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PERSPECTIVE

White paper of the Society of Abdominal Radiology hepatocellular carcinoma diagnosis disease-focused panel on LI-RADS v2018 for CT and MRI

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Abstract

The Liver Imaging and Reporting Data System (LI-RADS) is a comprehensive system for standardizing the terminology, technique, interpretation, reporting, and data collection of liver imaging with the overarching goal of improving communication, clinical care, education, and research relating to patients at risk for or diagnosed with hepatocellular carcinoma (HCC). In 2018, the American Association for the Study of Liver Diseases (AASLD) integrated LI-RADS into its clinical practice guidance for the imaging-based diagnosis of HCC. The harmonization between the AASLD and LI-RADS diagnostic imaging criteria required minor modifications to the recently released LI-RADS v2017 guidelines, necessitating a LI-RADS v2018 update. This article provides an overview of the key changes included in LI-RADS v2018 as well as a look at the LI-RADS v2018 diagnostic algorithm and criteria, technical recommendations, and management suggestions. Substantive changes in LI-RADS v2018 are the removal of the requirement for visibility on antecedent surveillance ultrasound for LI-RADS 5 (LR-5) categorization of 10-19 mm observations with nonrim arterial phase hyper-enhancement and nonperipheral "washout", and adoption of the Organ Procurement and Transplantation Network definition of threshold growth (≥ 50% size increase of a mass in ≤ 6 months). Nomenclatural changes in LI-RADS v2018 are the removal of -us and -g as LR-5 qualifiers.

Key words: LI-RADS—v2018—CT—MRI—HCC

Hepatocellular carcinoma (HCC) is the second leading cause of cancer-related death world-wide and the most common primary liver malignancy, with nearly 780,000 new cases diagnosed annually [1]. While most cases of HCC occur in Eastern Asia and Northern Africa, the incidence of HCC is rising in many regions of the world, including the United States [2]. The risk factors for HCC are well-established and include cirrhosis, chronic viral hepatitis infection from hepatitis B virus (HBV), alcoholic steatohepatitis, and nonalcoholic steatohepatitis (NASH) [3–5]. Patients diagnosed with symptomatic HCC have a dismal prognosis with a median 5-year survival rate of ~10%, however, this substantially improves to ~58% for patients receiving curative therapy with liver resection or liver transplantation [6]. Such improvement underscores the importance of systematic screening and early diagnosis.

Imaging plays a crucial role in the management of patients with known or suspected liver cancer. Multiphasic cross-sectional imaging with contrast-enhanced computed tomography (CT) or magnetic resonance imaging (MRI) allows for confident non-invasive diagnosis of HCC with high specificity, allowing most patients to forego percutaneous biopsy and its associated risks, which include bleeding and tumoral seeding [7]. Given that HCC is most commonly diagnosed by non-invasive means, accurate image interpretation and consistent reporting by radiologists is imperative. HCC imaging and reporting systems address this need by providing a diagnostic algorithm, stringent criteria for HCC diagnosis, and reporting requirements. Such diagnostic systems and structured radiology reporting have been advocated by several societies and have been shown to improve consistency in reporting and overall positive predictive value (PPV) for malignancy diagnosis [8–11].

The Liver Imaging and Reporting Data System (LI-RADS) is a comprehensive system for standardizing the terminology, technique, interpretation, reporting, and data collection of liver imaging. Supported by the American College of Radiology (ACR), it has been developed by a multi-disciplinary team of diagnostic and interventional radiologists, hepatologists, hepatobiliary surgeons, and hepatopathologists in order to reduce interpretation variability and errors, allow for optimal communication between radiologists and referring physicians, and assist in decision-making and follow-up. LI-RADS is intended for use by radiologists, radiologists-in-training, healthcare professionals caring for patients with liver disease, and researchers. LI-RADS version 2018 (LI-RADS v2018) represents the fourth update of this reporting and data system; it was first released in 2011, followed by three updates in 2013, 2014, and 2017 [12–15]. LI-RADS is analogous to the Breast Imaging Reporting and Data System (BI-RADS) which has been widely implemented in breast imaging guidelines and has been shown to increase inter-observer agreement and heighten the PPV of breast imaging for malignancy diagnosis [16, 17].

LI-RADS v2018 diagnostic algorithm for CT and MRI

The CT/MRI LI-RADS diagnostic algorithm describes a four-step approach to the assessment of liver observations which stand out relative to composite background liver tissue, at multiphasic CT or MRI. It is intended for use only for untreated observations without a histologic

diagnosis in patients who are considered at high risk for HCC. The LI-RADS v2018 definition of "high risk for HCC" is detailed in a subsequent section of this article as are elaborations of the LI-RADS categories, major features of HCC, and ancillary features of HCC. Step 1 of the algorithm is the designation of a preliminary LI-RADS category (Fig. 1). Step 2 of the algorithm is the optional application of ancillary features for improved detection, increased confidence, or category adjustment excluding upgrading from LR-4 to LR-5, which is not allowed (Fig. 2). Step 3 is the application of tiebreaking rules in situations of diagnostic uncertainty; if a radiologist is unsure between two categories, the category with the lower certainty should be assigned (Fig. 3). Step 4 is the final check to verify that the assigned category is reasonable and appropriate (Fig. 3).

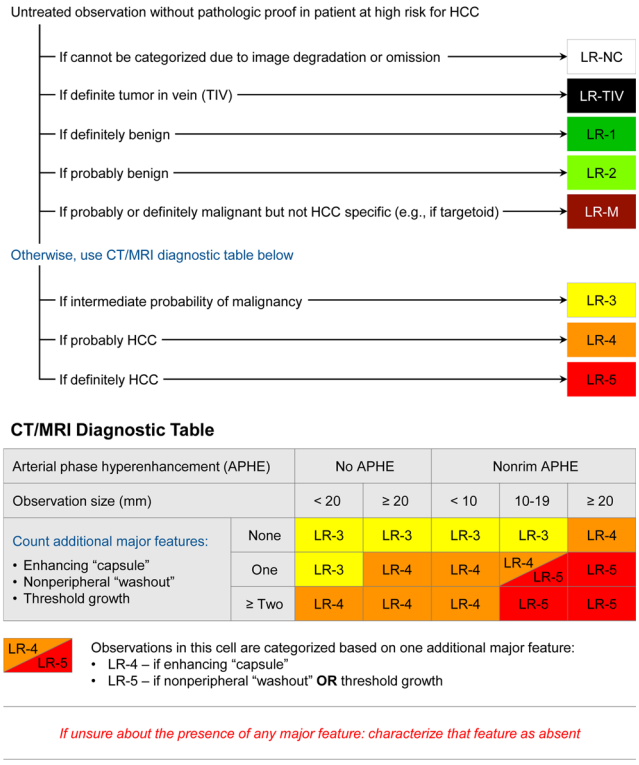


Fig. 1. Step 1 of the LI-RADS v2018 CT/MRI diagnostic algorithm for categorizing an untreated observation in patients at high risk for HCC.

Changes from LI-RADS v2017

The CT/MRI LI-RADS v2018 algorithm represents a short-term update to the CT/MRI LI-RADS v2017 algorithm. Motivated largely by the goal of aligning HCC diagnostic systems, these modifications facilitated integration of the LI-RADS diagnostic algorithm into the American Association for the Study of Liver Disease (AASLD) 2018 HCC clinical practice guidelines [18].

The following modifications were made to arrive at the v2018 algorithm:

Definition of threshold growth

The definition of **threshold growth** was revised and simplified. Threshold growth is now defined as size increase of a mass by ≥ 50% in ≤ 6 months (Figs. 4 and 5). Two other definitions of threshold growth used in the prior LI-RADS versions (i.e., a new observations ≥ 10 mm in ≤ 24 months and size increase of a mass by ≥

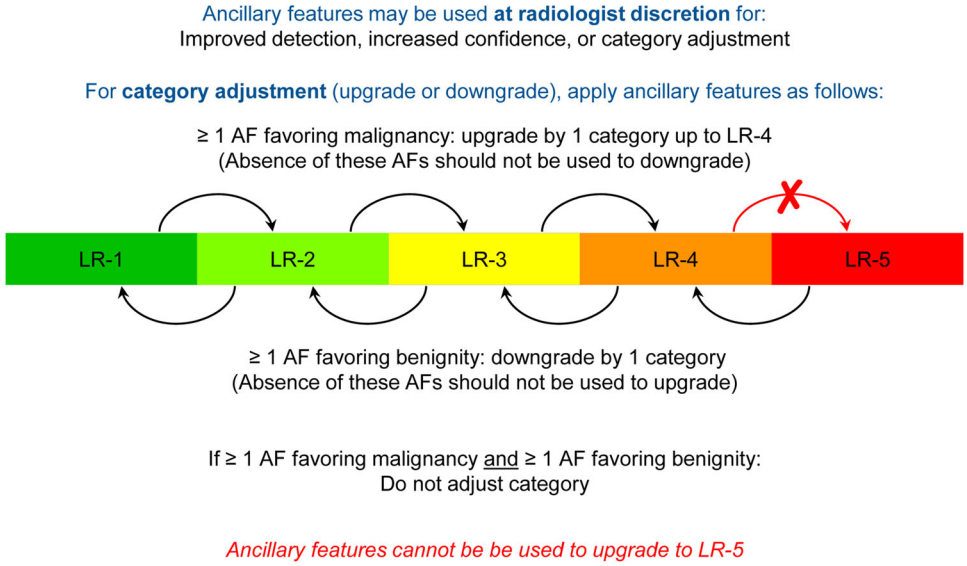


Fig. 2. Step 2 of the LI-RADS v2018 CT/MRI diagnostic algorithm: application of ancillary features.

100% in > 6 months) are considered subthreshold growth in v2018. Sub-threshold growth is an ancillary feature favoring malignancy in general, though not HCC in particular [19, 20]. The change in threshold growth definition impacts categorization in a subset of observations (Fig. 6).

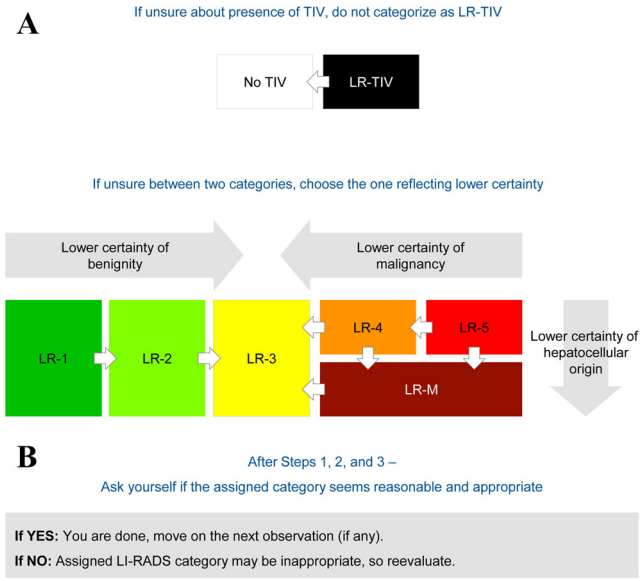


Fig. 3. Step 3 and Step 4 of the LI-RADS v2018 CT/MRI diagnostic algorithm.

The "diagonal cell"

The three substantive changes in v2018 all affect observations in the "diagonal cell" (Fig. 7). The "diagonal cell" contains observations with nonrim APHE and exactly one additional major feature (either non-peripheral "washout", enhancing "capsule" or threshold growth).

The LR-5g category was previously applied to observations 10–19 mm in size with nonrim arterial phase hyper-enhancement (APHE) on CT/MRI in addition to ≥ 50% increase in size in < 6 months, but without "washout" or "capsule". This category was originally introduced to facilitate translation to OPTN class 5 criteria—specifically OPTN 5A-g [12]. In LI-RADS v2018, 10-19 mm observations with APHE and threshold growth are now simply categorized LR-5, as the threshold growth definition is identical to that of OPTN.

The LR-5us category was previously applied to observations 10–19 mm in size with nonrim APHE, "washout" **and** visibility at antecedent screening ultrasound, in absence of either threshold growth or a "capsule". In LI-RADS v2018, the requirement for antecedent visibility on ultrasound has been removed, and a 10–19 mm observation with nonrim APHE and nonperipheral "washout" is categorized LR-5 (Fig. 8). Designations -g and -us were eliminated for simplicity.

As in prior versions, 10–19 mm observations with nonrim APHE and enhancing "capsule" remain LR-4 (Fig. 9).

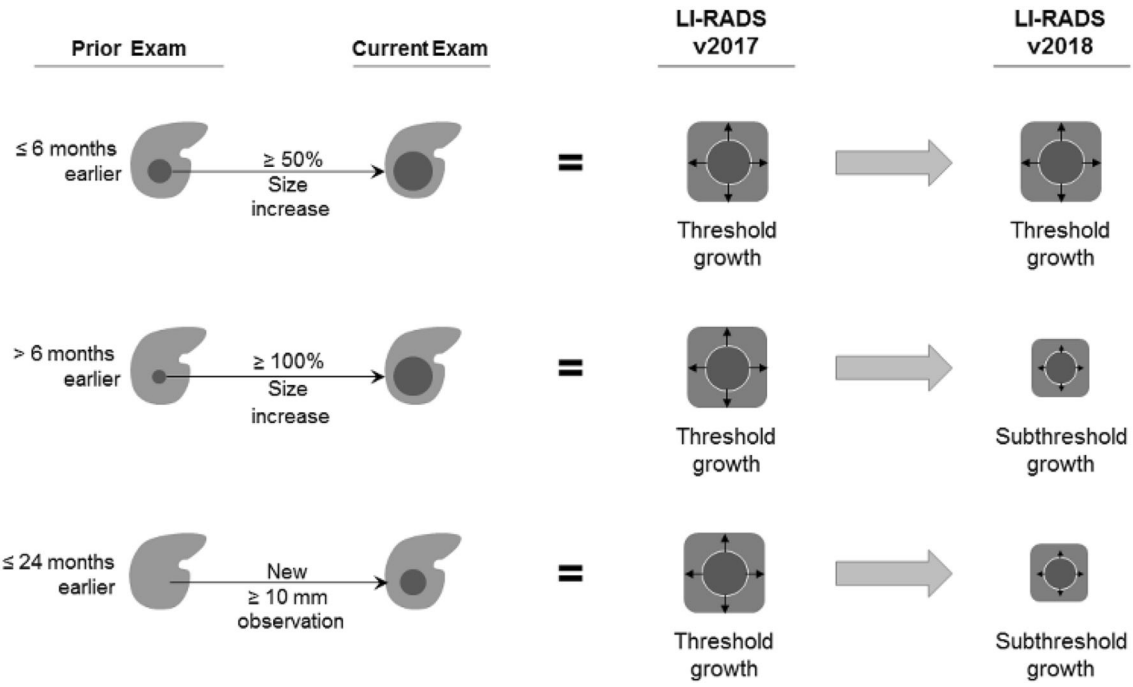


Fig. 4. LI-RADS v2018 modifications to the definition of "Threshold Growth".

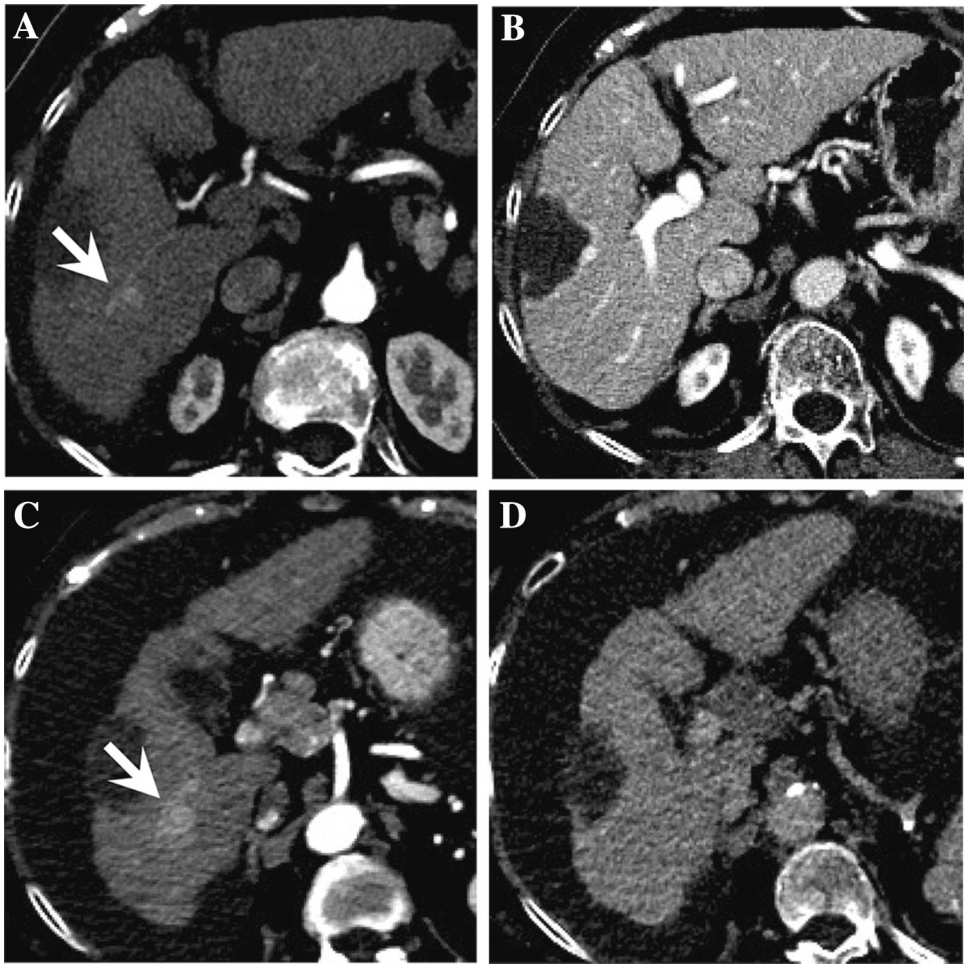


Fig. 5. Threshold growth. Contrast-enhanced CT in the arterial (**A**) and portal venous (**B**) phases show an observation in the right hepatic lobe of a cirrhotic liver measuring 8 mm exhibiting nonrim arterial phase hyperenhancement (APHE) (arrow), but no "washout" or "capsule', categorized LR-3. Contrast-enhanced CT in the arterial (**C**) and portal venous (**D**) phases three months later show that the observation has grown to a size to 13 mm, constituting threshold growth. The observation has nonrim APHE (arrow), threshold growth, no "washout" and no "capsule', and is categorized LR-5. Note is made of an adjacent treatment cavity.

Overview of LI-RADS v2018

Diagnostic population

LI-RADS is exclusively applied in a population of patients who are at high risk for developing HCC. This high-risk group includes those with cirrhosis, chronic HBV infection even in absence of cirrhosis, or current or previously diagnosed HCC. Assuming any of the three risk factors above are present, the high-risk group also applies to adult candidates for liver transplant surgery and those was are recipients post-transplantation. LI-RADS is not applied in young patients (i.e., under 18-year of age), patients with cirrhosis due to congenital hepatic fibrosis, and patients with cirrhosis due to vascular disorders (e.g., Budd-Chiari syndrome). Large regenerative nodules in patients with congestive hepatopathy can show arterial phase hyperenhancement which can mimic HCC [21]. Stringently defining the population in which LI-RADS is applicable ensures high specificity of LI-RADS categories for the diagnosis of HCC.

LI-RADS v2018 categories

LI-RADS v2018, similar to prior versions, assigns a diagnostic category for each observation ranging from LR-1 to LR-5 reflecting the relative probability of an observation being a benign entity or an HCC. LI-RADS also recognizes three other categories (LR-NC, LR-TIV, and LR-M), with specific criteria for each.

LR-NC (LR-Noncategorizable) is designated for observations that cannot be categorized due to technical limitations, preventing the identification of major features either due to image quality degradation or the absence of necessary imaging phases. For example, an

observation may be clearly identified on portal venous phase (PVP) imaging, however the arterial phase may be irreparably degraded by motion artifact, preventing a radiologist from narrowing down the range of possible categories from likely benign (LR-2) to more likely to be malignant (LR-4 or LR-5). In this scenario LR-NC would be the most appropriate designation. LR-NC should not be assigned to an observation when the categorization is simply challenging due to atypical imaging features [19].

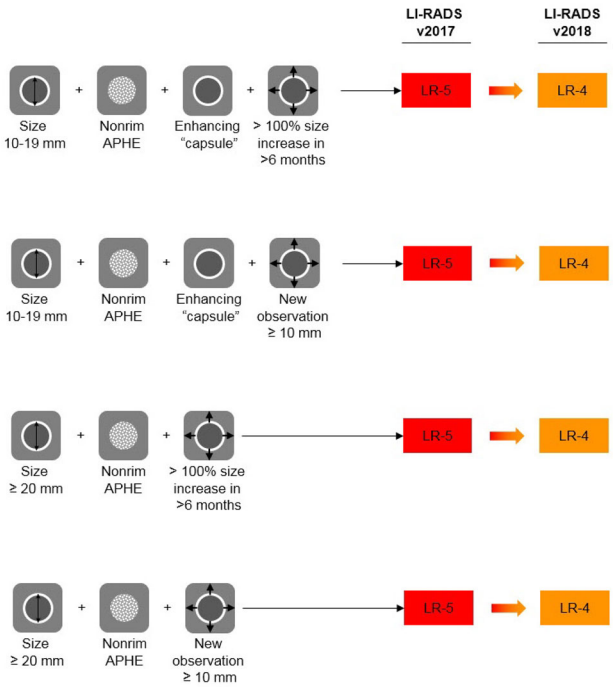


Fig. 6. Impact of modification to definition of threshold growth to LI-RADS v2018 for CT/MRI categories.

LR-1 through 5 categories each carry an estimated probability of being benignity, malignancy, or HCC specifically as indicated below [19, 22].

LR-1 (Definitely benign) category is assigned for observations for which there is 100% certainty of benignity. *LR-2* (Probably benign) category is assigned for observations that have high but not 100% certainty of being benign. *LR-3* (Intermediate probability of malignancy) category is assigned for observations with average probability of malignancy. *LR-4* (Probable HCC) category implies high but not 100% probability of HCC and *LR-5* (Definite HCC) category confers near 100% certainty of HCC. Based on recent meta-analysis, the percentages of HCC is 0% in LR-1, 13% in LR-2, 38% in LR-3, 74% in LR-4, and 94% in LR-5 [23], although the percentages for the lower categories may be inflated by selection bias for biopsied lesions.

LR-TIV (Tumor in vein) category is assigned for observations that are definitely malignant with unequivocal enhancing soft tissue in vein. This category was introduced in v2017, replacing the LR-5V category in older versions of LI-RADS, in recognition that non-HCC malignancies (e.g., cholangiocarcinoma) can occasionally present with macrovascular invasion. The *LR-TIV* designation does not require the visualization of a parenchymal mass [19, 22]. Several imaging features that suggest the presence of a tumor in vein have been described (Figs. 10, 11, 12); these do not allow the diagnosis of tumor in vein but should prompt the radiologist to scrutinize the vein for enhancing soft tissue.

LR-M (Probably or definitely malignant, not HCC specific) category is assigned for observations that have a high probability of malignancy, with a substantial possibility of nonhepatocellular origin. Based on emerging data, 93% of LR-M observations are malignant, and 36%

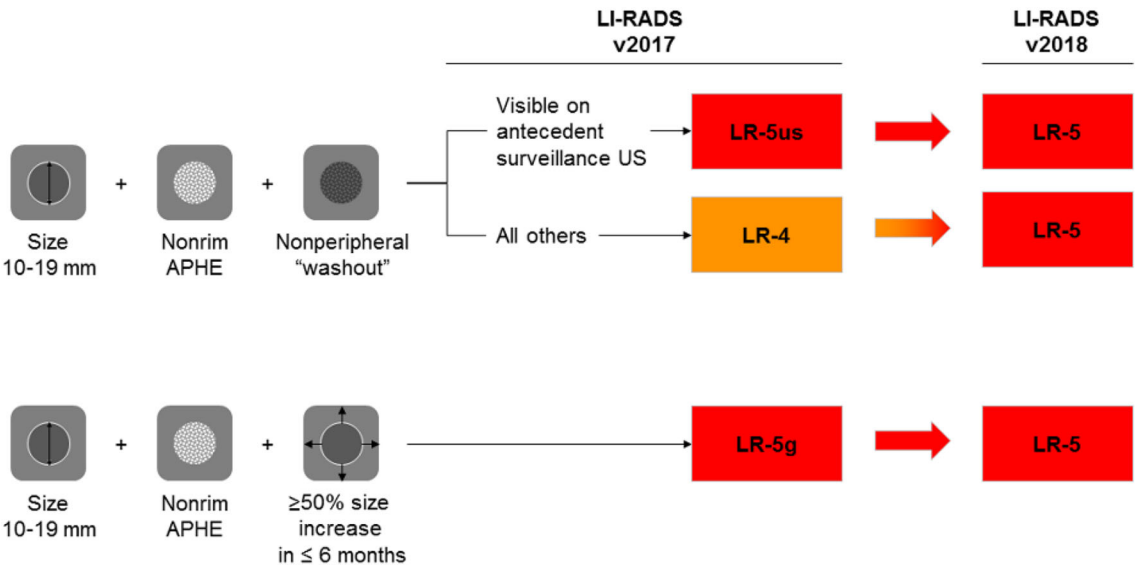


Fig. 7. Impact of changes introduced in the LI-RADS v2018.

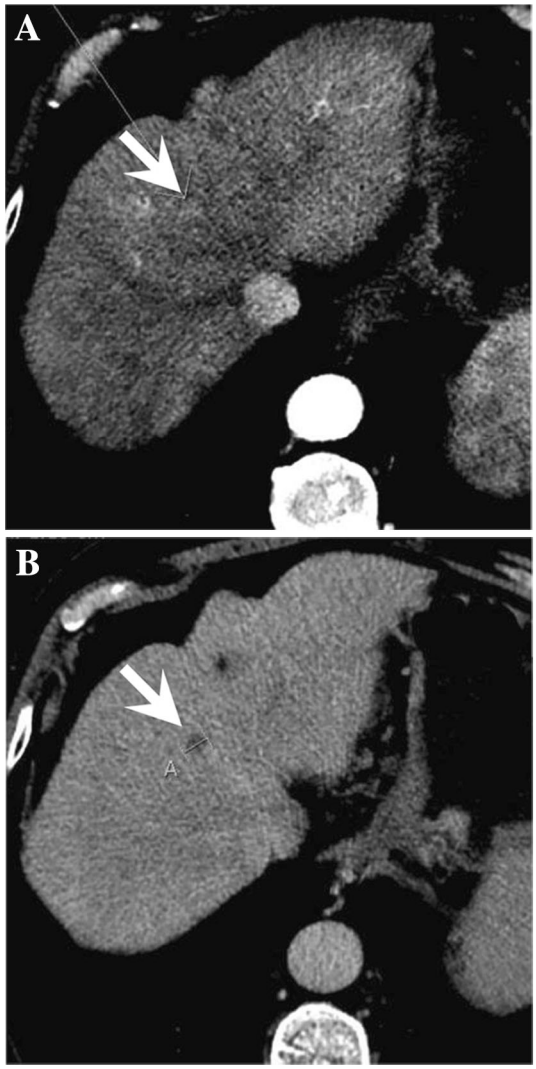


Fig. 8. LR-5 (10-19 mm) with APHE and "washout". Contrast-enhanced CT in the arterial (**A**) and portal venous (**B**) phases show an observation (arrow) in the central portion of a cirrhotic liver measuring 12 mm exhibiting nonrim arterial phase hyper-enhancement (APHE), nonperipheral "washout", and no enhancing "capsule" or threshold growth. In v2018, the lesion is categorized LR-5.

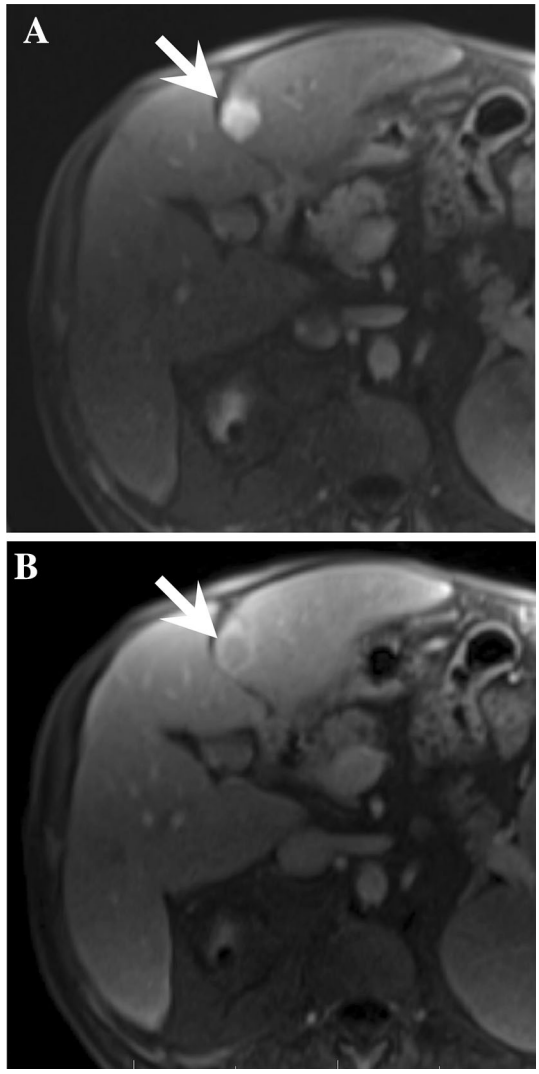


Fig. 9. LR-4 (10-19 mm) with APHE and "capsule". Contrast-enhanced MRI in the arterial (**A**) and delayed (**B**) phases show an observation (arrow) in the left hepatic lobe of a cirrhotic liver measuring 19 mm exhibiting nonrim arterial phase hyper-enhancement (APHE), and enhancing "capsule", but no "washout' or threshold growth. As with prior versions, this observation is categorized LR-4.

are HCC [23]. Formal LR-M inclusion criteria were introduced in v2017 and retained in v2018 (Figs. 13, 14, 15) [24]. The LR-M category allows LI-RADS to maintain the specificity of the LR-5 category for HCC, without losing the sensitivity for detecting other hepatic malignancies [19].

Technical recommendations for CT and MRI studies

LI-RADS provides recommendations for proper CT/MRI imaging techniques and use of contrast agents [25]. However, it does not recommend any specific modality or contrast agent. The choice of modality and contrast agent should be adjusted to each patient according to the discretion of the radiologist. All LI-RADS recommendations for CT and MRI are consistent with the OPTN guidelines and policies.

LI-RADS recommends using a multidetector, multiphasic CT (≥ 8 detector rows) to obtain images with adequate quality to characterize observations. Three phases are required: arterial phase (AP), portal venous phase (PVP), and delayed phase (DP). On the arterial phase images, the hepatic arteries are enhanced, while the hepatic veins exhibit no enhancement. The arterial phase is divided into early and late arterial phase depending on the enhancement of the portal vein [26]. To improve sensitivity, the late arterial phase is strongly preferred

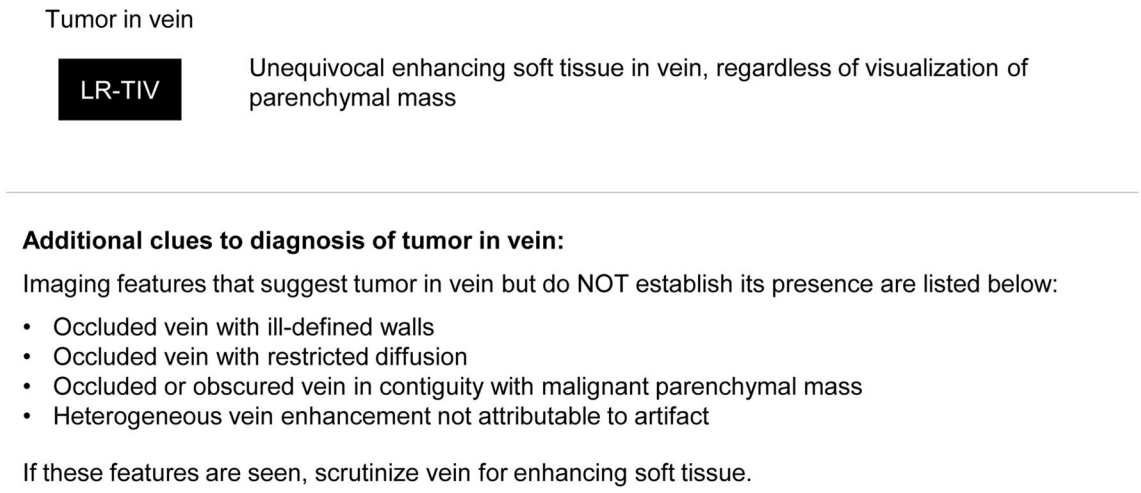


Fig. 10. Features of LR-TIV category in LI-RADS v2018 for CT/MRI.

since HCC typically demonstrates more enhancement in this phase compared to the early arterial phase. Moreover, some HCCs show hyper-enhancement only during the late arterial phase [27]. Pre-contrast imaging is suggested but not required in treatment-naïve patients. Pre-contrast imaging is required for patients with previous loco-regional treatment [25, 28, 29].

For MRI, LI-RADS recommends utilizing a 1.5T or 3T field strength and a torso phased-array coil. MRI may be performed either with gadolinium-based extracellular contrast agents (ECA) or hepatobiliary agents (gadobenate dimeglumine or gadoxetate disodium). Required MR sequences include unenhanced T1-weighted sequences with in-phase and out-of-phase imaging, a T2-weighted sequence with fat suppression, and multiphasic post-contrast fat saturated T1 weighted imaging. Diffusion-weighted imaging (DWI) and subtraction imaging are considered optional. Specific recommendations exist for MRI contrast agents. Pre-contrast, arterial, and portal venous phases are required for all contrast agents. With ECA or gadobenate, a delayed phase acquired 2–5 min after contrast injection is also required. When using gadoxetate disodium, the phase performed 2–5 min after injection is called transitional phase (TP). During TP, the hepatic vessels and parenchyma are similar in intensity. An additional T1-weighted post-contrast hepatobiliary phase (HBP) is acquired when using hepatobiliary agents. For gadobenate, the HBP is 1–3 h after injection and is optional (Table. 1). For gadoxetate, this phase occurs about 20 minutes after injection and is required. During the HBP, the hepatic parenchyma exhibits higher signal intensity than the hepatic vasculature [30]. Contrast is also seen in the biliary tree during the HBP.

Multiplanar reformations and acquisitions are suggested but not required for use with both CT and MRI, respectively.

Major features for HCC

Definitions of major imaging features favoring HCC on CT and MRI remain unchanged in LI-RADS v2018 version, with the exception of threshold growth, whose definition has been simplified as described above. The major features are: (1) Non-rim arterial phase hyper-enhancement (APHE); (2) non-peripheral "washout"; (3) enhancing "capsule"; (4) size; and (5) threshold growth [27, 31].

Non-rim arterial phase hyper-enhancement (APHE) is described as enhancement greater than the background liver parenchyma during the arterial phase of imaging (Fig. 16). This feature is best assessed in the late arterial phase of liver enhancement. Presence of nonrim APHE is mandatory for LR-5 categorization.

Non-peripheral washout appearance ("washout") refers to a temporal reduction in enhancement compared to background liver parenchyma during portal venous or

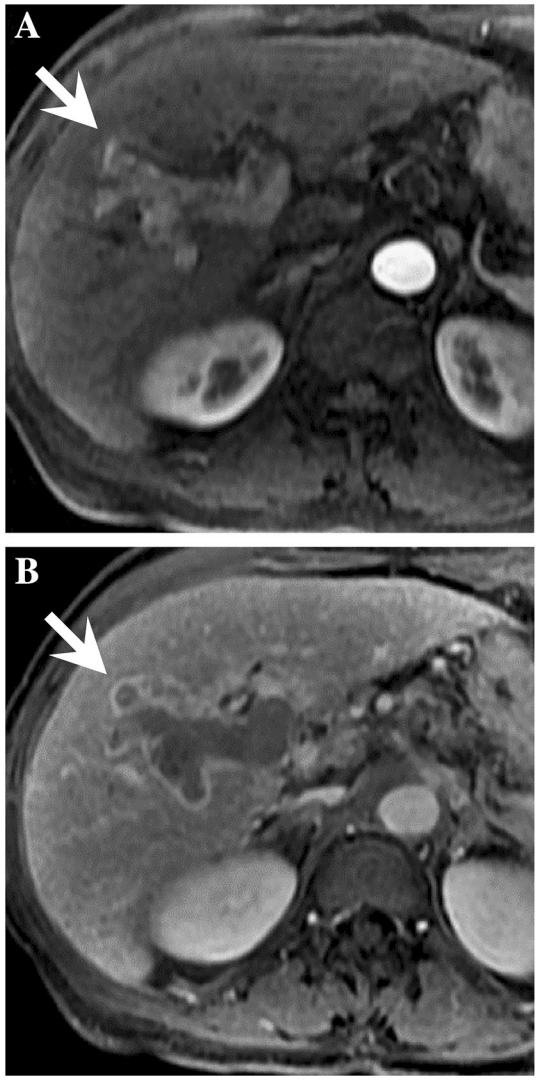


Fig. 11. Tumor in vein (LR-TIV). Contrast-enhanced MRI in the arterial (**A**) and delayed (**B**) phases show an expansile enhancing soft tissue (arrow) in the main and right portal veins of a cirrhotic liver not contiguous with a parenchymal mass. This is consistent with LR-TIV, likely due to HCC. Note arterial phase hyper-enhancement and "washout" seen within the expanded vein.

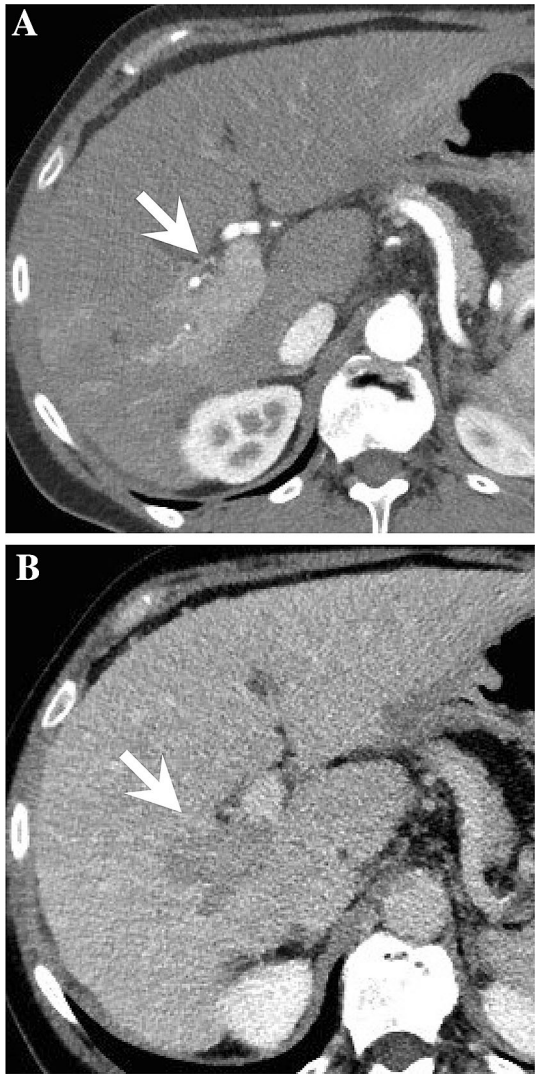


Fig. 12. Tumor in vein (LR-TIV). Contrast-enhanced CT in the arterial (**A**) and portal venous (**B**) phases show an expansile enhancing soft tissue (arrow) in the right portal vein of a cirrhotic liver not contiguous with a parenchymal mass. This is consistent with LR-TIV, likely due to HCC. Note arterial phase hyper-enhancement and "washout" seen within the expanded vein. Case courtesy of Dr. Kupa Patel-Lippman.

delayed phase of imaging if using extracellular agents (Fig. 16). When using gadoxetate disodium, assessment of "washout" is confined to the portal venous phase; the feature does not apply to and should not be characterized in the transitional or hepatobiliary phases [31].

Another major feature of HCC is enhancing "capsule", which is defined as a smooth distinctive rim either partially or completely surrounding an observation that is thicker or more conspicuous than fibrotic tissue surrounding other cirrhotic nodules (Fig. 16). "Capsule" may be observed during the portal venous, delayed, or transitional phase of imaging following administration of either extracellular or hepatobiliary contrast agents.

Size refers to the largest outer-edge-to-outer-edge dimension of an observation. Size should be measured on the image with greatest observation conspicuity and in

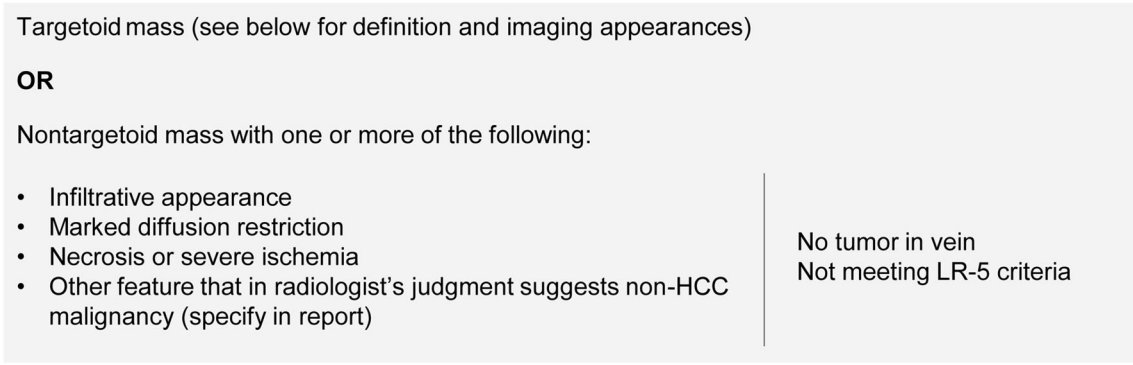


Fig. 13. Diagnostic imaging criteria for LR-M category in LI-RADS v2018 for CT/MRI.

which the margins of an observation are best delineated. When possible, size should be measured in a phase other than the arterial phase to avoid inclusion of perilesional enhancement that may cause size over-estimation [31]. Likewise, size should not be measured on diffusion-weighted images to avoid errors from anatomic distortion.

Threshold growth is the final major feature of HCC (Fig. 5). As described above, the definition of threshold growth has been simplified in LI-RADS v2018 to include only a size increase of a mass by ≥ 50% in ≤ 6 months. Also, the 5 mm minimal size increase required in prior LI-RADS versions has been removed. This simpler definition of threshold growth is now in alignment with AASLD and OPTN [32, 33]. Evaluation of threshold growth should be performed on the same post-contrast phase, imaging sequence, and imaging plane as the previous examination.

LR-M features

Definitions of LR-M features remain unchanged in LI-RADS v2018. These features are sufficient for categorization of an observation as LR-M when present in any combination. The features include targetoid patterns of enhancement, including rim APHE, peripheral "washout", and delayed central enhancement (Fig. 14) [24]. Additional LR-M features are targetoid appearance on diffusion-weighted imaging, TP, and/or HBP [24]. Nontargetoid LR-M features include marked diffusion restriction (Fig. 15), infiltrative appearance, and necrosis or severe ischemia. A final LR-M feature is an imaging appearance suggestive of non-HCC malignancy as determined by the radiologist, such as a new mass in the setting of known or suspected extrahepatic malignancy, or presence of biliary ductal dilation out of proportion to mass along with vascular encasement and/or capsular retraction. When LR-M features are present, the observation should be categorized LR-M regardless of other major or ancillary features suggesting HCC. The intention of the LR-M category is to maintain sensitivity for diagnosis of malignancy, while preserving specificity of LR-5 for HCC diagnosis.

Ancillary features (AFs)

AFs are divided into three subsets: those that favor malignancy in general (Table 2); those that favor HCC in particular (Table 3); and those that favor benignity (Table 4) [20]. AFs may be used to adjust a LI-RADS category up or down by 1 category. AFs allow for improved detection and increased confidence in diagnosis [20]. To reduce the potential complexity of LI-RADS, the application of ancillary features remains optional at the radiologist's discretion. When ≥ 1 AF favoring malignancy is/are present (Figs. 17, 18, 19), the category should be upgraded by 1 category only, up to LR-4. When ≥ 1 AF favoring benignity is/are present, the category should be downgraded by 1 category only. When conflicting AFs are present (i.e., AFs favoring both malignancy and favoring benignity), the category should not be adjusted. Moreover, AFs cannot be used to upgrade LR-4 to LR-5. This caveat is present in order to maintain specificity of the LR-5 category, and for con-

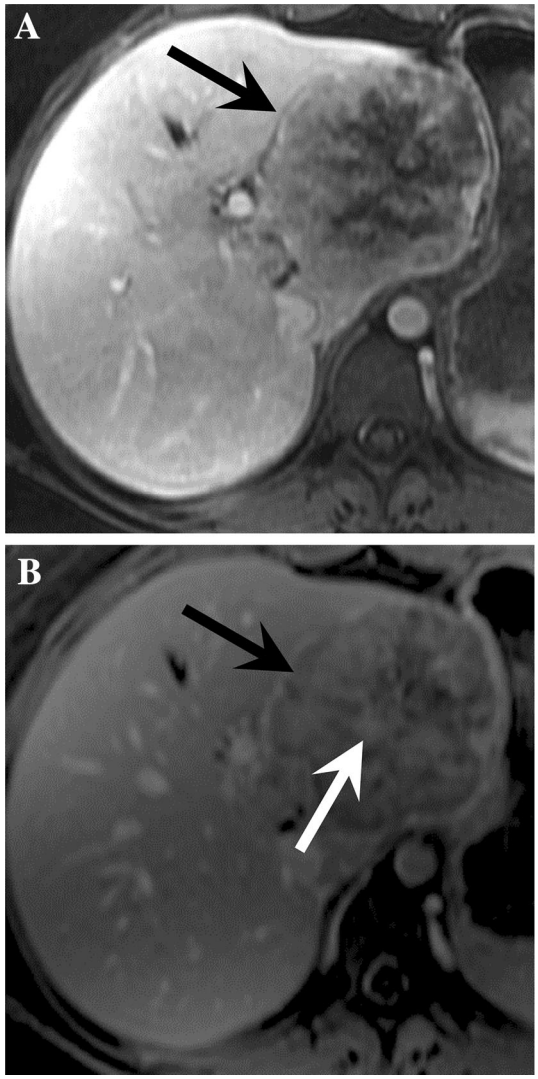


Fig. 14. LR-M in a 65-year-old woman with chronic hepatitis B virus infection. Hepatic observation in the left lobe with rim arterial phase hyper-enhancement (black arrow) (**A**), peripheral ''washout'' (black arrow), and **B** delayed central enhancement (white arrow). The patient underwent left hepatectomy and an intrahepatic cholangiocarcinoma was confirmed.

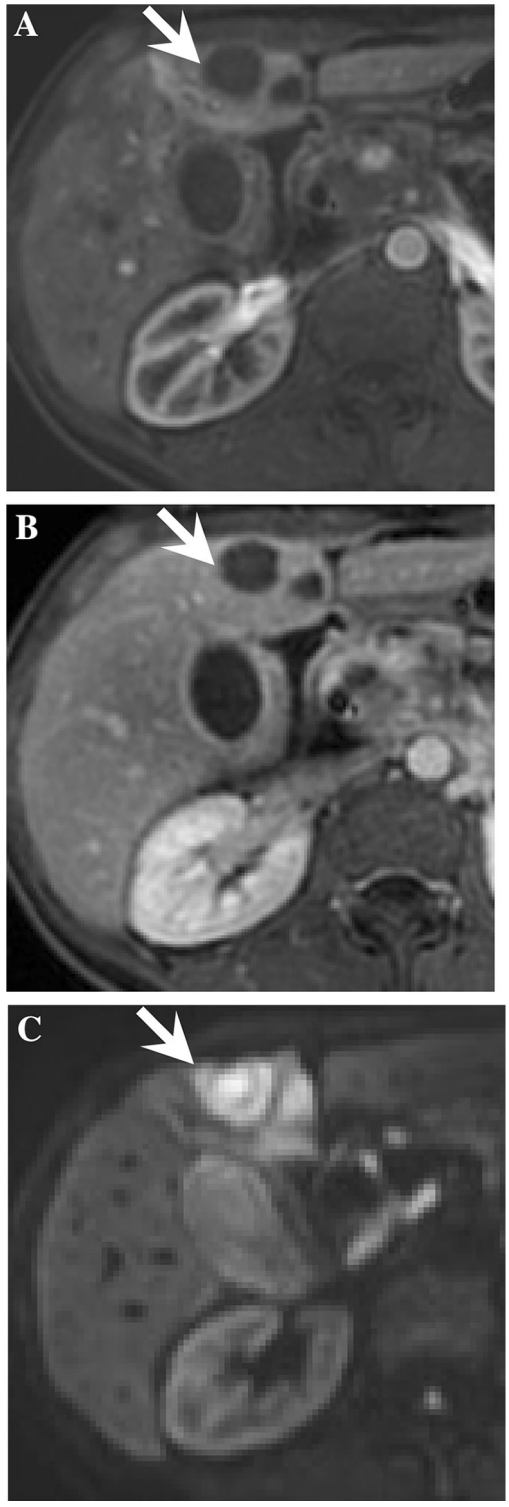


Fig. 15. LR-M in a 54-year-old man with hepatitis B virus cirrhosis. Contrast-enhanced MRI in the arterial (**A**) and delayed (**B**) phase images show a rim enhancing mass (arrow) in the medial left hepatic lobe, and diffusion-weighted (**C**) images show a targetoid appearance (arrow). This lesion was found to be metastatic pancreatic adenocarcinoma at biopsy.

Table 1. Technical recommendations for MRI phases

Contrast agent	Precontrast, arterial phase, portal venous phase	2–5 min phase	Delayed/transitional phase	Hepatobiliary phase	Hepatobiliary phase timing after injection
ECA	Required	Delayed Phase	Required	—	—
Gadobenate dimeglumine	Required	Delayed Phase	Required	*Optional*	1–3 hours
Gadoxetate disodium	Required	Transitional Phase	Required	Required	At 20 minutes

— not applicable

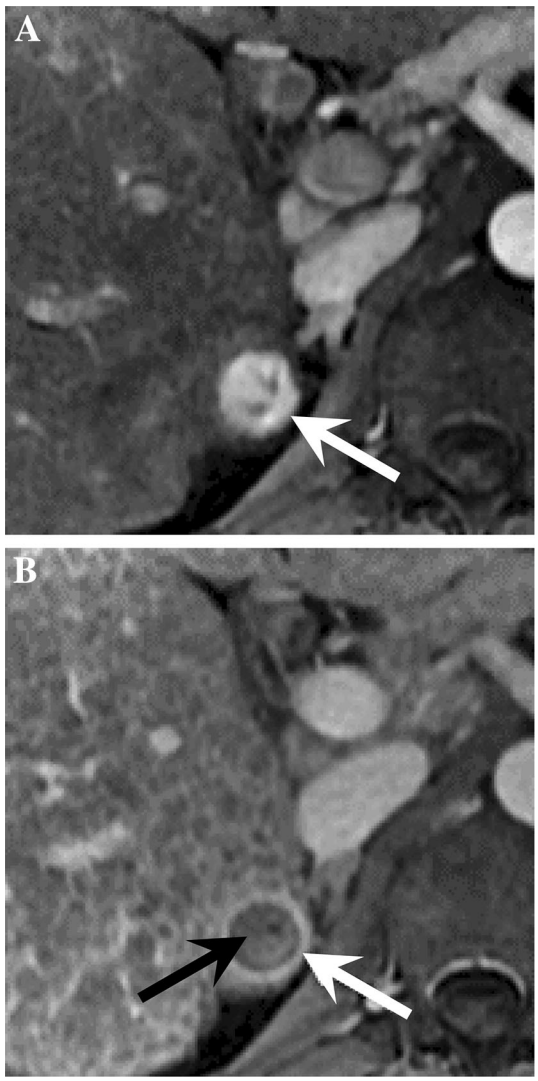


Fig. 16. Major features of HCC. Contrast-enhanced MRI shows a 25 mm observation in a cirrhotic liver exhibiting non-rim arterial phase hyper-enhancement (white arrow) in the arterial phase (**A**) and nonperipheral "washout", and enhancing "capsule" (white arrow) in the delayed phase (**B**), categorized LR-5.

Table 2. Ancillary features favoring malignancy, not HCC in particular

Feature	Definition	CT	MRI ECA	MRI HBA
US visibility as discrete nodule	Unenhanced US visibility as discrete nodule or mass corresponding to CT- or MRI-detected observation	+	+	+
Subthreshold growth	Unequivocal size increase of a mass, less than threshold growth.	+	+	+
Corona enhancement	Periobservational enhancement in late arterial phase or early PVP attributable to venous drainage from tumor	+	+	+
Fat sparing in solid mass	Relative paucity of fat in solid mass relative to steatotic liver **OR** in inner nodule relative to steatotic outer nodule	+/−	+	+
Restricted diffusion	Intensity on DWI, not attributable solely to T2 shine-through, unequivocally higher than liver and/or ADC unequivocally lower than liver	—	+	+
Mild-moderate T2 hyperintensity	Intensity on T2WI mildly or moderately higher than liver and similar to or less than non-iron-overloaded spleen	—	+	+
Iron sparing in solid mass	Paucity of iron in solid mass relative to iron-overloaded liver **OR** in inner nodule relative to siderotic outer nodule	—	+	+
Transitional phase hypointensity	Intensity in the transitional phase unequivocally less, in whole or in part, than liver	—	—	+
Hepatobiliary phase hypointensity	Intensity in the hepatobiliary phase unequivocally less, in whole or in part, than liver	—	—	+

+ Usually evaluable, — not evaluable, +/− may or may not be evaluable
ADC Apparent diffusion coefficient, *DWI* diffusion-weighted imaging, *ECA* extracellular agent, *HBA* hepatobiliary agent, *PVP* portal venous phase, *T2WI* T2-weighted imaging

Table 3. Ancillary features favoring HCC in particular

Feature	Definition	CT	MRI ECA	MRI HBA
Nonenhancing "capsule"	Capsule appearance not visible as an enhancing rim.	+	+	+
Nodule-in-nodule architecture	Presence of smaller inner nodule within and having different imaging features than larger outer nodule	+	+	+
Mosaic architecture	Presence of randomly distributed internal nodules or compartments, usually with different imaging features	+	+	+
Fat in mass, more than adjacent liver	Excess fat within a mass, in whole or in part, relative to adjacent liver	+/−	+	+
Blood products in mass	Intralesional or perilesional hemorrhage in the absence of biopsy, trauma or intervention	+/−	+	+

+ Usually evaluable, — not evaluable, +/− may or may not be evaluable
ECA Extracellular agent, *HBA* hepatobiliary agent

Table 4. Ancillary features favoring benignity

Feature	Definition	CT	MRI ECA	MRI HBA
Size stability ≥ 2 years	No significant change in observation size measured on exams ≥ 2 years apart in absence of treatment	+	+	+
Size reduction	Unequivocal spontaneous decrease in size over time, not attributable to artifact, measurement error, technique differences, or resorption of blood products	+	+	+
Parallels blood pool enhancement	Temporal pattern in which enhancement eventually reaches and then matches that of blood pool	+	+	+
Undistorted vessels	Vessels traversing an observation without displacement, deformation, or other alteration	+	+	+
Iron in mass, more than liver	Excess iron in a mass relative to background liver	+/−	+	+
Marked T2 hyperintensity	Intensity on T2WI markedly higher than liver and similar to bile ducts and other fluid-filled structures	—	+	+
Hepatobiliary phase isointensity	Intensity in hepatobiliary phase nearly identical to liver	—	—	+

+ Usually evaluable, — not evaluable, +/− may or may not be evaluable
ECA Extracellular agent, *HBA* hepatobiliary agent, *T2WI* T2-weighted imaging

gruency with OPTN which does not use AFs in diagnosis of definite HCC.

Management based on the CT/MRI LI-RADS v2018

LI-RADS v2018 provides suggested management options for each LI-RADS category. These suggestions are provided in consensus with AASLD. They primarily focus on further diagnostic work-up if needed, such as repeat or alternative diagnostic imaging modalities or multi-disciplinary discussion (MDD) to determine the need for tissue sampling and/or presumptive treatment (Fig. 20). The recommendation for MDD recognizes the importance of the multi-disciplinary team, individual patient co-morbidities and therapeutic options, and risks associated with additional diagnostic work-up. Hence, not only the LI-RADS category, but rather the complete clinical scenario including biochemical results, functional

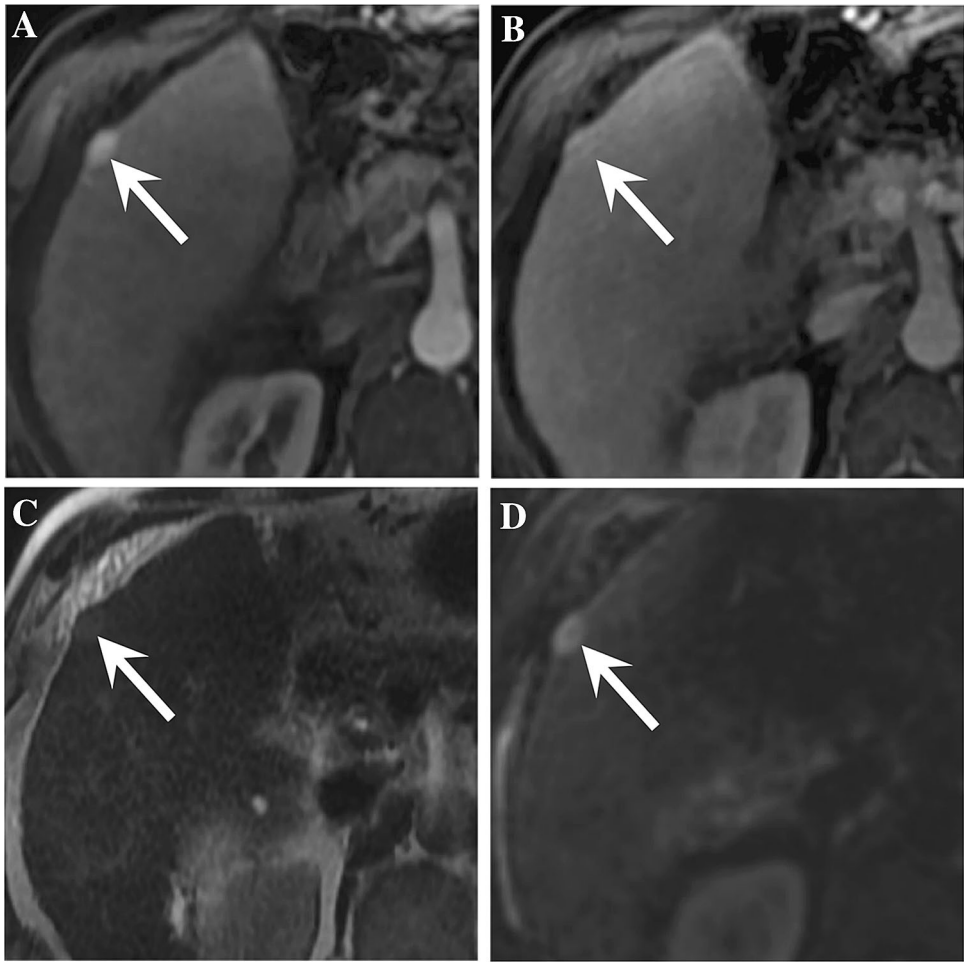
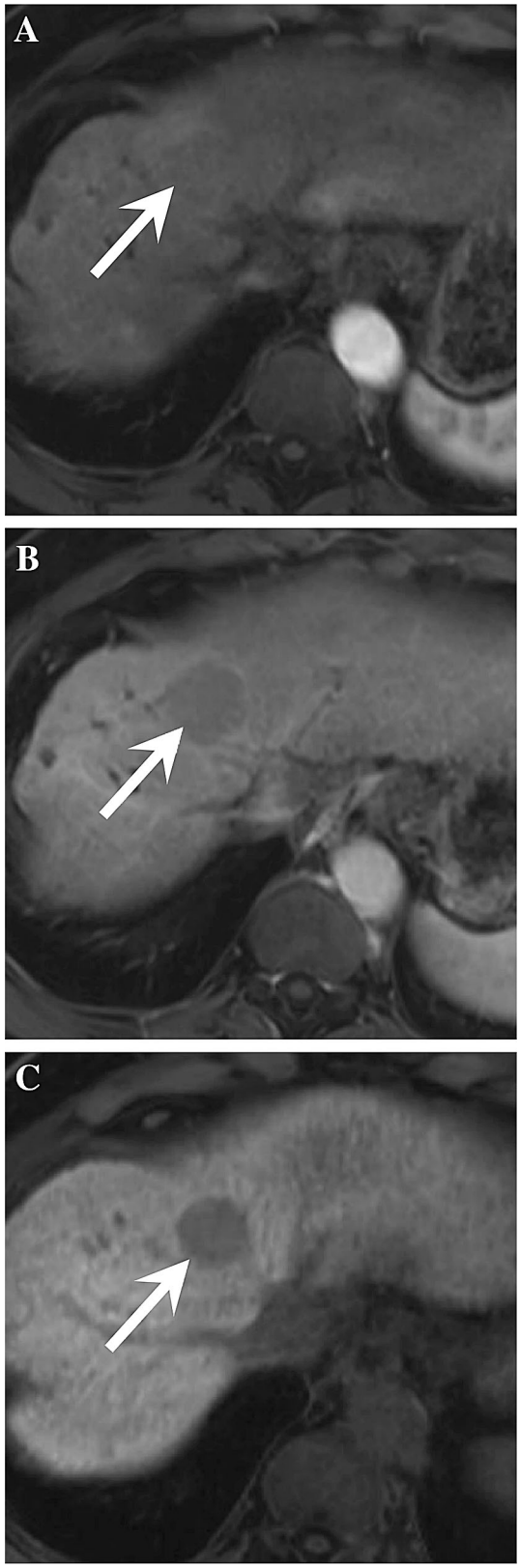


Fig. 17. Application of ancillary features. Arterial phase (**A**) in a 64-year-old man with hepatitis C cirrhosis demonstrates a 13 mm observation (arrow) with nonrim arterial phase hyper-enhancement. There is no nonperipheral "washout" or enhancing "capsule" on the portal venous phase (**B**). The observation is categorized LR-3. Two ancillary features (AFs) of malignancy are present: mild T2-hyperintensity (**C**) and restricted diffusion (**D**). Presence of AFs allows category upgrade to LR-4. Note that even though two AFs are present, the category can be upgraded only by one.

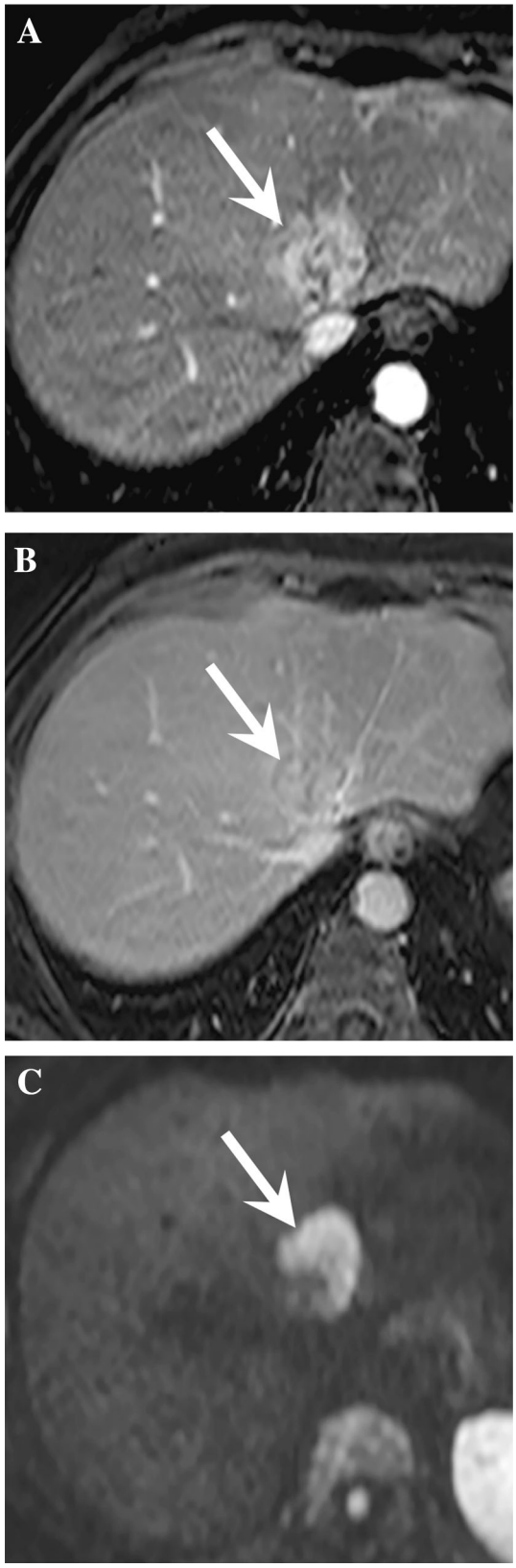
status, eligibility for liver transplantation, and other co-morbidities often dictate the next steps.

Conclusion

LI-RADS version 2018 has been updated to become congruent with AASLD and to help integrate standard radiology reporting to the needs of clinicians and surgeons. These changes, while small in number, are important for radiologists to become familiar with and follow in order to ensure LI-RADS reports are consistent. Continued research in the field of HCC imaging is encouraged in order to help refine future version of LI-RADS.



◄**Fig. 18.** Application of ancillary features. Arterial phase (**A**) in a 70-year-old man with hepatitis C cirrhosis demonstrates a 32 mm observation (arrow) without nonrim arterial phase hyper-enhancement. There is nonperipheral ''washout'' and no enhancing ''capsule'' on the portal venous phase (**B**). The observation is categorized LR-4. The observation demonstrates hypointensity on hepatobiliary phase images, an ancillary feature favoring malignancy (**C**). Despite presence of AF favoring malignancy, the category cannot be upgraded from LR-4 to LR-5. Therefore, the final category is LR-4.



◄**Fig. 19.** Ancillary feature of restricted diffusion. Contrast-enhanced MRI in the arterial (**A**) and delayed (**B**) phases and diffusion-weighted image (**C**) show a 37 mm observation (arrow) in a cirrhotic liver exhibiting arterial phase hyper-enhancement, enhancing ''capsule'', and restricted diffusion, categorized LR-5. Restricted diffusion favors malignancy, but not HCC in particular.

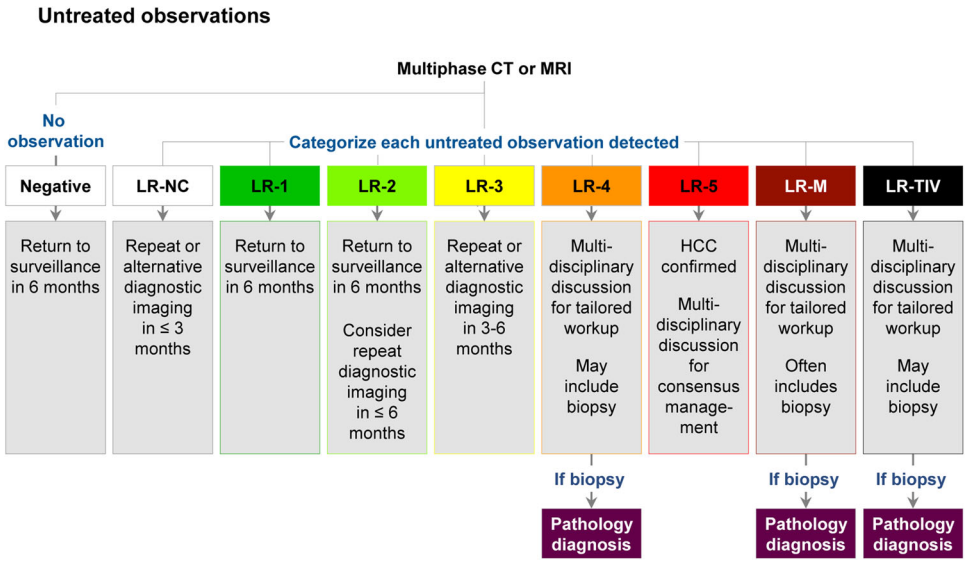


Fig. 20. Suggested imaging work-up options based on LI-RADS v2018 for CT/MRI categories.

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Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

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