, and possible adverse effects from some MRI contrast agents.

TERMINOLOGY

- "Oh no," you say, "must we have this section? Let me skip to the good parts." You can do that: just remember where this section is because you may have to refer to it later.
- Like politics, all terminology is local. Follow the terminology conventions used in your hospital or, alternatively, the person rendering your course grade, even if those conventions are different from what is described here.

Terminology Conventions Used in This Book

- **Image**: a good, all-around term that can be used to describe any type of rendering of a radiologic examination.
  - It works for all modalities; you may use it freely.
  - You could say you were looking at an "***image*** of the abdomen on a conventional radiograph," or a "CT ***image*** of the abdomen," or an "ultrasound ***image*** of the abdomen," and so on. (Don't use the term *picture* to refer to a radiologic image; ***image*** will make you sound much smarter.)
  - When you view your images, **remember you and the patient are always looking at each other face-to-face.** This is the convention by which most images are viewed **no matter what the position of the patient when the image was exposed.**
    - The patient's right side, whether it is on conventional radiographs or a CT scan, is on your left side, and the patient's left side should be on your right side.
- **Cassette:** a cassette is the flat device that looks like a huge iPad that **holds either a piece of film** or a **special digital plate** on which the latent image resides until it is ***processed*** in one of two ways, depending on whether the cassette contains **film** or a **digital phosphor plate** without film.
  - **If the cassette contains film,** the film will be removed from the cassette in a **darkroom** (or by something called a ***daylight loader*** that simulates a darkroom) and **sent through an automatic processor** that contains a series of chemicals **that will develop the image,** make it visible to the human eye, and fix it permanently on the film. A new, unexposed piece of film will then be loaded into the cassette, and the cassette will be ready for the next exposure.
  - **If it is a digital cassette and contains no film,** it will be **processed through an electronic reader** that will decipher the electronic image stored on the phosphor plate in the cassette and transmit that digital image to another system to store it. The electronic image in the cassette is then "erased" and the cassette is used again and again.
  - Another, similar method of recording the image is on a digital plate connected directly to the processing computers without the need to ferry digital cassettes back and forth to an electronic reader. This is sometimes called **direct digital radiography.**
- **Study** or **examination:** used interchangeably, they refer to a **collection of images that examine a particular part of the body or system**, as in "double contrast ***study*** of the colon" (a series of images of the colon using air and barium and produced through the use of x-rays); or an "MRI ***examination*** of the brain" (a collection of images of the brain using MRI to produce the images).
- **Contrast material (contrast agent):** usually a substance that is administered to a patient in order to make certain structures more easily visible (frequently referred to simply as **contrast**).
  - The **most widely used examples of radiologic contrast materials** include liquid **barium,** which is administered orally for upper gastrointestinal (UGI) examinations and rectally for barium enema (BE) examinations, and **iodine,** which is administered intravenously for contrast-enhanced CT scans of the body.
  - Contrast agents also are used for MRI (most often, some solutions of gadolinium injected intravenously for its paramagnetic properties) and for ultrasound (gas-filled microbubbles).
- **Dye:** the lay term for contrast. Although ***contrast*** is the better term, many patients, and some radiologists in explaining tests to patients, use the term ***dye***. Don't use the word dye unless you are talking to a patient explaining a test; use the term ***contrast*** or ***contrast agent***. In fact, if you can use the words **contrast** and **image** in the same sentence, people will think you are a genius.
- **Flat plate:** an archaic, but still used, term meaning a conventional radiograph or plain film of the abdomen, almost always obtained with the patient lying supine. This term is left over from the pioneer days of radiology before film was used as the recording medium and the image was produced on a flat, glass plate.
- **White and black:** these are not radiologic terms, but almost every modality displays its images in white, black, and various shades of gray.
  - With conventional radiography, an object's inherent density will determine whether it appears white, black, or one of those shades of gray.
- **"En face" and "in profile":** used primarily in conventional radiography and barium studies.
  - When you look at a lesion directly "head-on," you are seeing it ***en face***. A lesion seen tangentially (from the side) is seen ***in profile***.
  - Only a sphere, which, by definition, is perfectly round in every dimension, will appear exactly the same shape

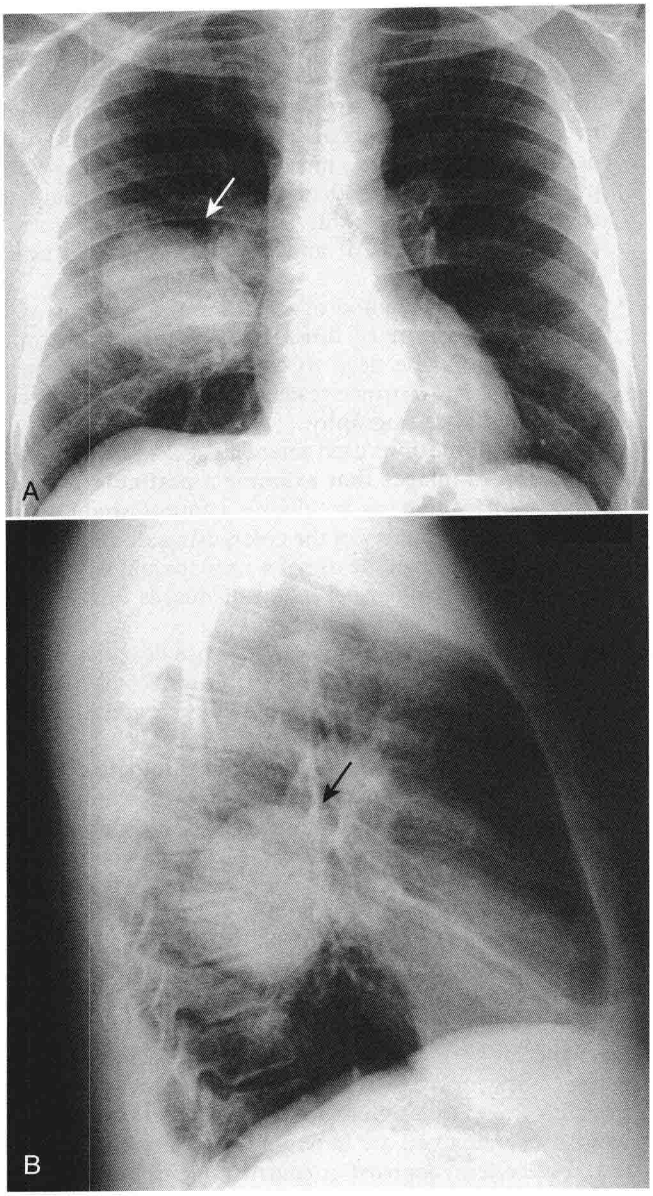

Figure 1-2 Right lower lobe bronchogenic carcinoma. A nearly spherical mass is in the right lower lobe of the lung seen on the frontal **(A)** (*solid white arrow*) and lateral **(B)** (*solid black arrow*) radiographs of this patient. Because the mass is nearly spherical, it has relatively the same shape when viewed ***en face*** and **in profile.**

no matter in which plane it is viewed (e.g., a nodule in the lung) (Fig. 1-2).

- Naturally occurring structures, whether normal or abnormal, of any shape other than a sphere will appear slightly different in shape if viewed ***en face*** or ***in profile.***
- This is not an easy concept to grasp because it **involves making a mental reconstruction of a three-dimensional object from the two-dimensional projections** conventional radiographs provide.
- For example, a disk-shaped object (one that looks like a playing piece used in the game of checkers), such as an ingested coin, will appear circular when viewed ***en face*** but rectangular when viewed in ***perfect profile*** (Fig. 1-3).

- **Horizontal versus vertical x-ray beams:** terms that describe the orientation of x-ray beams.
  - Horizontal and vertical beam orientation is an important concept to understand because it will help you in interpreting all kinds of conventional radiographic studies and in understanding their limitations. This may, in turn, prevent you from falling for a diagnostic pitfall.
  - An x-ray beam is usually directed either ***horizontally*** between the tube and the cassette (as in an upright chest examination) or ***vertically*** between the tube and the cassette (as in a supine radiograph of the abdomen with the patient lying on the examining table).
  - **Horizontal x-ray beams are usually parallel to the floor** of the examining room (unless the room was built by do-it-yourselfers on weekends).
  - In conventional radiography, **an air-fluid or fat-fluid level will be visible only if the x-ray beam is horizontal, *regardless of the position of the patient*** (Fig. 1-4).
  - An **air-fluid** or **fat-fluid** level is an interface between two substances of different densities in which the lighter substance rises above and forms a straight-edge interface with the heavier substance below.
  - **You** usually **don't have to specify whether you want the x-ray beam to be horizontal or vertical when ordering a study;** by convention, certain studies are always done using one method or the other (Table 1-1). In general, any study with the terms ***erect, upright, cross-table,*** or ***decubitus*** is always **done with a horizontal beam. You can see fluid levels (if present) with any of these types of studies.**

The Five Basic Densities

- **Conventional radiography is limited to demonstrating five basic densities,** arranged here from least to most dense (Table 1-2):
  - **Air,** which appears the blackest on a radiograph.
  - **Fat,** which is a lighter shade of gray than air.
  - **Soft tissue or fluid** (because both soft tissue and fluid appear the same on conventional radiographs, you can't differentiate between heart muscle and the blood inside of the heart on a chest radiograph).
  - **Calcium** (usually contained within bones).
  - **Metal,** which appears the whitest on a radiograph.
    - Objects of metal density are not normally present in the body. Radiologic **contrast media** and **prosthetic knees or hips** are **examples of metal densities** artificially placed in the body (Fig. 1-5).
- One of the major benefits of CT scanning is its ability to **expand the gray scale,** which enables us to differentiate many more than these five basic densities.
- Remember, the denser an object is, the more x-rays it absorbs, and the whiter it appears on radiographic images.
- The less dense an object is, the fewer x-rays it absorbs, and the blacker it will appear on radiographs.
- Unfortunately, the specific terms used to describe what appears as ***white*** on an image and what appears as ***black*** on an image change from one modality to another. Table 1-3 is a handy chart that describes the terms used for black and white using various modalities.

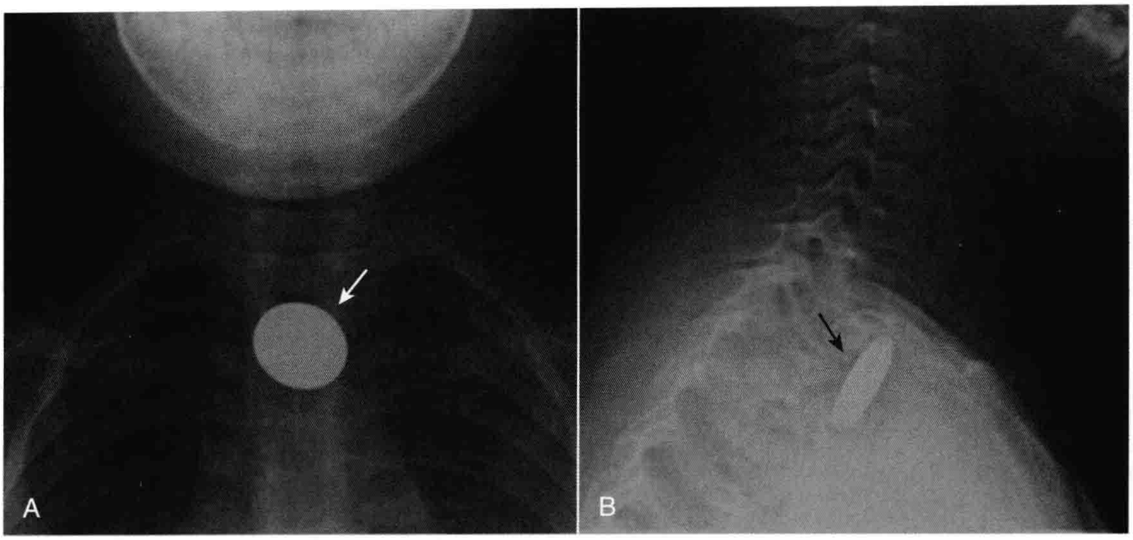

Figure 1-3 **Coin in the esophagus.** Both the frontal **(A)** and the lateral **(B)** images of this child's upper thorax demonstrate a radiopaque (white) metallic density in the region of the upper esophagus. The child swallowed a quarter, which is temporarily lodged in the esophagus just above the aortic arch. Notice how different the coin looks when viewed ***en face*** in **(A)** (*solid white arrow*) where it is seen as a circle and **in profile (B)** where it is seen on end (*solid black arrow*).

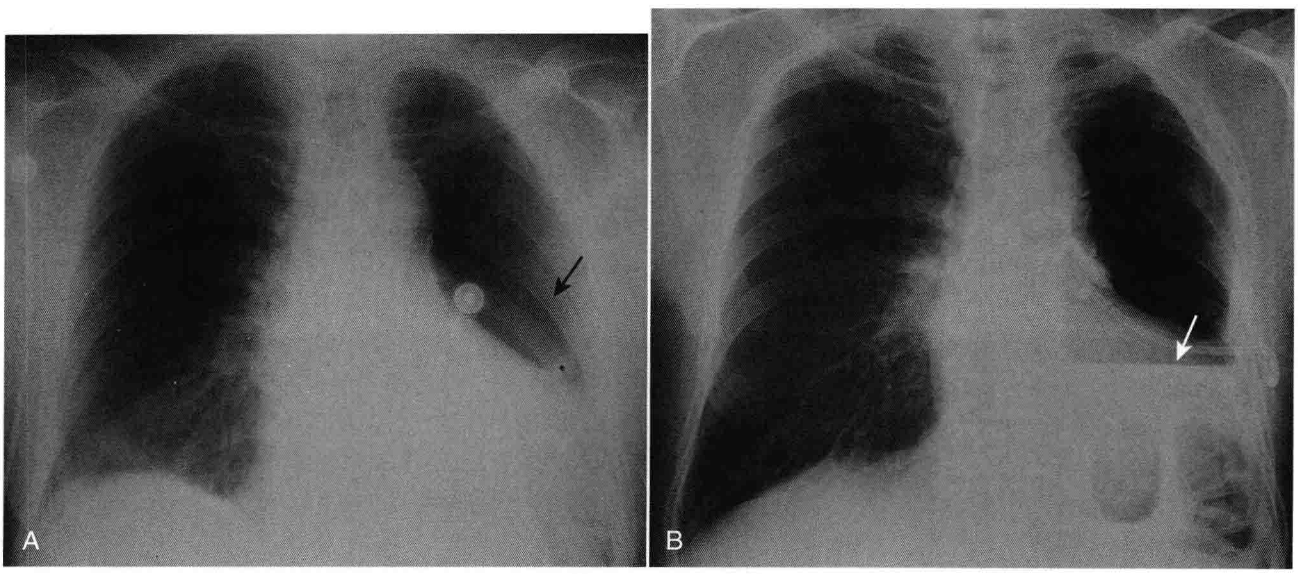

Figure 1-4 **Vertical versus horizontal x-ray beam.** The same patient with a hydropneumothorax is imaged a few hours apart, first with a vertical x-ray beam (**A,** supine chest) (*solid black arrow*) and then with a horizontal x-beam (**B,** upright chest) (*solid white arrow*). In both images, the patient has both air and fluid in the left hemithorax, but only in image **B** with the horizontal beam is the distinctive flat, air-fluid interface seen. An air-fluid interface will only be visible with an x-ray beam that is parallel to the floor (horizontal) no matter what position the patient is in.