Current Concepts

IMAGING OF THE HEPATOBILIARY TRACT

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OVER the past two decades, ultrasonography and computed tomography (CT) have emerged as the principal imaging methods for diagnostic examination of the liver and biliary tree. The other noninvasive imaging techniques, including magnetic resonance imaging (MRI), oral cholecystography, and nuclear scintigraphy, are used for difficult diagnostic problems, and invasive studies, such as angiography and direct cholangiography (transhepatic or retrograde), are increasingly used for treatment.

RECENT TECHNICAL ADVANCES

Advances in electronics have improved diagnostic imaging. Perhaps the most important advance in liver imaging has been the introduction of helical or spiral CT scanning.[1] With conventional CT scanners, the CT table remains stationary while the x-ray tube makes a single 360-degree rotation. In contrast, with helical scanners the table moves and the x-ray tube rotates continuously. This shortens a liver CT examination from 2 to 5 minutes to about 30 seconds. Consequently, the organ can be examined while the patient holds one or two breaths, greatly reducing artifacts due to nonuniform breathing. In addition, the liver can be scanned with intravenous contrast material during peak hepatic enhancement.[2] Newer applications, such as CT angiography, permit the noninvasive evaluation of vascular structures with rapid computer reformatting of the axial data into standard angiographic projections.[3] Vascular imaging with color-flow Doppler techniques has expanded the role of ultrasonography to permit the rapid evaluation of vessel patency, the direction of blood flow, and tissue perfusion without the administration of contrast material.[4]

RIGHT-UPPER-QUADRANT PAIN

Ultrasonography is the preferred method for diagnostic imaging of the liver and biliary tree in patients with acute right-upper-quadrant pain.[5] Ultrasonography is exceedingly sensitive (>95 percent) for gallbladder stones, and it permits the simultaneous evaluation of adjacent structures, such as the kidney.[6] Gallstones, gallbladder-wall thickening, and localized tenderness over the gallbladder (a sonographic Murphy's sign) correlate highly with the presence of acute cholecystitis.[7] However, thickening of the gallbladder wall by itself is nonspecific, because other conditions, such as hepatitis, ascites, adenomyosis, gallbladder carcinoma, and acquired immunodeficiency syndrome–associated cholangiopathy may also result in a thickened gallbladder wall.[8] CT is less reliable for demonstrating gallbladder-wall abnormalities, and its sensitivity for detecting gallstones is also considerably lower, since cholesterol gallstones can have the same density as bile.[9] Cystic-duct calculi are difficult to visualize ultrasonographically, so for patients whose clinical presentation is incongruent with the imaging findings, hepatobiliary scintigraphy may be used to evaluate the functional patency of the cystic duct.[10] Hepatobiliary scintigraphy, however, is of limited value in patients who have nonfunctioning gallbladders because of prolonged fasting or severe hepatic dysfunction.

Ultrasonography is less sensitive (about 75 percent for dilated bile ducts and 50 percent for nondilated ducts) for detecting choledocholithiasis, since gas in the duodenum can create an acoustic curtain that obscures visualization of the distal common bile duct.[11] The sensitivity of CT for detecting choledocholithiasis is similar (about 75 percent).[12] Hence, direct cholangiography (transhepatic or endoscopic retrograde) is often used in patients when there is a strong suspicion of choledocholithiasis. An advantage of endoscopic retrograde cholangiography is that after there has been diagnostic confirmation of choledocholithiasis, a therapeutic intervention such as stone extraction or papillotomy can be performed immediately. Recently, MRI cholangiography has emerged as an alternative to endoscopic retrograde cholangiography, averting the need for invasive diagnostic testing in patients who are unlikely to require any therapeutic intervention. With MRI cholangiography no contrast material is administered, but native high signal intensity of fluid on T_2-weighted images permits imaging of the biliary tree (Fig. 1).[13] A preliminary study has found that the sensitivity of MRI cholangiography for detecting choledocholithiasis is over 90 percent.[14]

OBSTRUCTIVE JAUNDICE

In patients with posthepatic biliary obstruction, ultrasonography or CT may be used in the initial evaluation. Although these techniques are both equally reliable in identifying the level of biliary obstruction, ultrasonographic evaluation of the retroperitoneum

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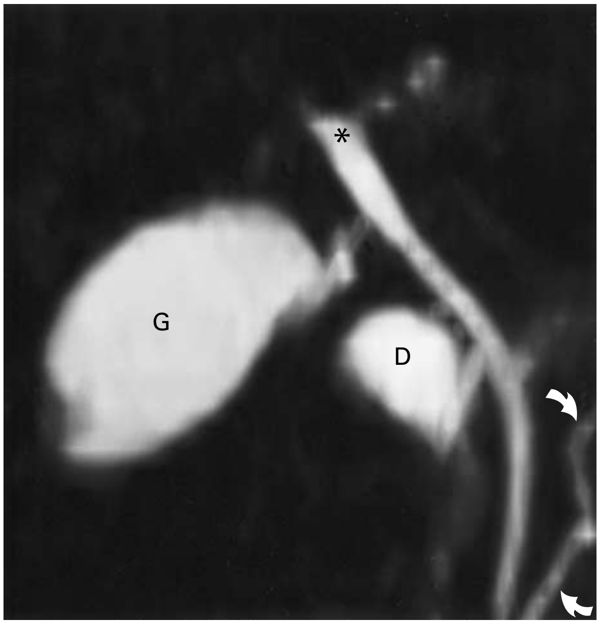

Figure 1. MRI Cholangiogram in a Normal Subject.

The asterisk indicates the common bile duct, and the arrows indicate the distal portion of the pancreatic duct. D denotes duodenum, and G gallbladder.

may be limited if there is gas in any overlying bowel. Thus, CT provides a more comprehensive examination that permits evaluation of the liver, biliary tree, pancreas, portal and retroperitoneal lymph nodes, and vascular structures.[15] In patients with cholangiocarcinoma, periportal metastases, or ampullary tumors, no discrete mass may be identified. However, an abrupt change in the caliber of the bile duct from dilated to normal is highly suggestive of a malignant obstruction. In contrast, gradual tapering is more consistent with a benign stricture, such as may occur in patients with chronic pancreatitis.[16]

DETECTION OF METASTASES

Contrast-enhanced CT has become the primary imaging method for screening evaluations of the liver in patients with a history of cancer.[17] Iodinated contrast material can increase the difference in density between tumor and normal liver, but it is critical to pay close attention to the way the contrast medium is administered (how much and at what rate) and the timing of scanning in relation to the injections of contrast medium (Fig. 2).[18] The principal advantage of CT is that it permits a more comprehensive examination and allows simultaneous evalu-

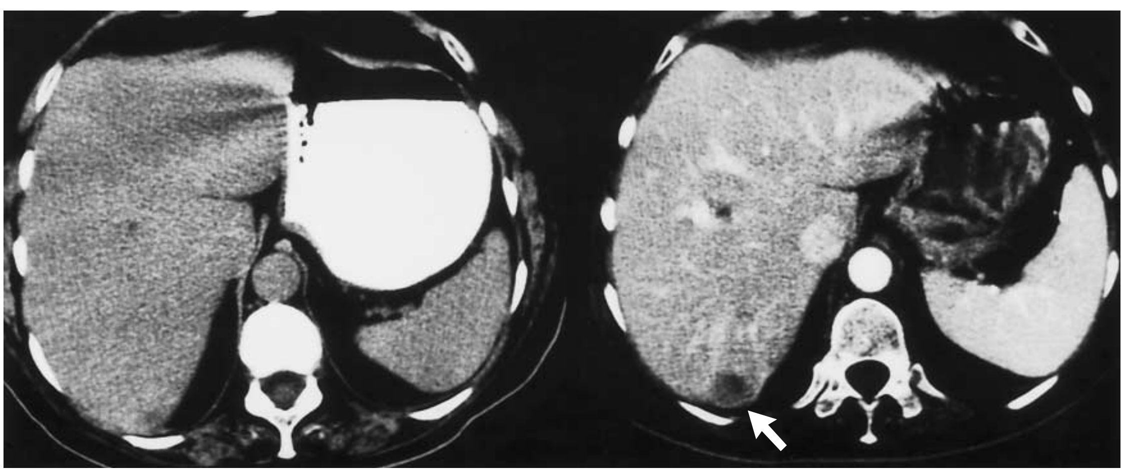

Figure 2. Metastasis Detected by CT.

The image at the left was obtained before the use of contrast material, and the image at the right was obtained with contrast enhancement. The metastasis (arrow) is visualized better on the contrast-enhanced image. Iodinated contrast material in liver CT should produce pronounced vascular enhancement, which indicates that there is adequate enhancement to allow increased contrast between liver parenchyma and metastases.

ation of the extrahepatic abdomen and even the pelvis and chest. The sensitivity of ultrasonography and CT for detecting the presence or absence of metastatic disease in the liver is about 85 percent.[19,20] However, for the identification of individual lesions the sensitivity of these techniques is considerably lower. About one in three lesions is missed,[19,20] usually lesions under 2 cm in diameter. Although helical scanning has improved the performance of CT, its sensitivity for detecting small lesions is under 60 percent.[21]

Liver-cancer staging (to determine the number and location of individual lesions) is most commonly required for patients with metastatic colon cancer who may be eligible for hepatic resection. In such patients, CT during arterial portography is used to examine the liver preoperatively. In this technique, contrast material is administered through the superior mesenteric artery or the splenic artery,[18] which results in selective enhancement of the liver through the portal vein, because hepatic cancers are primarily perfused through the hepatic artery.[22] Alternatively, intraoperative ultrasonography may be used for the staging of liver cancer.[20] Both CT during arterial portography and intraoperative ultrasonography have a sensitivity in excess of 85 percent for detecting individual liver lesions.[20,23]

In patients with fatty infiltration of the liver, the sensitivity of CT scanning and ultrasonography for detecting liver lesions is lower. Hence, in these patients and those who may be allergic to iodinated contrast material, MRI of the liver should be considered.[24] MRI without contrast enhancement has a sensitivity of about 85 percent for detecting the presence of liver cancer and about 75 percent for detecting the individual lesions.[25] In patients with treated lesions, positron-emission scintigraphy, which detects cellular glucose metabolism, is useful for determining the presence of viable tumor.[26]

INCIDENTAL LIVER MASSES

At least 20 percent of adults have benign liver tumors.[27] Hence, in patients with incidental liver masses and those undergoing workups to detect liver metastases, the classification of focal lesions is an important objective. In the appropriate clinical setting, ultrasonographic features and contrast-enhanced CT characteristics are adequate for classifying the majority of focal liver lesions, particularly cysts, metastases, and hemangiomas (Fig. 3).[28] Indeed, whenever possible, follow-up imaging can be used to confirm whether a lesion is benign or malignant. When the ultrasonographic or CT features are atypical, however, and when the clinical presentation and the radiologic findings are incongruent, MRI has become the preferred imaging method for classifying liver lesions. MRI can identify over 90 percent of liver hemangiomas and the vast majority of cases of focal

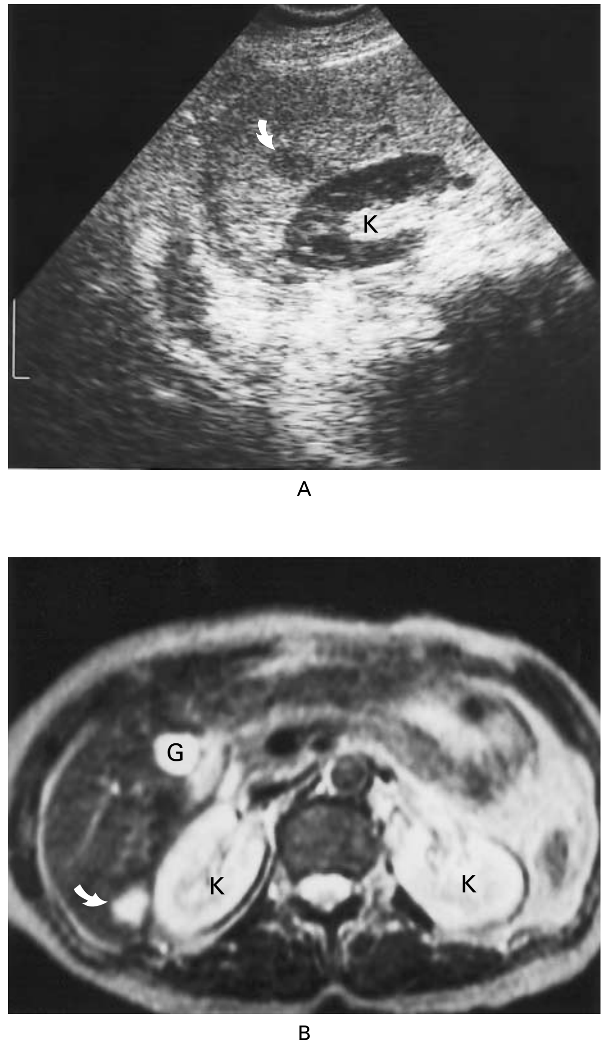

Figure 3. Hemangioma.

A hypoechoic mass (arrow) lying adjacent to the kidney has an indeterminate appearance on ultrasonography (Panel A). On T_2-weighted MRI, however, the mass has the high signal intensity characteristic of a liver hemangioma (Panel B). K denotes kidney, and G gallbladder.

nodular hyperplasia.[29,30] It is particularly adept at identifying focal fatty infiltration of the liver, which appears as a focal hepatic mass on ultrasonography and CT. MRI is also useful for evaluating livers with heterogeneous fatty infiltration.[31] Many nuclear scintigraphic tests are available, such as technetium-labeled red-cell study to identify hemangioma, hepatobiliary scintigraphy to identify focal nodular hyperplasia and liver-cell adenoma, and scintigraphy targeted to reticuloendothelial cells with technetium-labeled sulfur colloid examination to identify focal nodular hyperplasia. Each of these tests identifies only one type of lesion, whereas a single MRI examination can classify a variety of lesions. Alternatively, image-guided fine-needle aspiration or biopsy of the lesion may be considered; these techniques are safe even with vascular lesions such as hemangiomas.[32] Increasingly, lesions smaller than 1 cm in diameter are being detected by CT. Although these lesions are difficult to classify, most are likely to be benign, even in patients with known cancer, and they are therefore evaluated with follow-up examinations.[33]

CIRRHOSIS

Gross morphologic features of a cirrhotic liver, such as an enlarged caudate lobe or a nodular surface, can be seen with cross-sectional imaging. Unfortunately, these findings are present only in advanced disease.[34] Therefore, diagnostic imaging does not have an important role in the diagnosis of liver cirrhosis. Ultrasonography and CT are, however, helpful in evaluating complications of cirrhosis, such as vascular patency and neoplasia.

Regular liver screening is recommended in patients with a chronic liver disease, such as hepatitis or hemochromatosis, who may be at risk for hepatocellular carcinoma.[35] Despite the low sensitivity of ultrasonography (about 50 percent) in detecting tumors in advanced cirrhosis, repeated imaging is thought to be appropriate for identifying the slow-growing, well-differentiated tumors that may be most suited to surgical intervention.[36,37] In patients with a high likelihood of hepatocellular carcinoma, however, such as those with elevated levels of serum alpha-fetoprotein, arterial-phase MRI or helical CT scanning may be used to identify a suspected hepatoma.[38] When they are scanned during the arterial phase (about 25 to 45 seconds after the start of injection), highly vascularized tumors appear against a background of relatively unenhanced liver that is primarily enhanced during the portal venous phase (about 70 to 90 seconds after the start of injection) (Fig. 4). When a liver mass is detected at a screening examination, MRI may be used to differentiate among regenerating nodules, dysplastic nodules, and hepatocellular carcinoma.[39]

TRAUMA

In patients with abdominal trauma, rapid diagnostic imaging of the entire abdomen and pelvis is generally required. In patients with splenic injury, for example, pelvic imaging is critical because blood may be located in the lower pelvis. Therefore, contrast-enhanced CT is the study of choice. CT scanners are increasingly located in emergency rooms and staffed 24 hours a day to allow urgent studies even of relatively unstable patients. With the current scanners, large areas of the body such as the chest or abdomen can be scanned while the patient holds a few breaths. In hepatic evaluation, both ultrasonography and contrast-enhanced CT are highly sensitive, and equally so, for the detection of subcapsular and perihepatic collections, liver lacerations, intraparenchymal hematomas, and foci of active arterial bleeding.[40] However, collections of fluid (blood or bile) in areas remote from the liver are better demonstrated with CT. In patients with active leakage of bile, hepatobiliary scintigraphy may be used, although evidence of leakage can also be confirmed after percutaneous drainage of a suspected biloma.[10]

INFECTION

In patients with a suspected liver abscess (bacterial or parasitic), both ultrasonography and contrast-enhanced CT can be used to evaluate the liver. CT is better for detecting small abscesses, as well as for identifying extrahepatic collections. In addition, air and calcification (echinococcal cysts) are detected better with CT scanning. Differentiating a liver tumor from an abscess is not generally feasible, however, and an image-guided biopsy or aspiration may be necessary for diagnosis. Portal venous air can be detected on both ultrasonography and CT but is more readily detected on CT.

EVALUATION AFTER LIVER TRANSPLANTATION

Hepatic imaging in transplanted livers is generally undertaken with both ultrasonography and CT. The former is preferred for noninvasive evaluation of the hepatic artery and portal vein, whereas the latter is preferred for the detection of abscesses (including extrahepatic ones), bilomas, and infarcts. Direct or indirect cholangiographic evaluation may be required for the evaluation of dilated bile ducts.[41]

HEPATITIS

Diagnostic imaging does not have a role in the examination of patients with acute hepatitis. There are no specific findings in such patients, and the examination may be entirely normal.

IRON OVERLOAD

MRI is the most sensitive technique for identifying hepatic iron overload, and it allows simultaneous evaluation of the spleen and pancreas. This technique has been shown to permit parenchymal iron overload (hemochromatosis) to be distinguished from reticuloendothelial iron overload (hemosiderosis).[42] Preliminary work shows that MRI can also quantitate hepatic iron, which may be useful in monitoring iron-depletion therapy.[43] A hyperdense liver on CT scanning is also indicative of iron overload, but this is a far less sensitive examination than MRI. Drugs such as amiodarone also increase liver density on CT.[44]

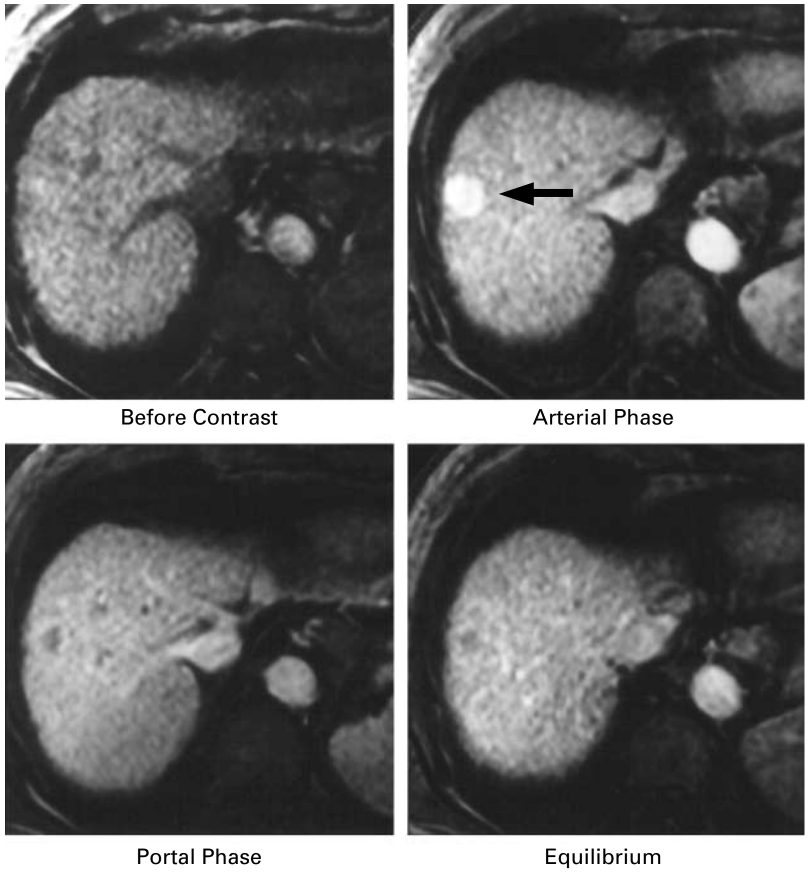

Figure 4. Hepatocellular Carcinoma.

A T_1-weighted MRI scan is shown before the use of contrast material and during the arterial, portal, and equilibrium phases after the administration of gadolinium-based extracellular contrast material. The tumor (arrow) is most conspicuous in the arterial-phase image. Liver imaging with CT or MRI during the arterial phase is critical for the detection of hepatocellular carcinoma in high-risk patients.

VASCULAR DISEASES

Color-flow Doppler ultrasonography is especially suitable for determining the presence and direction of flow in the hepatic vascular system.[45,46] Contrast-enhanced CT can also provide this information, but it is less reliable than ultrasonography because of limited flexibility in the imaging planes and the short time available for imaging the vessels before the iodinated contrast medium is redistributed into the extracellular compartment.[47] When ultrasonographic imaging is not easy, as in patients with fatty livers, MRI may be considered because it can also directly image the vascular system while providing information on the direction of blood flow.[48] However, none of these techniques allow adequate quantification of blood flow.

CONCLUSIONS

With the exception of gallbladder examination, CT is rapidly emerging as the preferred technique of hepatobiliary imaging. An important reason is that whereas ultrasonography is a targeted examination, CT offers a more comprehensive analysis of the liver and extrahepatic abdomen and pelvis. Internists should consider the more global examination, particularly when the differential diagnosis is broad. Another advantage of CT scanning is that it is much less dependent on the operator's skills. This is critical when tumor measurements are used on follow-up examinations to evaluate therapy. Nonradiologists also prefer CT images because they are much easier to read and understand.

Finally, in today's health care environment, no discussion would be complete without a comment on the costs of imaging. The Medicare reimbursement for abdominal CT is about twice that for ultrasonography. With technical advances, the time required for a CT examination continues to decrease, and one can now be completed in under 10 minutes, whereas it is hard to reduce the time needed for an ultrasound examination. The difference in cost between the two is likely to decline and make CT even more attractive for hepatic imaging.

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