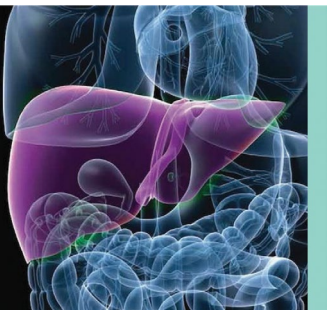

Computed Tomography Versus Magnetic Resonance Imaging for Hepatic Lesion Characterization/ Diagnosis

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Computed tomography (CT) and magnetic resonance imaging (MRI) are both extremely helpful in the diagnosis of liver lesions. Each has strengths and weaknesses for particular indications, and having an appropriate history is important in choosing the best modality for the patient.

In CT, there are several protocols to choose from when imaging the abdomen and, in particular, when imaging the liver. In addition to the unenhanced scan, a dedicated liver CT has three phases after intravenous contrast agent administration: the late arterial (25-35 seconds), portal venous (60-75 seconds), and delayed (3-5 minutes) phases.

Liver parenchyma is mainly supplied by the portal vein, and thus predominantly enhances during the portal venous phase. Liver lesions, however, are supplied only by the hepatic artery.[1] The multiphasic CT and magnetic resonance protocols take advantage of the various enhancement patterns of each type of lesion to noninvasively characterize them. For instance, hypervascular lesions appear brighter than the background liver on the arterial phase, whereas hypovascular ones are darker on the portal venous phase when the background liver enhances maximally. Moreover, peculiar enhancement patterns are typically seen in some liver lesions, for example, early peripheral nodular enhancement and delayed fill-in is characteristic of liver hemangioma.

For assessment of focal liver lesions, standard MRI protocol should include:

Abbreviations: CC, cholangiocarcinoma; CSI, chemical shift imaging; CT, computed tomography; DWI, diffusion-weighted imaging; FAP, familial adenomatous polyposis; FNH, focal nodular hyperplasia; GFR, glomerular filtration rate; GSD, glycogen storage disease; HCA, hepatocellular adenoma; HCC, hepatocellular carcinoma; HNF-1A, hepatocyte nuclear factor-1 alpha; LI-RADS, Liver Imaging Reporting and Data System; MODY3, maturity-onset diabetes of the young; MRCP, magnetic resonance cholangiopancreatography; MRI, magnetic resonance imaging; OCP, oral contraceptive pill; SI, signal intensity; T2WI, T_2-weighted imaging.

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1. T_2-weighted sequences
   - Half-Fourier-acquired single-shot turbo spin-echo: provides an anatomic overview and highlights the bright signal of fluid-containing spaces and structures, such as gallbladder and bile ducts
   - T_2 fat-saturated: assesses T_2-signal characteristics of liver lesions
2. T_1-weighted sequence
   - T_1 in- and opposed-phase: drop of signal intensity (SI) on opposed-phase relative to in-phase images indicates microscopic fat in a liver lesion, while a drop of signal on in-phase images is detected in a siderotic liver nodule as a result of iron deposition
   - T_1 fat-saturated: T_1 bright signal in a liver lesion can be seen in a hemorrhagic cyst, hemorrhagic metastasis, or melanoma metastasis
3. Diffusion-weighted imaging (DWI): improves sensitivity for the detection of small, even subcentimeter, focal lesions[2]
4. Multiphase imaging before and after intravenous injection of an extracellular contrast agent includes precontrast, late arterial, portal venous, and delayed phases

Newer hepatobiliary-specific agents used in MRI are specifically taken up by hepatocytes and excreted in the bile. The enhancement of normal liver parenchyma and bile ducts peaks at the hepatobiliary phase (20-60 minutes), helping to detect nonhepatocellular origin lesions, such as metastases, which have no functioning hepatocytes to take up the contrast and will be hypoenhancing during the hepatobiliary phase, while functioning hepatocytes of lesions of hepatocellular origin, such as focal nodular hyperplasia (FNH), take up the contrast and are enhancing during the hepatobiliary phase.[3]

Liver MRI protocol varies according to the provided clinical history. In patients who have diffuse liver disease and a suspected liver lesion, a standard liver MRI is performed with multiphasic postcontrast imaging. If the patient presents with a cholestatic liver profile, magnetic resonance cholangiopancreatography (MRCP) should be added to assess the degree and level of biliary obstruction and to determine whether the obstructive lesion is periductal or endoluminal. In asymptomatic patients who have incidentally detected liver lesions, hepatobiliary-specific agents may be used instead of extracellular fluid contrast agents to differentiate FNH from hepatocellular adenoma (HCA). Hepatobiliary contrast agent-enhanced MRI is also recommended in oncology patients who need accurate detection and mapping of hepatic metastases.

Each modality has advantages and specific limitations (Table 1). CT attenuation or MRI signal characteristics are exploited to characterize liver lesions. Awareness of the key imaging features would help to decide the modality of choice for each diagnostic category (Table 2). In this review, we discuss the spectrum of imaging features of the most common focal hepatic pathologies (Table 3).

SIMPLE HEPATIC CYST

Cysts are incidentally discovered on cross-sectional imaging of the liver and show CT fluid attenuation or MRI fluid SI without enhancement. The hyperintense T_2 signal on MRI similar to cerebrospinal fluid is characteristic of benign cysts. CT is usually sufficient for detecting cysts, but in cases of lesions <1 cm, MRI may be more useful in differentiating cysts from subcentimeter metastases.[4,5]

HEPATIC ABSCESS

The imaging features of liver abscess vary according to its evolution. At an early stage, it can appear as a heterogeneous solid mass on CT, whereas a mature abscess has a necrotic hypoattenuating center and enhancing rim.[3]

TABLE 1. ADVANTAGES AND LIMITATIONS OF CT AND MRI IN LIVER IMAGING

	CT	MRI
Advantages	• Quick to perform • Accessible • No need for long breathhold • Scanning the entire abdomen and pelvis is feasible	• No radiation • Unenhanced MRI can be performed safely in pregnant patients • Better tissue characterization • Privilege of hepatocyte-specific agents
Limitations	• Radiation exposure • Risk for contrast nephropathy	• Longer examination time • Needs patient's cooperation • Small risk for nephrogenic systems sclerosis in very low GFR • May be contraindicated with pacemaker and metal implants • Lower image quality in ascites • Uptake of hepatocyte-specific agents is compromised in impaired hepatocyte function

TABLE 2. PROS AND CONS OF CT VERSUS MRI IN CHARACTERIZATION OF LIVER LESIONS

	CT	MRI
Pros	• Detection of calcification (e.g., calcified calculi, calcified metastasis, granuloma, chronic hematoma, hydatid disease) • Better detection of gas within a lesion (e.g., necrotic tumor and abscess) • Initial assessment and follow-up of hepatic metastasis • Diagnosis of HCC and monitoring treatment response • Vascular invasion in perihilar CC • Assessment of acute bleeding/rupture of HCC and HCA	• Persistent hyperintensity on heavily T2WI helps differentiate cysts and hemangioma from metastasis • Superior to CT in diagnosis of FNH, especially with hepatobiliary contrast agents • Detection of microscopic fat on CSI (e.g., in HCA and HCC) • Useful in categorizing HCA subtypes • Superior to CT in detection of delayed capsular appearance in HCC (major feature) • Hepatobiliary contrast agent MRI improves detection of HCC and small metastasis (<1 cm) • Accurate assessment of longitudinal extension in perihilar CC • DWI is highly sensitive for lesion detection • Can be used to assess most ancillary features in LI-RADS for liver observations in patients at risk for HCC
Cons	• Limited characterization of small lesions <1 cm, critical in surgical planning • Limited assessment of longitudinal extension in perihilar CC • Background liver steatosis and fibrosis affects the diagnostic accuracy • Limited diagnosis/differentiation of HCA and FNH	• Limited by susceptibility artifacts from surgical clips (after liver surgery) • Lesions close to the diaphragm are more prone to respiratory motion artifact • Overestimates vascular invasion in perihilar CC after stenting

The clinical and laboratory findings, including fever, right upper quadrant abdominal pain, neutrophilic leukocytosis, and elevated alkaline phosphatase, can be very useful for the diagnosis of abscess.[6] In some cases, however, it may be quite challenging to differentiate an abscess from a necrotic tumor, and biopsy with tissue diagnosis may be required.[6] Some features on MRI may help to make this distinction. The "double target sign" refers to a layered-wall enhancement surrounding the abscess cavity where the outer layer shows a delayed enhancement relative to the inner one.[6] In one study, this lesion was more frequently found in abscesses. However, delayed washout of the outer layer was more noted in malignant tumors.[7]

HEMANGIOMA

The typical features of hemangioma of early peripheral interrupted enhancement and delayed progressive enhancement (fill-in) are sufficient to make the diagnosis on CT and MRI.[8] However, MRI may be required in some atypical hemangiomas, particularly in patients with a known malignancy or at risk for hepatocellular carcinoma (HCC).[9] Capillary hemangiomas appear as small hyperenhancing lesions and may be difficult to differentiate from small hypervascular tumors. On MRI, marked hyperintensity on heavily T_2-weighted imaging (T2WI) is helpful to diagnose a hemangioma.[8] Sclerosed hemangiomas have atypical imaging appearance on CT and MRI. A comparison with the previous examination is advisable to determine whether typical features of hemangioma were present in this location previously. A "bright dot sign" is a helpful feature to diagnose this type of hemangioma and refers to a peripheral enhancing dot without complete delayed enhancement. However, a biopsy may still be needed to confirm the diagnosis because of overlapping appearances between sclerosed hemangiomas, cholangiocarcinoma (CC), and metastases.[8,9]

FNH

On CT/MRI, FNH shows marked arterial phase hyperenhancement and becomes isoenhancing to the liver parenchyma during the portal venous and delayed phases.[3] Hepatobiliary contrast agent-enhanced MRI has the advantage over CT by showing contrast taken up by the functioning hepatocytes within the FNH, which enhances during the hepatobiliary phase. This allows confident diagnosis of FNH and differentiating it from HCAs, HCC, and metastasis.[10] In a systematic review, gadoxetic acid (hepatobiliary contrast agent)-enhanced MRI was able to discriminate between HCA and FNH on the hepatobiliary phase with 91% to 100% sensitivity and 87% to 100% specificity.[11]

HCA

HCAs are difficult to accurately diagnose on CT due to a similar appearance to benign lesions (e.g., FNH) and malignant tumors (e.g., HCC).[9] However, MRI can be useful

TABLE 3. HCA SUBTYPES, EPIDEMIOLOGY, AND IMPORTANT IMAGING FEATURES AT MRI

	Frequency	Risk Factors and Associations	Complications	Signal Dropout on CSI	T_2 Signal	Enhancement
Inflammatory HCA	40%-50%	More in women, OCPs, obesity, and systemic inflammatory syndromes	Highest risk for hemorrhage	Absent or only focal	Markedly hyperintense more toward the periphery "atoll sign"	Strong arterial enhancement, persists on the portal venous and delayed phases
HNF-1A mutation HCA	30%-35%	Almost exclusively in women OCPs MODY3	Low risk for complications in tumors <5 cm	Diffuse signal dropout	Isointense to slightly hyperintense	Moderate arterial enhancement, does not persist on the portal venous phase
β-Catenin activated HCA	10%-15%	More in men Anabolic steroids, GSD, and FAP	Highest risk for malignancy	No specific feature May mimic HCC showing strong arterial enhancement and portal venous washout		
Unclassified HCA	<5%	No specific gene mutation	No specific imaging features			

in diagnosing HCA and in recognizing HCA subtypes.[12] Inflammatory HCAs usually demonstrate high SI on T2WI and marked hyperenhancement on the arterial phase, which persists on the portal and delayed phases. These MRI features have 85% to 88% sensitivity and 88% to 100% specificity for the diagnosis of inflammatory HCA.[13,14] In HCA with hepatocyte nuclear factor-1 alpha (HNF-1A) mutation, diffuse intratumoral microscopic fat is shown as diffuse and homogeneous signal dropout on T_1 opposed-phase relative to in-phase images (Fig. 1), with a sensitivity of 87% to 91% and specificity of 89% to 100%.[13,14] β-Catenin-activated HCA and unclassified HCA have no specific imaging features on MRI. Thus, if a suspected HCA cannot be confidently classified as either an inflammatory subtype or an HNF-1A mutated subtype, a biopsy may be considered for definitive diagnosis.[10]

CHOLANGIOCARCINOMA

On CT/MRI, CC may appear as a biliary stricture in periductal infiltrative (perihilar) CC, hypovascular tumor with peripheral enhancement in mass-forming CC, or intraductal nodular mass.[15] CT provides an accurate assessment of vascular invasion but tends to underestimate the biliary extent of perihilar CC.[16] MRCP is an accurate, noninvasive method for evaluation of the biliary extension of the tumor and the entire biliary tree, with an accuracy rate of 95%. However, MRCP may suffer motion artifact.[17] Although vascular invasion also can be identified on MRI and magnetic resonance angiography, it may be overestimated because of misinterpretation of the peritumoral inflammation and fibrosis as tumor infiltration, especially in patients after biliary stenting. Therefore, unless immediately required, stenting should be delayed after staging MRI.[18] In mass-forming CC, hepatobiliary-specific agent MRI, including DWI, is more accurate in detecting intrahepatic metastasis. On the contrary, it may mask perihilar CC because of the simultaneous enhancement of liver parenchyma during the hepatobiliary phase.[17]

METASTASIS

CT is the preferred imaging modality for the initial assessment and posttreatment surveillance because it allows an excellent overview of the primary tumor and other potential sites for metastases.[19] Calcified metastases, such as colorectal metastases, are better assessed with CT[20] (Fig. 2). MRI has better sensitivity in the detection of small liver metastasis that can be missed on CT[21] (Fig. 3). MRI is also

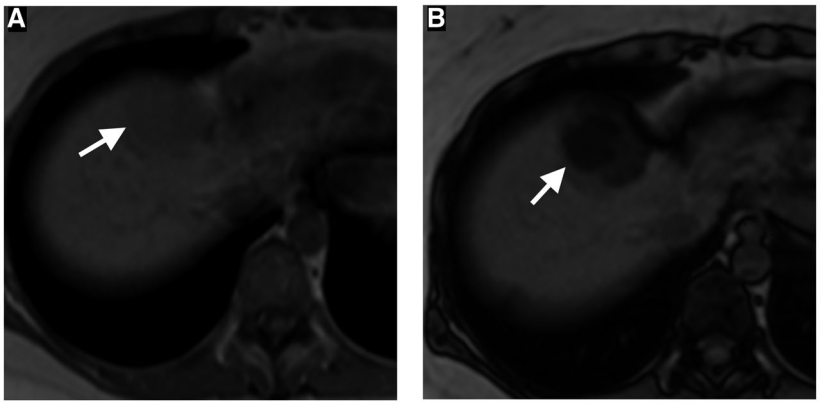

FIG 1 A 35-year-old woman with HNF-1A mutation hepatic adenoma. Axial in-phase (A) and out-of-phase (B) chemical shift MRIs show significant drop of signal on out-of-phase image because of intravoxel fat, a characteristic imaging feature of HNF-1A mutation hepatic adenoma.

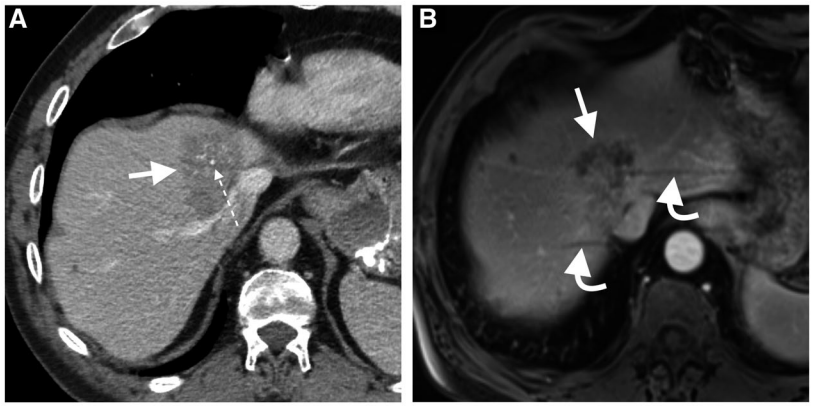

FIG 2 A 65-year-old woman with hepatic metastasis from mucinous colorectal cancer. Central calcification (dotted arrow) within a hypoattenuating liver mass is seen only on portal venous phase CT image (A). The mass is heterogeneous hypoenhancing on the axial dynamic postcontrast portal venous-phase MRI (B), but calcification is not seen. Also, note the respiratory motion artifacts on MRI (curved arrows), a recognized limitation of MRI in the assessment of liver lesion close to the hepatic dome.

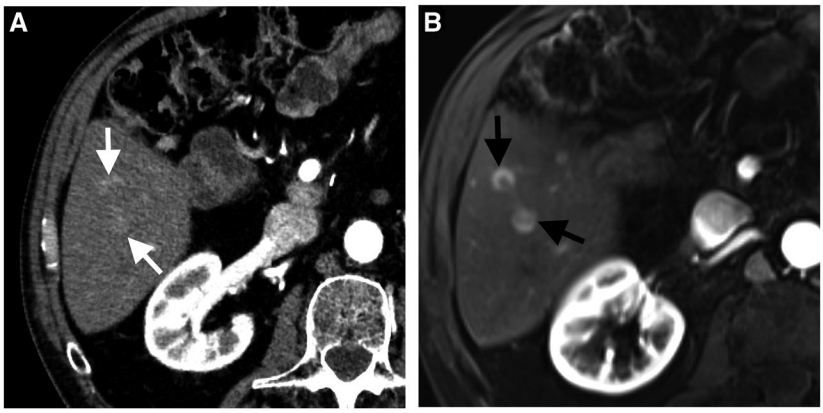

FIG 3 A 43-year-old man with hepatic metastasis from pancreatic neuroendocrine tumor. Axial arterial-phase CT image (A) shows two subtle arterial-phase hyperenhancing metastatic nodules in hepatic segment 6 (white arrows). Axial arterial-phase dynamic postcontrast MRI (B) shows improved visibility of subtle metastases (black arrows).

useful in presurgical planning for resection of metastasis or when hepatic metastasis precludes resection of the primary tumor (e.g., pancreatic cancer).[19,22] In one study, gadoxetic acid (hepatobiliary contrast agent)-enhanced MRI had a sensitivity of 86% for the detection of colorectal hepatic metastases ≤1 cm compared with 50% with contrast-enhanced CT. Gadoxetic acid-enhanced MRI combined with DWI had the highest sensitivity (95%).[23] Moreover, liver steatosis is a known limitation for the assessment of small hypoattenuating metastases on CT; therefore, MRI is a problem-solving tool in this condition.[19,22]

CONCLUSIONS

CT and MRI have been established cross-sectional imaging modalities useful for the evaluation and characterization of liver lesions. CT is usually more easily available, and scan time is short. MRI has a better contrast resolution and is an excellent problem-solving tool. Choosing which modality to start with is dependent on many factors and requires good communication between requesting physicians and the radiologist to optimize the imaging modality and technique.

CORRESPONDENCE

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