The Clinician's Guide to Diagnostic Imaging

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Preface

Because communication between radiology and the clinical services is often poor, the clinician may be on his or her own when choosing among diagnostic imaging tests. In addition, radiology has fragmented to the extent that its subspecialists are sometimes less than fully informed about the potential of imaging techniques other than their own. This volume is designed to bridge the gaps between the imaging modalities available and between radiology and the clinical services.

The Clinician's Guide to Diagnostic Imaging is a practical, work ing manual designed for use by the practicing clinician, house officer, and medical student. It presents state-of-the-art information in the form of clear, cogent imaging protocols, and deals with problems whose work-up is dominated by imaging: Is suspected acute cholecystitis best studied by ultrasound or nuclear HIDA exams? Are hepatic metastases better identified by computed tomography or the nuclear liver-spleen scan? Is the occult abscess best sought by computed tomography, ultrasound, or gallium-67? These problems and many others are analyzed in terms of the most direct and least invasive imaging route to a diagnosis.

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General

Introduction

> One of the remarkable paradoxes in contemporary American medicine is the presence of a vague but definite malaise surrounding radiologic diagnosis at a time of unparalleled excitement and accomplishment in the development of imaging hardware and techniques. . . . Too many available choices—especially if imperfectly understood—create confusion and anxiety in the chooser. . . .
>
> The clinical service . . . enters the radiologic "supermarket," whose shelves are increasingly filled with exotic and expensive studies, and orders tests. . . . It is no indictment of clinical services to say that confusion surrounds the imaging workup.
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> Heilman, R. S. "What's Wrong with Radiology." *N. Engl. J. Med.* 306(1982):447–479

HOW TO USE THIS BOOK

The Clinician's Guide to Diagnostic Imaging has been designed and constructed as a practical, working manual: a brief text containing state-of-the-art information in the form of clear, cogent imaging protocols covering important problems: Is suspected acute cholecystitis best studied by ultrasound or nuclear HIDA exams? Are hepatic metastases better identified by computed tomography or the nuclear liver-spleen scan? Is the occult abscess best sought by computed tomography, ultrasound, or gallium 67? These problems and many others—ranging from "Hypertension: Is It Renovascular?" to "Solitary Pulmonary Nodule"—are analyzed in terms of the most direct and least invasive imaging route to a diagnosis.

We have selected problems in which the workup is dominated by imaging; we have avoided discussion of laboratory tests and physical findings. Clinicians do not need to be taught clinical medicine by radiologists, and such material is exhaustively covered and readily available elsewhere, in major medical, surgical, and pediatric texts, which devote little space to modern imaging.

This book should be consulted on a problem-by-problem basis and will be most effective when the clinician has a specific finding to work with or a tentative diagnosis in mind. *Each section addresses a single problem and is designed to stand alone*, obviating the need for the busy clinician to flip back and forth between sections. The luxury of this independence carries a small penalty: i.e., a certain redundancy. For example, digital video subtraction angiography is mentioned in many sections and is explained each time in three or four lines of text. Our judgment is that this minimal redundancy is well worth the practicality and utility that such a structure engenders.

When a section is first consulted, we suggest a read-through, followed by a second reading of the summary and conclusions. We have striven for clarity, but the material is highly condensed; therefore, *a cover-to-cover reading of the entire text is not recommended and would probably prove tedious even to the most retentive and disciplined mind.*

This book is not intended to replace or supersede consultation with the radiologist and nuclear imager; indeed, we stress throughout that communication is the surest means of defining the best imaging solution to a clinical problem. Although our protocols cover many variations and contingencies that affect the workup, unique circumstances will inevitably arise that are best approached through discussion between the imager and clinician. Nonetheless, we strongly believe that communication is most effective when both parties are well informed about the options under consideration.

GENERAL CONSIDERATIONS

Although familiarity with imaging technique is not a prerequisite for understanding the individual problem-oriented sections, we have provided the following basic, practical information for those who wish to acquaint themselves with the general terminology and methods of modern imaging.

Computed Tomography

Computed tomography (CT) is a radiographic technique. X-rays pass through the patient as in standard radiography. However, the X-ray beam is "fired" from many angles to generate each image.

Whereas the X-rays of standard radiography are detected by film, in CT they strike radiation detectors that produce a minute electrical impulse proportional to the intensity of the X-ray beam. The electrical current is quantitated numerically ("digitized") and registered in the form of computer-stored data. (Standard X-ray films, of course, record the effect of X-rays as film "blackening," a nonquantitative measure that cannot be computer-stored.) Whereas radiographs cannot be improved once they are developed, CT images can be re-created, with different degrees of photographic contrast, by recalling and manipulating original computer-stored data, *without reexamining the patient.* Thus, the images can be optimized electronically, and in some cases different views can be constructed.

The standard plane of CT is termed "transaxial," and its view of the body is analogous to looking at a slice from a loaf of bread. CT's superiority over conventional radiography is largely the result of the transaxial projection, because organs are not superimposed in this view. Moreover, the data quantitation and the sensitivity of the radiation detectors (as opposed to film) result in greater sensitivity to small radiographic density changes. In other words, *CT can detect slight variations in tissue density when no difference in radiographic film "blackening" would occur;* this is termed superior "contrast resolution." Despite these advantages, CT's resolution of fine anatomic detail ("spatial resolution") is inferior to that of standard radiography.

Like standard radiography, CT is a "photographic" rather than a "contact" procedure; a beam passes through the patient, and *instrument-to-skin contact* is not required. Therefore, CT is not inhibited by surgical dressings or drains, skin lesions, or wounds. Because the X-ray beam penetrates well, all but the most obese patients can be examined. (In fact, even the morbidly obese can be penetrated by the beam, but they may be too large to fit through the instrument portal—the "gantry.") Whereas early scanners required 3.5 to 5 min of intermittent X-ray exposure to generate data *for a single image,* modern scanning times of 2 to 10 sec are commonplace. Therefore, the frequently observed motion blur of first- and second-generation scanners is rare today. Nonetheless, a moving patient cannot be properly imaged (see the Appendix regarding patient preparation for imaging procedures). An occasional impediment to CT is an abundance of surgical clips or sutures, whose metallic content creates image artifacts.

CT without radiographic contrast medium will detect many lesions. However, detection and characterization of other lesions can be greatly improved by peripheral intravenous injection of contrast medium. Studies with and without contrast medium are termed "enhanced" and "unenhanced," respectively. The contrast media ("dye") currently used are identical with those used in intravenous pyelography ("IVP").

Although contrast medium for CT is diagnostically valuable, it introduces a small but finite risk, because occasional morbidity and rare mortality can be associated with its infusion. Moreover, *the use of contrast agents in renal failure, diabetes, and multiple myeloma is controversial, and each such patient should be discussed individually with the radiologist* in order to minimize untoward reactions.

Unenhanced CT images structure. Functional change can be inferred only where structure is affected; for example, a common bile duct stone may produce visible biliary tract dilatation, but unenhanced CT does not directly assess cholestatic hepatic parenchymal injury. Enhanced CT, however, addresses an important functional parameter—vascularity. Because intravenous infusion of radiographic contrast medium produces an increase in the radiographic density of the body blood pool, CT after contrast injection provides a good estimate of tissue (or lesion) vascularity. Moreover, because contrast media are filtered and excreted by the kidneys, enhanced renal CT provides a rough estimate of renal function, similar to an IVP.

In abdominal CT, the differentiation between bowel and fluid-density lesions (e.g., abscess, necrotic tumor) is essential. Introduction of contrast medium orally or per rectum is almost always required. The bowel lumen filled with contrast medium is more readily differentiated from pathologic processes.

Because CT was originally termed "computed axial tomography," the abbreviation "CAT" or "CAT scan" appears in portions of the medical literature. Currently, however, "CT" is preferred in the radiology literature. Because the radiation detectors register energy transmitted through the patient from an X-ray tube, "TCT" (for "transmission computed tomography") is sometimes used.

Ultrasound

Unlike CT, ultrasound is a *contact* procedure. The hand-held transducer passes over the skin, gliding along a thin film of acoustical gel (applied to the skin before the examination). Any skin lesions, as well as surgical dressings, drains, or wounds, inhibit sonography; the sonographer must circumvent these impediments, and sometimes the appropriate transducer angle for optimum views is unobtainable.

Sonography depends on penetration of the body by high-frequency sound, emanating from the hand-held transducer and bouncing off internal structures; the returning sound beam ("echo") is perceived by the transducer and built into an image. Sonography, therefore, ***delivers no ionizing radiation***. The effects of ultrasound are not fully known, but ***virtually all authorities agree that any deleterious effects would be minimal compared with those of standard radiography, CT, or nuclear imaging***. Because it delivers no ionizing radiation, ***sonography is particularly valuable for the study of pregnant females, children, and females of childbearing age***. In a certain diagnostic sense, however, the strength of sonography is also a weakness; whereas ionizing radiation easily penetrates gas and bone, the sound-wave frequencies of diagnostic medical ultrasound do not penetrate these media. Therefore, ultrasound of the brain, after the fontanelles have closed, is unfeasible, and ultrasound of the lungs is not possible. Moreover, intestinal gas is an impediment to viewing portions of the abdomen, and parts of the liver and spleen under the ribs may be inaccessible.

Like unenhanced CT, ***ultrasound images structure***. Functional assessments are possible only where organ architecture is affected. For example, a glomerulonephritic kidney may swell, and sonography may demonstrate edema, but the sonogram does not assess the function of glomeruli or tubules.

Although the ***interpretation*** of CT requires great skill and knowledge, the ***production*** of CT images is routine for qualified technologists. *Production* of high-quality sonographic images, however, demands considerable attention, patience, and persistence from technologist and physician alike. High-quality sonograms are always the product of dedication and are never "routine."

Synonyms for ultrasound include sonography, "sono," "sound," "echo," and echography.

Radionuclide Imaging

Radiography and CT depend on *transmitted* X-rays produced by an X-ray tube; nuclear imaging procedures depend on *emitted* gamma rays from *in vivo* radiopharmaceuticals previously delivered parenterally or orally. Therefore, the method is sometimes broadly categorized as "emission imaging," as opposed to "transmission imaging."

Nuclear techniques are almost completely noninvasive, and they usually (but not always) deliver less radiation than standard radiography or CT. The occasional morbidity and rare mortality associated with radiographic contrast medium, used for enhanced CT, are virtually absent with nuclear pharmaceuticals, which are delivered in subpharmacologic doses. With the exception of gamma cisternography, in which radiopharmaceutical is delivered to the subarachnoid space via lumbar puncture, the means of delivery are virtually free of complications.

Because nuclear imaging utilizes organ- or system-specific pharmaceuticals, the technique is superior for study of *function:* bone-seeking agents accumulate in the skeleton according to osseous blood flow and metabolism, rather than architectural change; renal studies assess glomerular filtration rate, tubular excretion, and blood flow, as well as size and contour. However, in most instances, the *structural* or *anatomic* information provided by nuclear studies is *inferior* to that of standard radiography, CT, and ultrasound. Thus, the *spatial resolution* of CT and ultrasound is superior to that of nuclear imaging, but in functional assessment nuclear techniques excel.

Radionuclide imaging uses many isotopes with different half-lives and gamma-ray energies, but by far the most common isotope in modern practice is technetium (pronounced "tech-knee-see-um") 99m; this iosotope (abbreviated Tc-99m) can be bound to many chemicals whose structures will determine the *in vivo* distribution of the Tc-99m-chemical complex. Therefore, from the point of view of nuclear imagers, a request for a "technetium scan" has little meaning: Is a Tc-99m-HIDA study for the gallbladder intended, or a Tc-99m-MDP scan for the skeleton, or perhaps a Tc-99m-pertechnetate scan for the thyroid? Because it is unreasonable to expect the busy clinician to keep track of the many pharmaceuticals available, most departments urge that the scan be ordered according to the *system* under study for a *given tentative diagnosis;* thus, an ideal requisition would read "bone scan, rule out bone metastases" or "gallbladder scan, rule out acute cholecystitis."

The many synonyms for radionuclide imaging include nuclear imaging, isotope imaging, nuclear medicine, nuclear medicine imaging, scintigraphy, gamma scintigraphy, nuclear scanning, nuclear medicine scanning, isotope scanning, and radionuclide scanning.

Angiography

Conventional angiography is performed by introducing radiographic contrast medium directly into a given blood vessel and immediately obtaining a rapid series of radiographs. In order to deliver contrast medium to the desired site—for example, the superior mesenteric artery, carotid artery, etc.—a catheter is threaded through an appropriate blood vessel after percutaneous introduction. Arteriography is thus more invasive than CT, ultrasound, or nuclear imaging, but the information gained is unique.

The contrast media used for angiography are similar to those for the IVP and enhanced CT, and similar precautions apply. Moreover, angiography carries a *small* but significant risk of potentially serious complications such as hemorrhage, vascular perforation, embolism, thrombosis, and even organ infarction. In patients with bleeding diatheses, the exam is usually contraindicated, and a platelet count and coagulation profile are usually mandatory before an angiogram is performed.

Digital Video Subtraction Angiography

Recent technological developments applied to angiograpy can produce relatively good *arterial* images from *intravenous* injection of contrast medium, so that no arterial puncture or catheterization is necessary. For example, with these techniques, a bolus injection of contrast medium into a peripheral or central *vein* will usually produce diagnostically adequate *aortic* images when radiographs are obtained after the injection. Ordinarily, the contrast medium would be too dilute in the aorta to be radiographically visible, but the "digital" technique succeeds where conventional techniques would fail. The X-ray beam strikes a radiation detector, and its effect is expressed as a minute electric current, which is then quantitated and computer-stored ("digitized"); the result is greater sensitivity to small density changes than conventional film "blackening" achieves. A digitized image of abdominal structures is produced *before* arrival of contrast medium, and this image (known as a "mask") is then *electronically subtracted* from the arterial image, leaving only contrast-medium-filled vessels.

The place of digital angiography has not fully gelled, but a reasonable approach in many situations is to attempt a digital angiogram first, in lieu of a standard angiogram; if vascular opacification is sufficient, the patient is spared the more invasive arterial procedure. A number of technical factors, however, may interfere with digital images, necessitating subsequent conventional angiography. Although the risk of contrast medium remains, the more serious potential risks associated with arterial puncture and catheterization are avoided.

A common synonym for digital video subtraction angiography is "DIVA" ("digital intravenous angiogram"), or simply "digital."

A Word about References

In keeping with the brief, concise nature of this book, we have avoided referencing well-established facts that are common knowledge among imagers and are well documented in the literature. However, newer findings and controversial statements are referenced whenever possible.

GASTROINTESTINAL

1

Acute Cholecystitis

INTRODUCTION

A major question in the study of possible acute cholecystitis is whether nuclear imaging or ultrasound is the best screen. Although this issue was unresolved as these examinations evolved, the place of each technique has now gelled.

Radionuclide gallbladder studies use HIDA (an acronym for hepatobiliary iminodiacetic acid) or one of its many chemical congeners—e.g., diisopropyl IDA (DISIDA), paraisopropyl IDA (PIPIDA), etc. After intravenous injection, these compounds are cleared and rapidly excreted by the liver into the biliary tree; they fill the gallbladder by retrograde passage down the cystic duct and enter the duodenum via the common duct. HIDA is extremely useful for establishing the presence or absence of *cystic duct patency; filling of the gallbladder establishes with certainty that patency exists at the time of the examination*. Because cystic duct *obstruction* by a stone is the hallmark of *acute cholecystitis,* the HIDA compounds are excellent for excluding this condition (1).

The sonogram is often able to locate the gallbladder precisely, aiding the clinician in evaluating tenderness. Whereas calculi and a thickened gallbladder wall are valuable sonographic findings, they are not diagnostic of *acute cholecystitis* (a thick gallbladder wall frequently accompanies chronic cholecystitis). The finding of fluid around the gallbladder—"pericholecystic edema"—suggests acute cholecystitis, but it can be mimicked by ascites; moreover, the sign may be absent, even in advanced, gangrenous cases.

PLAN AND RATIONALE

Step 1: HIDA

In patients with right-upper-quadrant pain and appropriate clinical findings, technetium-99m-HIDA is the screen of choice. The radiopharmaceutical is administered intravenously, so nausea and vomiting are not contraindications. *If the gallbladder is visualized, cystic duct patency is established with absolute certainty; acute cholecystitis drops from a high level of consideration to a very, very low level of likelihood.* In almost all such cases, the gallbladder imaging workup ends.

Admittedly, occasional cases of "acalculous acute cholecystitis" occur—these rarities have been attributed to reflux of pancreatic juice into the gallbladder, vasculitis of the gallbladder wall, seeding of the gallbladder in generalized bacteremia, or intermittent obstruction from a moving stone in the gallbladder neck. In some of these rare cases the gallbladder may fill with HIDA, because the cystic duct may be patent, although inflammatory edema of the cystic duct usually prevents gallbladder filling (2).

Unfortunately, whereas gallbladder filling almost certainly excludes acute cholecystitis, *failure to visualize the gallbladder does not prove the presence of acute cholecystitis.* The gallbladders of patients who have not eaten for 12 hr, or who have had a history of alcoholism and/or pancreatitis, sometimes fail to visualize after intravenous HIDA, perhaps because of viscous, static gallbladder bile, which allows no room for HIDA to enter (3,4,5). The most persistent problems with nonvisualized ("non-vis") gallbladders have occurred in patients on total parenteral nutrition (TPN). In an attempt to reduce the number of non-vis cases, some centers administer an intravenous dose of either cholecystikinin (CCK) or sincalide—the terminal octapeptide of CCK—about 20 min before HIDA. The logic for administering these short-acting agents is to contract the gallbladder prior to HIDA injection, permitting HIDA to enter the emptied but relaxed gallbladder. This technique has been highly effective in most cases of fasting but has been less effective in TPN and chronic alcoholism.

If the gallbladder fails to visualize *after CCK and HIDA, and if TPN and chronic alcoholism have been excluded, acute cholecystitis is*