Overview
Within the past 20 years, the various imaging tools used to evaluate patients with abdominal symptoms have changed dramatically. In this era with relatively easy access to cross-sectional imaging and endoscopy, plain radiography and fluoroscopic (“barium”) exams have lost much of their utility, though not all. Ultrasonography (US), computed tomography (CT), and magnetic resonance (MR) are now the dominant modalities in common use.

Many surgeons and other physicians caring for patients with hepatobiliary, pancreatic, or gastrointestinal (GI) disorders are likely to have received relatively little formal instruction in cross-sectional imaging anatomy or its appearance on imaging studies during medical school or residency. Moreover, the continuing rapid evolution of imaging equipment and scan protocols may make it difficult for radiologists, and nearly impossible for other physicians, to keep abreast of newer and important developments. With this introductory chapter and the rest of this book, we hope to make our readers more knowledgeable and comfortable in understanding the proper role and interpretation of various imaging tools for evaluation of abdominal disorders.

We will start with a brief overview of individual imaging modalities and an assessment of their strengths and limitations, acknowledging that there are legitimate reasons for considerable variability in practice patterns based on the training of physicians and the availability of specific equipment.

Imaging Modalities and Equipment
Radiography
Plain radiography has undergone the least technical advancement and the most drastic decline in use over the past 2 decades. Like other imaging techniques, “plain films” are now acquired and displayed digitally, which offers advantages in image quality, lower radiation dose, and ease of distribution throughout the medical environment. No longer do physicians need to physically visit the radiology department to view or check out an abdominal film of their patient. Film reporting is now done by voice recognition, allowing almost immediate availability of the formal interpretation, obviating the need to hear the interpretation directly from a radiologist or waiting (hours or even days) for the paper report to make it to the patient’s chart. On balance, these changes are good, but all of us “senior” radiologists miss the opportunity to discuss individual patients with referring physicians. Without question, the most ideal setting is one in which the referring physician selects the ideal imaging modality based on the patient’s clinical presentation, and the radiologist interprets the study with a full understanding of the concerns and questions to be addressed in his or her report. Regrettably, this is rarely the case today.

The most common indication for an abdominal plain film today is to check the position of a feeding tube or other device. For this, a supine portable film is sufficient and accurate. A term sometimes used as a synonym for a plain film is a KUB (meaning kidneys, ureters, bladder), and this reflects the prior belief that such films were quite accurate in detecting calculi within the renal collecting system. A similar belief that plain films reliably depicted free intraperitoneal air (bowel perforation) and bowel obstruction persisted until CT came into widespread use, causing us to conclude that we had been missing a lot of disease on plain films.

If plain films are to be used to detect any abdominal disorder other than tube malposition, the study must include supine and either upright (not sitting) or decubitus views. The latter are essential in order to detect free intraperitoneal air or air-fluid levels.

Fluoroscopy
The other major “victim” of the modern era has been the fluoroscopic study of the GI tract. During the senior author’s training and earlier practice, air-contrast barium studies of the entire GI tract were commonly employed to diagnose almost the whole spectrum of inflammatory, infectious, ischemic, and neoplastic disorders. Today, in most industrialized countries, most fluoroscopic studies are performed to evaluate patients before and after surgical procedures. Among the more common of these are antireflux (GERD), such as fundoplication, and bariatric surgical procedures, such as sleeve gastrectomy and Roux-en-Y gastric bypass. For patients who have had all or part of the colon resected, some form of contrast enema is generally performed to ensure there is no anastomotic stricture or leak.

Fluoroscopy has retained a primary role in evaluation of patients with dysphagia or symptoms of GERD and is complementary to various endoscopic and manometric procedures. These protocols and disorders are discussed at length in the Esophagus section of this book.

Ultrasonography
US has become the most widely utilized imaging study in the world, owing to its portability, affordability, and lack of ionizing radiation. Some physicians consider US an extension of the physical exam and encourage its use by practitioners of all sorts. This trend has been accelerated by the availability of small, inexpensive US units that can be used in the office, clinic, or emergency department. At the same time, some caution is warranted. Although some conditions and disorders may be readily apparent to even the infrequent US practitioner, such as large amounts of fluid in the peritoneal cavity, other conditions require considerable experience and expertise in US for accurate assessment.

US has at least 2 inherent limitations: A rather small field of view and its inability to image structures “hidden” by overlying bone or air. Although these can, to some extent, be overcome by repositioning the patient, US imaging of the GI tract will always be technically challenging. US has a primary role in evaluation of hepatobiliary disorders, as discussed at length in subsequent chapters.

Endoscopic US has attained an important role in evaluation of hepatobiliary and pancreatic disorders. A high-frequency US transducer placed near the tip of an endoscope provides direct visualization and high-resolution images of the bile ducts and pancreas, along with the ability to biopsy or otherwise retrieve tissue or fluid samples for laboratory analysis.

US equipment and protocols have evolved along 2 somewhat diverging paths: The simple but cheap and the complex but more expensive. The latter includes developments such as power Doppler, harmonic imaging, and even US contrast agents. Recently approved for use in the USA as well as in Europe and Asia are US “bubble” contrast agents. Real-time US imaging of the abdomen following IV bolus injection of one of these agents has shown great promise in evaluation of the vascularity and etiology of many neoplastic and other disorders. For more comprehensive and sophisticated
applications of US, considerable expertise and experience are demanded for both its performance and interpretation.

Computed Tomography
CT has assumed a dominant role in evaluation of abdominal disorders of almost any etiology. With current CT scanners, high-resolution images can be obtained through the abdomen and pelvis in much less time than a minute with almost instantaneous “reconstruction” of the images available in any desired plane, such as coronal or sagittal (multiplanar CT). We routinely review all CT studies of the abdomen and pelvis in at least the axial and coronal planes. Curved planar reformations can be extremely instructive in evaluation of structures, such as the biliary and pancreatic ducts and blood vessels, as will be illustrated in multiple chapters. The ability of modern scanners to quickly acquire thousands of submillimeter-thick axial sections, coupled with powerful computers, has also led to the development of specific applications, such as CT enterography, colonography, and angiography, each of which has important uses in abdominal imaging.

The newer generation of CT scanners also provides CT hardware and software that has markedly decreased the dose of ionizing radiation to patients with many CT protocols now resulting in an effective dose that is less than yearly background radiation. Many educational and decision-support tools are available on the internet that can help guide referring physicians in ordering the most appropriate imaging studies, including those offered by the American College of Radiology and the American Board of Internal Medicine (through its Choosing Wisely campaign). Referring physicians should always weigh the risk:reward ratio in evaluation of any diagnostic or therapeutic procedure, and consultation with radiologists in a particular case is very useful in choosing the most appropriate imaging test and protocol.

Unlike other imaging studies, CT need not be limited to evaluation of a single organ or region, such as the right upper quadrant, and it is equally effective in depicting the spectrum of inflammatory, infectious, vascular, and neoplastic disorders that may affect any of the thoracic, abdominal, pelvic, or retroperitoneal organs. For almost all CT protocols, with the exception of suspected renal calculi, abdominal CT scans are most informative when performed during the rapid bolus infusion of iodinated contrast medium. Newer contrast agents can be administered safely, even to patients with renal insufficiency, utilizing smaller volumes of contrast media, newer CT scan protocols (e.g., lower kilovoltage tube current), and adequate hydration of the patient before and after the study. The prevalence of contrast-induced nephropathy (CIN) from IV administration of contrast for CT is extremely low, especially in adequately hydrated patients. There have been numerous, well-designed studies of CIN and its relationship to CT scanning, and there is broad agreement that the risk of CIN from CT has been greatly exaggerated. We agree with the recommendations of the Mayo Clinic and the American College of Radiology that IV contrast media should not be withheld when it is deemed necessary for accurate CT diagnosis.

Another technical advance in CT has been the faster acquisition and display of images, allowing selective imaging through large structures or regions (e.g., the entire liver or abdomen) in the arterial, venous, &/or delayed phase of contrast passage and uptake. Such multiphasic contrast-enhanced CT protocols have greatly improved our ability to detect disorders, such as GI bleeding, as well as hypervascular tumors and their metastases. We will discuss and illustrate specific uses of multiphasic CT in subsequent chapters.

Magnetic Resonance
No imaging modality has undergone more rapid and varied development over the last decade than MR. MR is inherently more sensitive to slight differences in tissue contrast than CT or US and can directly depict the body in any plane of section. Individual MR sequences and protocols can be utilized to display and quantitate, for example, the fat or iron content of the liver, the presence of hemorrhage, or many other characteristic features that allow more accurate diagnoses of abdominal disorders. Owing to the length of most abdominal MR protocols (> 30 minutes), MR is less optimal for imaging clinically unstable patients or larger anatomic regions (e.g., chest, abdomen, and pelvis). Because of its expense and more limited distribution, MR may be reserved for more detailed analysis of a disorder 1st suggested by CT or US, but it is assuming a more prominent role as the 1st-line imaging study in many cases, as discussed throughout this book.

As with CT and US, MR protocols have evolved to include the use of novel contrast agents. For abdominal MR protocols, the most important of these is gadoxetate disodium, commercially known in North America as Evovist and elsewhere as Primovist. Gadoxetate differs from most other gadolinium-based contrast agents in having substantial (~50%) hepatobiliary excretion. Gadoxetate-enhanced MR protocols are of proven value in allowing improved quality MR cholangiography and in helping to characterize certain hepatic disorders and masses, as addressed in subsequent chapters.

Nuclear Medicine
Radionuclide scintigraphy is inherently limited in its spatial resolution but offers unique physiologic properties that allow it to retain an important role in abdominal imaging. Foremost among these is the pairing of the physiologic display of glucose metabolism (radiolabeled FDG) and the anatomic display of CT into combined (“fused”) PET/CT studies. PET/CT has achieved a critical role in oncologic imaging and is uniquely valuable in the initial staging, evaluation of response to treatment, and ongoing surveillance of GI malignancies. Unique PET tracers have been designed for specific targets, such as somatostatin analogues. Gallium 68-DOTATATE PET/CT is of proven superiority in detection and staging of neuroendocrine tumors, as discussed in other chapters. PET/MR is already entering clinical practice and will find its place in abdominal imaging as well.

Selected References
Common Symptoms, Signs, and Conditions

**Imaging Anatomy and Overview**

(Left) US demonstrates the normal appearance of the gallbladder (GB). Note the thin GB wall (which should measure < 3 mm) and the clear, anechoic bile distending its lumen. **(Right)** The GB fundus is its distal tip, whereas the neck represents the proximal portion of the GB, which tapers toward the junction of the GB with the cystic duct. The cystic duct is not routinely visualized well on US but is seen here as a tubular, tortuous structure.

(Left) Sagittal US section shows the normal look and relationships of collecting bile duct (CBD) and portal vein (PV). The hepatic artery lies between the CBD and PV. The CBD is normally ~ 40% the diameter of the accompanying branch of the PV. **(Right)** Sagittal US through the liver shows its homogeneous echogenicity with interspersed vessels and small intrahepatic bile ducts. The right kidney and liver have similar echogenicity, which helps determine whether the liver is abnormally echogenic, suggesting steatosis.

(Left) US shows the confluence of the hepatic veins with the inferior vena cava (IVC). Note the uniform, low-level echogenicity of the normal hepatic parenchyma. The diaphragm is marked. **(Right)** Transverse US demonstrates the normal right and left PVs, both of which have the thick echogenic wall that is characteristic of the portal venous system (and allows PVs to be easily differentiated from hepatic veins).
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(Left) First of 6 axial CECT images through a normal liver shows the middle hepatic veins joining the IVC. (Right) More caudal CT section shows the lateral and medial segments of the left PV. The hepatic veins travel in a more cephalocaudal direction and are seen in short axis on this axial image.

(Left) More caudal section shows the anterior branch of the right PV and the undivided left PV. The middle and right hepatic veins are seen in cross section. The hepatic veins tend to have a more vertical course, unlike the more horizontal course of the PVs. (Right) More caudal section shows the posterior branch of the right PV as well as the right hepatic artery. The common hepatic artery branches from the celiac trunk along with the splenic and left gastric arteries.

(Left) More caudal section shows the falciform ligament cleft, separating the medial and lateral segments of the left lobe. Also noted are the GB and superior mesenteric artery and vein. (Right) More caudal section shows the inferior segments of the right hepatic lobe and GB. The pancreatic head lies between the superior mesenteric vein and the 2nd portion of the duodenum.

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(Left) First of 3 arterial-phase contrast-enhanced T1 MR sections shows the homogeneously enhancing hepatic parenchyma and the enhanced left PV. The middle and right hepatic veins are not yet enhanced on this early phase of imaging and appear dark. (Right) More caudal section shows the anterior branch of the right PV as well as the nonenhanced hepatic veins. The falciform ligament cleft is also seen.

(Left) More caudal section shows the posterior branch of the right PV. Also note the celiac trunk and brisk enhancement of the pancreatic body. (Right) First of 3 axial fat-suppressed nonenhanced T2 MR sections shows normal, low-intensity liver parenchyma and very low signal (flow void) within vessels, such as the right hepatic vein, IVC, and aorta. Note bright signal from static fluid within the intrahepatic bile ducts and cerebrospinal fluid within the spinal canal.

(Left) More caudal MR section shows bright signal within the right hepatic duct, which lies immediately anterior to the right PV. The intrahepatic bile ducts are the branching, high-intensity (bright) foci within the liver. (Right) More caudal MR section shows bright signal from bile within the neck of the GB and the right hepatic duct. Low-signal flow voids mark the hepatic artery, PV, and celiac trunk.
Imaging Anatomy and Overview

**Left** Coronal MRCP, obtained without the use of contrast media, shows bright signal from fluid within the GB (3), common duct (2), and intrahepatic bile ducts (1). A portion of the pancreatic duct (6) and fluid-filled duodenum (5) are also seen on this plane of section. **Right** Section from an MRCP study shows the GB, cystic duct (6), and common hepatic (3) and intrahepatic ducts (1) as well as a portion of the pancreatic duct (4), which was better seen on other planes of section.

**Left** CT angiogram shows enhancing arteries, including the common hepatic (3), gastroduodenal (6), splenic (3), and superior mesenteric arteries (2). CT and MR angiography usually make catheter angiography unnecessary for diagnosis, reserving this for interventions. **Right** Venous-phase, contrast-enhanced MR angiogram shows bright enhancement of venous structures, including the PVs (4) and hepatic veins (5). Portions of the splenic (6) and superior mesenteric vein (7) are included in this plane.

**Left** In this 1st axial CECT, the normal pancreas is seen as a homogeneous, soft tissue density viscus lying just ventral to the splenic vein (5), which lies in a groove along the dorsal surface of the pancreatic body (3). The pancreatic tail lies on a more cephalic plane and inserts into the hilum of the spleen (3). The stomach (6) lies just ventral to the pancreas. **Right** More caudal section shows most of the pancreas, including the body, neck (3), head (2), and uncinate process (6), which lies dorsal to the superior mesenteric vein (6).