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CT MRI LI-RADS in Routine Practice

Karthik Ganesan[1] Shivsamb Jalkote[1] Swarup Nellore[1]

[1] Department of Radiology, Sir H. N. Reliance Foundation Hospital and Research Center, Mumbai, Maharashtra, India

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Address for correspondence Karthik Ganesan, MBBS, DNB, FSAR, Department of Radiology, Sir H. N. Reliance Foundation Hospital and Research Center, Raja Ram Mohan Roy Road, Girgaum, Mumbai 400004, Maharashtra, India (e-mail: drkarthikg@gmail.com; karthik.s.ganesan@rfhospital.org).

Abstract

Primary liver cancer is the third most common cause of cancer-related deaths worldwide with hepatocellular carcinoma (HCC) comprising the vast majority of the cases. HCC unlike most solid cancers can be diagnosed based on imaging findings alone using multiphasic contrast-enhanced computed tomography (CT) or magnetic resonance imaging (MRI) without the need for histopathological confirmation in the majority of the cases. Liver Imaging Reporting and Data System (LI-RADS) was first introduced by the American College of Radiology in 2011 with the help of a multidisciplinary team of liver disease experts to improve the accuracy, consistency, and clarity of communication of imaging findings between radiologists and treating physicians. To date, LI-RADS has undergone four major updates in 2013, 2014, 2017, and 2018. This article reviews the technical aspects, categorization, and major and ancillary imaging features for the application of LI-RADS version 2018 using CT and MRI in routine clinical practice.

Keywords
- APHE
- CT
- LI-RADS
- LR-TR
- MRI

Introduction

Liver disease is leading cause of mortality and morbidity across the world accounting for 2.14 million deaths in 2017 with a substantial increase of 11.4% since 2012. Cirrhosis and hepatocellular carcinoma (HCC) are the major factors responsible for deaths due to liver disease.[1] As per World Health Organization, liver cancer is third most common cause of cancer related deaths worldwide in 2020 out of which 90% cases are due to HCC.[2] HCC unlike most of the solid cancers can be diagnosed based on imaging findings alone using multiphasic contrast-enhanced computed tomography (CT) or magnetic resonance imaging (MRI) without need for histopathological confirmation in majority of the cases. Several classification systems such as American Association for the Study of Liver Diseases (AASLD), European Association for the Study of the Liver, and Asian Pacific Association for the Study of the Liver have been used in HCC management with key differences based on regional practice guidelines.[3] Presence of multiple classification systems limits the standardization, interpretation, and research due to lack of unification and consistency. Liver Imaging Reporting and Data System (LI-RADS) was first introduced by American College of Radiology in 2011 with the help of multidisciplinary team of liver disease experts to improve the accuracy, consistency, and clarity of communication of imaging findings between radiologist and treating physicians. Since its inception, LI-RADS is an evolving system with increasing global acceptance for providing standardized terminology, technique, interpretation, and reporting of liver imaging allowing higher accuracy and effective communication. Till date, LI-RADS has undergone four major updates in 2013, 2014, 2017, and 2018.[4] The 2018 update is considered as a major milestone in LI-RADS evolution as AASLD incorporated LI-RADS in its practice guidelines highlighting the key role of radiologist in HCC management.[5] This incorporation required modification of LR-5 category to include all 10-to19-mm observations with nonrim arterial phase hyperenhancement (APHE) and washout appearance. Requirement of qualifier -us and -g was removed from the LR-5 category.

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Threshold growth definition was matched to Organ Procurement and Transplantation Network: more than or equal to 50% increase in the lesion size in less than 6 months.

US-LIRADS provides algorithm for screening and surveillance in high-risk patients. Contrast-enhanced ultrasound (CEUS) is robust technique and offers comparable accuracy to CT and MRI in assessment of focal liver lesions. CEUS offers higher safety than contrast CT/MRI in patients with nephrotoxicity, contrast allergies, and pediatric age group. CEUS can be complimentary to CT/MRI in indeterminate cases.[6] CEUS LI-RADS algorithm has been used for diagnosis of HCC in at risk population. Detailed discussion of US LI-RADS and CEUS LI-RADS is beyond the scope of this article and interested readers are requested to visit ACR Web site for further details. This article will mainly focus on the CT/MRI LI-RADS and treatment response LI-RADS.

LI-RADS Diagnostic Population

LI-RDAS aims to achieve higher specificity in diagnosing HCC; hence, it is currently applied only to certain subset of patients having higher pretext probability of developing HCC. Inclusion and exclusion criteria for eligibility for LI-RADS have been detailed in ►**Table 1**.[7] The major limitation of evaluating focal lesions in cirrhosis secondary to vascular disorders is the presence of benign arterialized nodules that can mimic HCC leading to reduced specificity; hence, LI-RADS is not used in these cases. LI-RADS is still not validated for use in the pediatric population; hence, patients under 18 years old are excluded from the diagnostic algorithm. Diagnostic accuracy of LI-RADS in noncirrhotic HCC is not completely established in current literature.

LI-RADS Technical Consideration for CT and MRI

Standardized hepatic imaging protocols are required to yield good quality images providing consistent accuracy and reproducibility. Multiphasic CT and MRI using intravenous contrast form cornerstone of imaging evaluation. MRI is more sensitive than CT in detection of smaller lesions ($<$ 1 cm), assessment of arterial phase enhancement and enhancing capsule due to higher inherent soft tissue resolution. Currently LI-RADS guidelines do not recommend use of MRI over CT.[8] Contrast used in liver MRI imaging is usually of two broad categories—hepatobiliary-specific agents or extracellular agents (nonspecific). Hepatobiliary-specific contrast used in current practice is gadobenate (also known as gadobenate dimeglumine or Gd-BOPTA) and gadoxetate (also known as gadoxetic acid or Gd-EOB-DTPA), out of which gadoxetate is not available in India.

The LI-RADS Technique Working Group presents imaging protocol and hardware specifications for CT and MRI based as detailed in ►**Table 2**.[9] Recommended postcontrast phases in CT and MRI when using extracellular contrast agent or gadobenate dimeglumine are late arterial, portal venous, and delayed phase acquisitions (►**Figs. 1** and **2**). Late arterial phase shows enhancement of hepatic artery along with early enhancement of portal vein (homogenous/heterogenous) without antegrade enhancement of hepatic veins. Late arterial phase is strongly recommended as it offers optimal enhancement of hypervascular lesions in form of APHE that is a major diagnostic feature of HCC. Early AP is equivalent to the angiographic phase and shows no or less enhancement of the portal vein than the liver. Portal venous phase (PVP) is characterized by enhancement of portal vein and hepatic veins more than the background liver and corresponds to peak parenchymal enhancement. Delayed phase can be differentiated due to lower degree enhancement of liver and intrahepatic vessels as compared with PVP. If postcontrast imaging is done using fixed delay technique, the suggested timings for acquisition after start of injection are 30 to 45 seconds for late arterial phase, 60 to 75 seconds for PVP, and 2 to 5 minutes for delayed phase.[10] Portal venous and delayed phase imaging is required for the evaluation of washout and capsule appearance characteristic of HCC as well as vascular thrombosis. In cases of gadoxetate injection, the phase acquired after 2 to 5 minutes is termed as transitional phase instead of delayed phase. Transitional phase hypointensity is useful ancillary imaging features favoring malignancy.

Hepatobiliary phase (HBP) is postcontrast phase acquired after injection of hepatobiliary contrast (gadoxetate or gadobenate) and is identified by hepatic parenchyma appear-

Table 1 Diagnostic population for LI-RADS

Inclusion
• Adults with cirrhosis
• Chronic hepatitis B infection without cirrhosis
• Current or prior HCC including adult liver transplantation candidates and patients post-transplant
Exclusion
• Pediatric patients (age $<$18 years)
• Cirrhosis due to congenital hepatic fibrosis
• Cirrhosis due to a vascular disorder such as hereditary hemorrhagic telangiectasia, Budd-Chiari syndrome, chronic portal vein occlusion, cardiac congestion, or diffuse nodular regenerative hyperplasia

Abbreviations: HCC, hepatocellular carcinoma; LI-RADS, Liver Imaging Reporting and Data System.

Table 2 LI-RADS technical recommendations for CT and MRI

CT	Scanner	Multidetector CT with ≥ 8 detector rows
	Contrast	≥ 300 mg/mL for a dose of 1.5–2.5 mL/kg body weight injected at a rate of ≥ 3 mL/sec using a power injector followed by a saline chaser bolus (30–40 mL) with the same injection rate
	Required images	Late arterial phase, PVP, DP
	Acquisition	Bolus tracking or fixed-time delay
	Optional images	• Precontrast if locoregional treatment • Multiplanar reformations
MRI	Scanner	1.5T or 3T, Torso phased-array coil
	Contrast	ECA or gadobenate or gadoxetate. Inject the weight-adjusted dose using a power injector at a rate of 1–2 mL/s followed by saline chaser bolus (30–40 mL) with the same injection rate
	Required images	• Unenhanced T1-weighted OP and IP imaging • T2-weighted imaging (fat suppression per institutional preference) All contrast agents: Multiphase T1-weighted imaging • Precontrast imaging, late arterial phase, portal venous phase Extracellular contrast agents or gadobenate dimeglumine: • Delayed phase (2-5 minutes after injection) Gadoxetate disodium contrast: • Transitional phase (2–5 minutes after injection) • Hepatobiliary phase (~20 minutes after injection)
	Optional images	• Diffusion-weighted imaging • Subtraction imaging • Multiplanar acquisition • 1- to 3-hour hepatobiliary phase with gadobenate dimeglumine • Quantitative imaging techniques

Abbreviations: CT, computed tomography; DP, delayed phase; ECA, extracellular contrast-enhanced; IP, in-phase; LI-RADS, Liver Imaging Reporting and Data System; MRI, magnetic resonance imaging; OP, out-of-phase; PVP, portal venous phase.

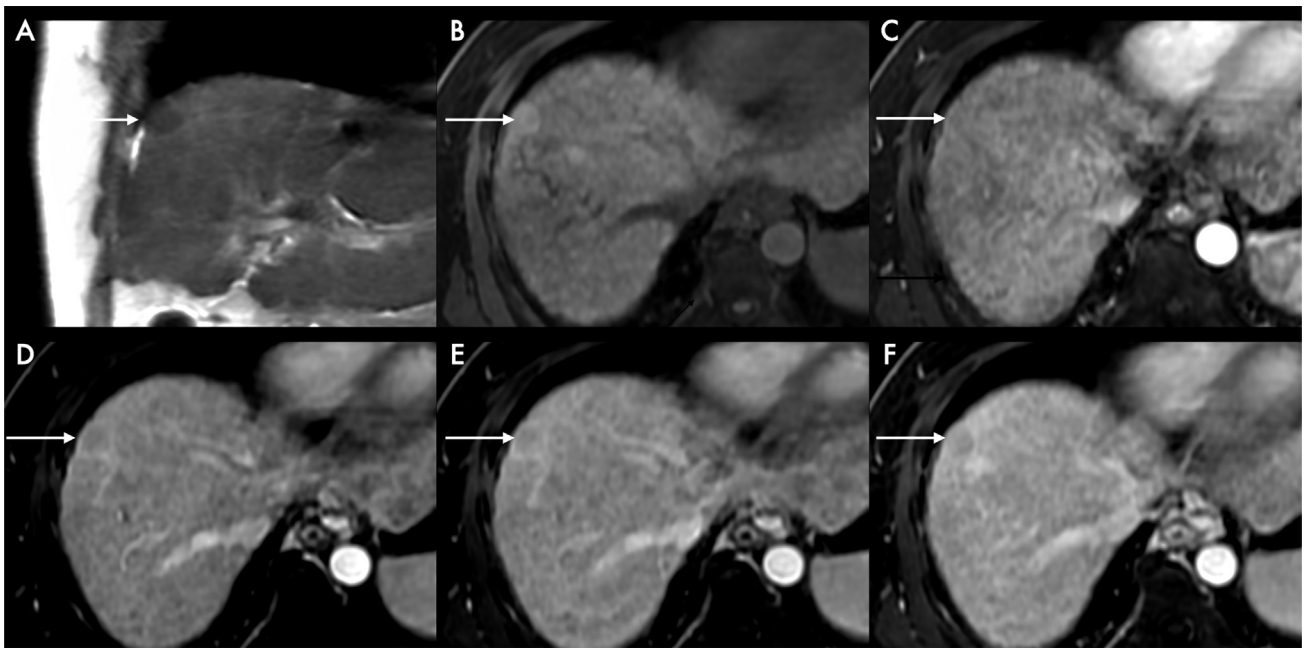


Fig. 1 (**A–F**) LR-2 observation: A 8 mm focal observation (white arrow) is seen in the subcapsular location of segment VIII, appearing hypointense on single short fast spin echo coronal images and mildly hyperintense on precontrast T1-weighted images. Observation shows no definitive enhancement on dynamic postcontrast images.

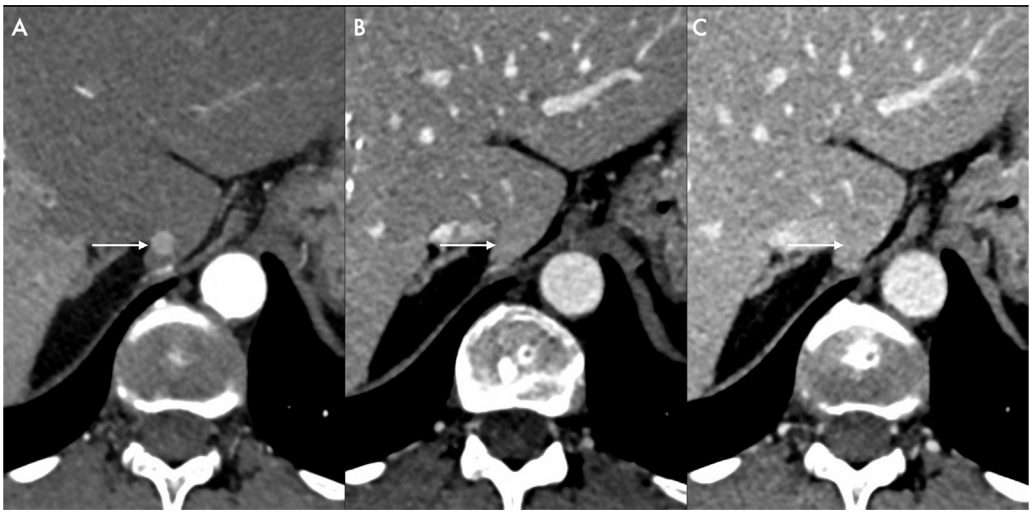


Fig. 2 (**A–C**) LR-3 observation: Contrast-enhanced computed tomography study shows a 5 mm observation (white arrow) in segment I showing nonrim arterial phase hyperenhancement in late arterial phase (**A**), without showing washout in portal venous phase (**B**) or enhancing capsule in delayed phase (**C**).

ing hyperintense compared with hepatic vasculature. The HBP is typically acquired approximately 20 minutes after injection of gadoxetate and 1 to 3 hours after injection of gadobenate. HBP isointensity and hypointensity are used as ancillary features for favoring benignity and malignancy (not specific for HCC), respectively. Hepatobiliary contrast agents are helpful in the diagnosis of small (<2 cm in size) HCC and early HCC (without showing arterial enhancement or washout).[11]

Term Observation in LI-RADS

Observation is a generic term used in LI-RADS to denote any focal area appearing distinct from the background liver parenchyma. Term observation is preferred over lesion or nodule as it allows incorporation of true lesions as well as pseudolesions in the liver. Pseudolesions are non-pathological conditions and are likely to represent perfusion alterations, artifacts, and hypertrophic pseudomass. True lesions can be of HC or non-HC origin and range from benign to neoplastic and from premalignant to malignant spectrum.

The stepwise approach to diagnosis of nontreated observation is listed in ►**Table 3**.

LI-RADS Diagnostic Categories

Focal lesion in cirrhotic liver can vary in spectrum from benign nature to malignancy (HC or non-HC). To address the broad-spectrum nature of the untreated lesions, LI-RADS gives eight categories including LR-NC (noncharacterizable), LR-1 (definitely benign), LR-2 (probably benign), LR-3 (intermediate probability of malignancy), LR-4 (probably HCC), LR-5 (definitely HCC), LR-M (probably or definitely malignant not HCC specific), and LR-TIV (malignancy with tumor in vein) as detailed in ►**Table 4**.[12] Readers should remember that LI-RADS categories do not correspond exactly to histologic categories, instead reflect probability of benignity, HCC, non-HCC malignancy, and TIV.

Table 3 Stepwise approach to CT/MRI LI-RADS diagnosis of nontreated observation

Step 1	Untreated observation detected
Step 2	LI-RADS category can be applied (Inclusion and exclusion criteria)
Step 3	Technically optimal study (CT/MRI)
Step 4	Apply LI-RADS algorithm for categorization
Step 5	Optional: Apply ancillary features to downgrade or upgrade
Step 6	Optional: Apply tie-breaking rules
Step 7	Final check

Abbreviations: CT, computed tomography; LI-RADS, Liver Imaging Reporting and Data System; MRI, magnetic resonance imaging.

LR-NC category should be reserved if quality and completeness of dynamic post-contrast study do not allow assessment of one or major imaging features. These patients should be assessed via repeat or alternative diagnostic imaging in less than or equal to 3 months.

Categories LR-1 and LR-2 are on the benign spectrum of the LI-RADS scale with LR-1 being 100% benign and LR-2 being probably benign (►**Fig. 2**). LI-RADS does not strictly define the imaging criteria of benign lesions and instead leaves it to radiologists' understanding of common benign entities. Category LR-1 incorporates benign, non-HC lesions, and pseudolesions. The majority of LR-2 lesions are benign with exception of dysplastic or malignant lesions that can contribute up to 14% cases. The cirrhotic liver can show many benign entities that can be due to underlying cirrhosis (e.g., regenerative nodules, vascular shunts, confluent fibrosis) or be incidental non-HC lesions (e.g., cysts, hemangiomas). Examples of LR-1 and LR-2 lesions are detailed in ►**Table 5**.[13] In general, MRI allows better characterization of lesions as LR-1 and LR-2 as compared with CT. Patients

Table 4 Summary of CT and MRI diagnostic LI-RADS diagnostic categories

Diagnostic category	Conceptual definition	CT/MRI Criteria
LR-NC: Noncategorizable	Observation that cannot be categorized because image omission or degradation prevents assessment of 1 ≥ major features	Both of the following: • One or more major features cannot be assessed because of image omission or degradation AND • As a direct result, all possible categories can range from LR-1 to LR-5, LR-M
LR-1: Definitely benign 0% HCC 0% malignancy	100% certainty observation is nonmalignant	LI-RADS does not provide criteria for most of the entities that be categorized as LR-1 and instead provides examples
LR-2: Probably benign 13% HCC 14% malignancy	High probability but not 100% certainty observation is nonmalignant	LI-RADS does not provide criteria for most of the entities that be categorized as LR-2 and instead provides examples
LR-3: Intermediate probability of malignancy 38% HCC 40% malignancy	Nonmalignant and malignant entities each have moderate probability	Nonrim APHE AND < 20 mm with no additional major features. Arterial phase hypo- or isoenhancement AND • < 20 mm with ≤ 1 additional major feature OR • ≥ 20 mm with no additional major features
LR-4: Probably HCC 74% HCC 80% malignancy	High probability but not 100% certainty observation is HCC	Nonrim APHE AND • < 10 mm with ≥ 1 additional major feature OR • 10–19 mm with "capsule" as the only additional major feature OR • ≥ 20 mm with no additional major feature Arterial phase hypo- or isoenhancement AND • < 20 mm with ≥ 2 additional major features OR • ≥ 20 mm with ≥ 1 additional major feature
LR-5: Definitely HCC 94% HCC 97% malignancy	100% certainty observation is HCC	Nonrim arterial phase hyperenhancement AND: • 10–19 mm with nonperipheral "washout" OR • 10–19 mm with threshold growth OR • ≥ 20 mm with ≥ 1 additional major feature
LR-TIV: Malignancy with TIV	100% certainty for malignancy with TIV	Presence of definite enhancing soft tissue in vein, regardless of visualization of parenchymal mass
LR-M: Probably or definitely malignant, not HCC specific	High probability or 100% certainty observation is malignant but features are not HCC specific	Targetoid mass with any of the following imaging appearance on various phases or sequences • Targetoid dynamic enhancement: rim APHE, peripheral washout appearance, delayed central enhancement (any of these) • Targetoid diffusion restriction • Targetoid TP or HBP signal intensity Nontargetoid mass not meeting LR-5 criteria and without TIV with one or more of the following: • Infiltrative appearance • Marked diffusion restriction • Necrosis or severe ischemia • Other features suggesting non-HCC malignancy (specify in the report)

Abbreviations: APHE, arterial phase hyperenhancement; CT, computed tomography; HBP, hepatobiliary phase; HCC, hepatocellular carcinoma; LI-RADS, Liver Imaging Reporting and Data System; MRI, magnetic resonance imaging; TIV, tumor in vein; TP, transitional phase.
Additional major features include nonperipheral washout, enhancing capsule, and threshold growth.

with LR-1 and LR-2 lesions undergo routine surveillance at 6 months interval.

LR-3 category represents indeterminate lesions that can range from benign to dysplastic nodules to HCCs (►**Fig. 2**). The hypervascular pseudolesion is considered to be most common cause of LR-3 observation.[14] Up to 11% observations from LR-3 category can evolve into LR-5 or uncommonly to LR-M by 12 months. LR-3 lesions should be reassessed with routine or alternative diagnostic imaging in 3 to 6 months.

LR-4 category incorporates lesions with high but not 100% probability of HCC (►**Fig. 3**). LR-4 does not exclude non-HCC malignancy. LR-4 lesions require multidisciplinary discussion for tailored workup that may include biopsy.

LR-5 category aims at achieving the highest specificity and positive predictive value for the diagnosis of HCC using stringent imaging criteria with combination of major imaging features. Majority of the LR-5 lesions is progressed HCCs (►**Fig. 4**). It should be remembered that not all HCCs meet

Table 5 Examples of LR-1 and LR-2 lesions

LR-1	LR-2
Definite • Cyst • Hemangioma • Perfusion alteration • Hepatic fat deposition/sparing • Hypertrophic pseudomass • Confluent fibrosis or focal scar Spontaneous disappearance	Probable • Cyst • Hemangioma • Perfusion alteration • Hepatic fat deposition/sparing • Hypertrophic pseudomass • Confluent fibrosis or focal scar Distinctive nodule without malignant imaging features (solid nodule < 20 mm distinctive in imaging appearance compared with background nodules AND with no major feature of HCC, no feature of LR -M, and no ancillary feature of malignancy)

Abbreviation: HCC, hepatocellular carcinoma.
Lists above are not meant to be exhaustive.

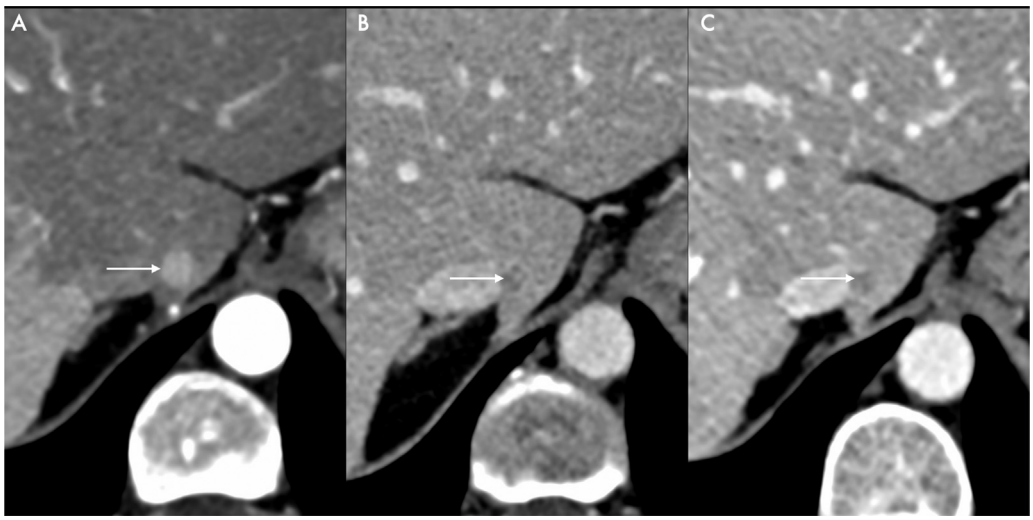


Fig. 3 (**A–C**) LR-4 observation: Contrast-enhanced computed tomography study shows a 9 mm observation (white arrow) showing nonrim arterial phase hyperenhancement in late arterial phase (**A**), with nonperipheral washout in portal venous phase (**B**) and delayed phase (**C**) without any enhancing capsule in delayed phase (**C**).

the stringent criteria of LR-5 and are considered atypical HCCs. LR-5 lesions require multidisciplinary discussion for consensus management.

Though the HCC is the commonest malignancy (~90%) in cirrhotic liver, other non-HCC malignancies (~10%) like intrahepatic cholangiocarcinoma (iCCA), combined hepatocellular cholangiocarcinoma (HCC-CCA), hepatic metastasis, and lymphoma are also seen in these patients. Category LR-M incorporates all those lesions that have high probability of malignancy not specific to HCC. LR-M category allows maintaining specificity of diagnosis of HCC without losing sensitivity for diagnosis of non-HCC malignancies. Targetoid morphology (►**Fig. 5**) on dynamic post-contrast imaging, diffusion-weighted imaging (DWI) or HBP imaging is characteristic of iCCA and combined HCC-CCA.[15] The presence of peripheral vascularity surrounding the central fibrotic core forms the histological basis for targetoid imaging morphology. Targetoid morphology can also be seen in atypical HCC hence LR-M also includes HCC (►**Fig. 5**). Up to 50% of LR-M lesions turn out to be atypical HCCs on histopathology. Unlike many other LI-RADS categories, LR-M does not have a set size criterion. It should be remembered that differentiation of LR-M into HCC and non-HCC malignancies has a bearing on prognostication and treatment planning. iCCA shows an early tendency for extrahepatic metastasis; hence, these patients are not considered transplant candidates in United States due to high-risk recurrence after transplant. LR-M lesions require multidisciplinary discussion for consensus management including biopsy.

LR-TIV denotes 100% certainty for malignancy with a tumor in vein in presence of definite enhancing soft tissue in vein, regardless of visualization of parenchymal mass (►**Fig. 6**). Previous versions of LI-RADS used category LR-5V to denote venous thrombosis due to HCC that had certain limitations. As TIV is not always caused by HCC, LR-TIV category offers broader spectrum allowing tumoral thrombosis from malignant lesions beyond HCC like iCCA or combined HCC-CCA as well as those cases where no distinct parenchymal lesion is visualized. Features that are suggestive but not definite for a TIV include occluded vein with ill-defined walls, occluded vein with restricted diffusion, occluded or obscured vein contiguous with malignant parenchymal mass, and heterogeneous vein enhancement not attributable to the artifact.[16] Depending on the underlying

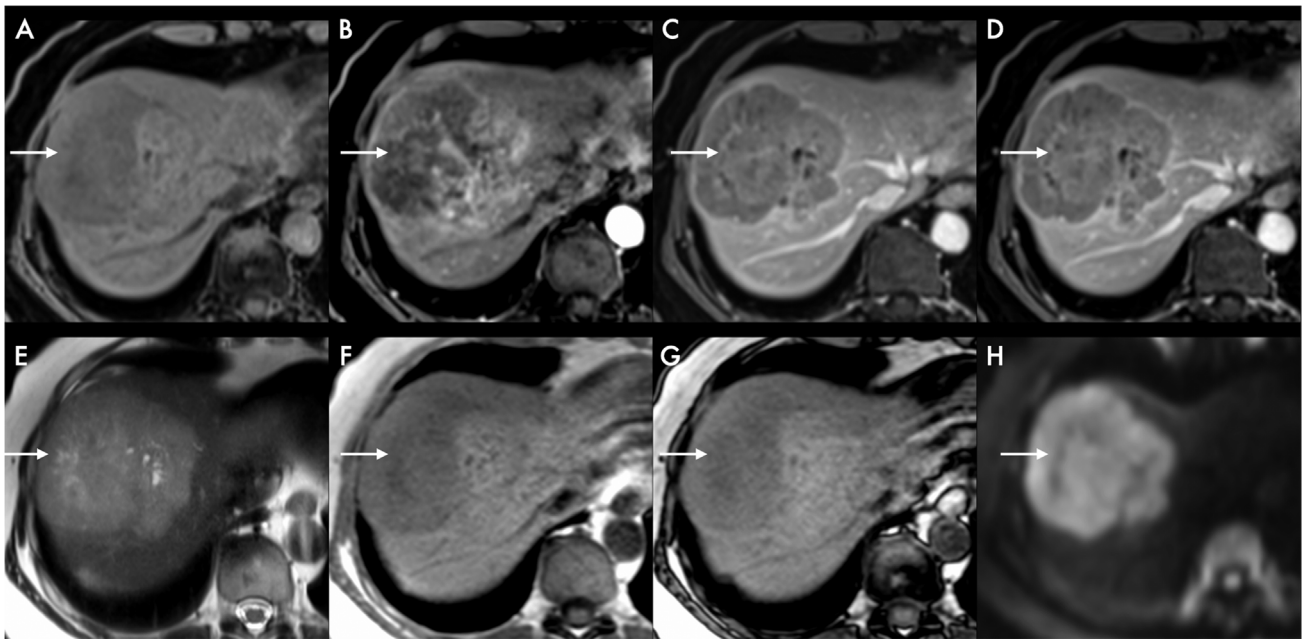


Fig. 4 (**A–C**) LR-5 observation: Magnetic resonance imaging (MRI) showing the major imaging features of LI-RADS: Contrast-enhanced MRI study shows a 70 mm observation (white arrow) appearing hypointense on T1-weighted (T1W) images (**A**), showing heterogenous arterial phase hyperenhancement on arterial phase images (**B**) with washout on portal venous phase images (**C**) and delayed enhancing rim on delayed phase images (**D**). Observation appears hyperintense on T2W images (**E**) showing diffusion-weighted imaging hyperintensity (**H**), and does not contain fat in phase and out of phase (**F, G**).

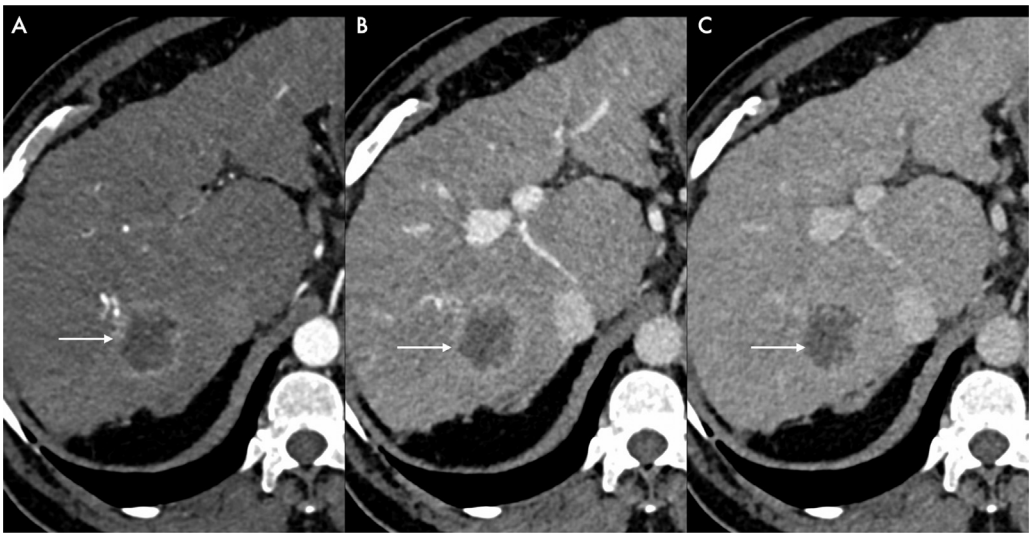


Fig. 5 (**A–C**) LR-M observation: Contrast-enhanced computed tomography study shows a 32 mm observation (white arrow) in segment VII showing rim arterial phase hyperenhancement in late arterial phase (**A**) and portal venous phase (**B**) with peripheral washout in delayed phase (**C**).

primary lesion, radiologist should report LR-TIV as TIV due to LR-4/5 lesion or LR-M lesion. LR-TIV lesions require multidisciplinary discussion for consensus management including biopsy.

In general, pathologically proven lesions are not assigned the LI-RADS category to avoid confusion in communication, except for benign or premalignant HC lesions like regenerative or dysplastic nodules.

The diagnostic approach to nontreated observation is detailed Algorithm 1 and CT/MRI diagnostic table (►**Table 6**).

Major Imaging Features of LI-RADS on CT and MRI

LI-RADS uses five major imaging features of HCC for assigning categories from LR-3 to LR-5 (►**Figs. 2–4**) as detailed in the later part article. These features include nonrim APHE, nonperipheral washout, observation size, threshold growth, and enhancing capsule (►**Table 7**).[17]

APHE is due to neoangiogenesis in the progressed HCC leading to increase in the hepatic arterial blood flow. APHE

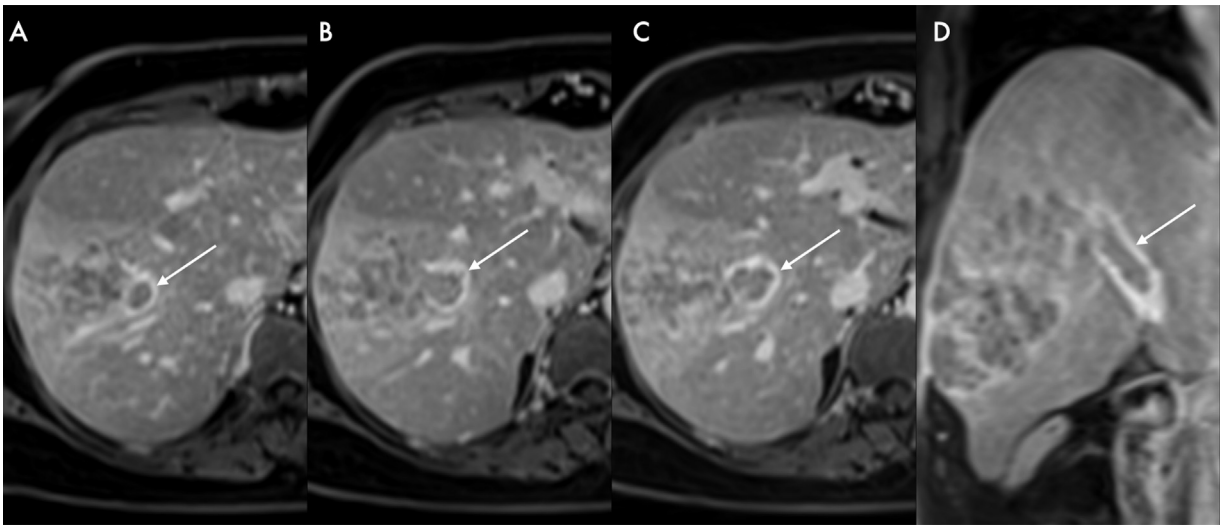


Fig. 6 (**A–D**) LR-TIV: Magnetic resonance imaging venous phase axial (**A–C**) and coronal images (**D**) showing a large heterogeneously enhancing lesion in segment VIII (arrow) with definite enhancing soft tissue seen contiguously infiltrating into anterior branch of right portal vein and right portal vein consistent with tumor in vein (TIV).

Table 6 CT/MRI diagnostic table

APHE (Arterial phase hyperenhancement)		No APHE		Nonrim APHE		
Observation size (mm)		< 20	≥ 20	< 10	10–19	≥ 20
Count Additional major features: • Enhancing capsule • Nonperipheral washout • Threshold growth	None	LR-3	LR-3	LR-3	LR-3	LR-4
	One	LR-3	LR-4	LR-4	LR-4 LR-5	LR-5
	≥ Two	LR-4	LR-4	LR-4	LR-5	LR-5
LR-4 LR-5	Observations in this cell are categorized based on one additional major feature: • LR-4—if enhancing "capsule" • LR-5—if nonperipheral "washout" OR threshold growth					

Abbreviations: APHE, arterial phase hyperenhancement; CT, computed tomography; MRI, magnetic resonance imaging.

Table 7 Major LI-RADS imaging features on CT and MRI

Feature	Definition
Nonrim APHE	Nonrim-like enhancement in arterial phase unequivocally greater in whole or in part than the liver. Enhancing part must be higher in attenuation or intensity than the liver in arterial phase
Nonperipheral "washout"	Nonperipheral reduction in the enhancement of lesion from earlier to later phase resulting in hypoenhancement relative to the liver Washout must occur in an extracellular postarterial phase: • For extracellular contrast agents and gadobenate: hypoenhancement in PVP, delayed phase (DP), or both • For gadoxetate: hypoenhancement in PVP only Hypointensity in TP or HBP does not qualify a washout
Enhancing "capsule"	Smooth, uniform, sharp border around most or all of observation, and visible as enhancing rim in PVP, DP, or transitional phase
Threshold growth	Size increase of a mass by ≥ 50% in ≤ 6 months
Size	Largest outer-edge-to-outer-edge dimension of an observation

Abbreviations: APHE, arterial phase hyperenhancement; CT, computed tomography; DP, delayed phase; HBP, hepatobiliary phase; LI-RADS, Liver Imaging Reporting and Data System; MRI, magnetic resonance imaging; PVP, portal venous phase; TP, transitional phase.

can be of rim and nonrim subtypes. Nonrim APHE is major features of HCC, while rim APHE is LR-M feature. Nonrim APHE is defined as nonrim-like enhancement of lesion (in whole or in part) in arterial phase unequivocally more than the liver. It reflects angiogenesis within the lesion. Late arterial phase is preferred as it allows optimal assessment of APHE. Early HCC may not show APHE and can appear iso or hypoenhancing due to insufficient arterialization and decreased portal flow.[18]

Nonperipheral "washout" is defined as nonperipheral reduction in the enhancement of observation from earlier to later phase resulting in hypoenhancement relative to the liver. For extracellular contrast agents and gadobenate, hypoenhancement in PVP, delayed phase (DP), or both are indicative of washout. For gadoxetate, washout is defined only on PVP and not on transitional phase as apparent hypointensity on transitional phase may be due to relative hyperenhancement of the liver parenchyma rather than a true lesional washout.[19] Nonperipheral washout may be homogeneous or heterogeneous; if heterogeneous, it may be focal, scattered (patchy, spotty), nodule-in-nodule, or mosaic. Different mechanisms contributing to washout appearance include reduction in portal venous flow, early venous drainage, tumoral high cellularity, and expanded extracellular space of the surrounding fibrotic liver.[20] Visual qualitative assessment of lesion enhancement relative to the liver is usually enough and does not require quantitative measurements. Lesions that lack enhancement do not qualify for washout assessment. Fade should not be interchangeably used with washout as it represents reduction in the enhancement of observation relative to the liver from hyperenhancement in an earlier phase to isoenhancement or minimal hyperenhancement in all later phases.

Enhancing "capsule" is defined as enhancing smooth, uniform, sharp border around most or all of observation, which is either thicker or more conspicuous than fibrotic tissue associated with chronic liver disease. It is assessed PVP, DP, or transitional phase but not on arterial phase. Imaging appearance of capsule can be due to true capsule or pseudocapsule. Histologically, true fibrous capsule is a feature of progressed HCC and is not seen in early HCC, dysplastic nodules, or regenerative nodules. Some of HCCs do not have a true fibrous capsule and instead are surrounded by prominent histopathological hepatic sinusoids and/or peritumoral fibrosis that is termed as pseudocapsule. Imaging alone cannot differentiate between a true capsule and pseudocapsule of HCC.[21]

Size is measured as the largest outer-edge-to-outer-edge dimension of observation. Enhancing capsule should be included in final size of the lesion. Size measurements should be avoided in the arterial phase (pitfall from perilesional enhancement) and DWI sequence (pitfall from distortion) particularly if lesion margins are well visible in the rest of the sequences. Arterial phase measurement can be erroneous due to presence of perilesional enhancement. DWI is prone for distortion; hence, measurement can be unreliable. Current LI-RADS algorithm allows assessment of observations below 10 mm as well as above 10 mm in size.

Interval in size of lesion is usually feature of malignancy and is not specific for HCC.

An increase in size of a mass by more than or equal to 50% in less than 6 months is termed as threshold growth. Subthreshold growth is termed as size increase in a mass less than threshold growth.

Subthreshold growth can be any of one the following: size increase of less than 50% over any period, or any size increase over a time interval more than 6 months, or a new mass of any size. Change in size of lesion due to intralesional hemorrhage or due to error in measurement owing to technical differences does not qualify for growth. Comparison with previous CT/MRI but not US or CEUS is allowed for the assessment of growth. Measurement of the lesion should be done on the same phase, sequence, and plane on serial exams if possible.

In isolation, major imaging features are not specific for HCC but combination of these features provides higher specificity as shown in categories LR-3 to LR-5. If a radiologist is unsure about the presence of any major imaging feature, then that feature is considered as absent.

Ancillary Imaging Features of LI-RADS on CT and MRI

Ancillary features are helpful in improving detection and diagnostic confidence of radiologist. Unlike major features, the ancillary features are optional and can be used at the radiologist's discretion. Ancillary imaging features can be grouped under three broad groups favoring malignancy in general, favoring HCC in particular, or benignity as enlisted in ►**Table 8**.[12] The presence of one or more ancillary feature of benignity allows downgradation of a lesion by 1 category from higher category. The presence of one or more ancillary feature of malignancy allows upgradation of lesions by 1 category from lower category up to LR-4. LI-RADS does not allow use of any ancillary feature to upgrade lesion from LR-4 to LR-5 category due to lack of their specificity for diagnosing HCC. If any lesion exhibits ambiguous ancillary features favoring both malignancy and benignity, then a change in category is not allowed. The absence of ancillary features should not be used to upgrade or downgrade a category. If a radiologist is unsure about the presence of any ancillary imaging feature, then that feature is considered as absent.[22] Key aspect of ancillary imaging features are detailed in ►**Tables 9**, **10**, and **11**.

Tie-Breaking Rule of LI-RADS on CT and MRI

If radiologist is unsure to select between the two categories, then choose the one reflecting lower certainty. In case of doubtful benign lesions, choose a higher category like LR-2/ LR-3. In case of doubtful malignant lesions, choose a lower category like LR-3/ LR-4 to maintain specificity. If unsure about the presence of TIV, then avoid the LR-TIV category.

Table 8 Ancillary LI-RADS imaging features on CT and MRI

Favoring malignancy (not HCC in particular)	Favoring HCC in particular	Favoring benignity
• US visibility as a discrete nodule • Subthreshold growth • Restricted diffusion • Mild-to-moderate T2 hyperintensity • Corona enhancement • Fat sparing in a solid mass • Iron sparing in a solid mass • Transitional phase hypointensity • Hepatobiliary phase hypointensity	• Nonenhancing capsule • Nodule-in-nodule • Mosaic architecture • Blood products in mass • Fat in mass, more than adjacent liver	• Size stability $>$ 2 years • Size reduction • Parallels blood pool • Undistorted vessels • Iron in mass, more than liver • Marked T2 hyperintensity • Hepatobiliary phase isointensity

Abbreviations: CT, computed tomography; HCC, hepatocellular carcinoma; LI-RADS, Liver Imaging Reporting and Data System; MRI, magnetic resonance imaging; US, ultrasound.

Table 9 Key aspects of ancillary LI-RADS imaging features favoring HCC in particular on CT and MRI

Nonenhancing capsule	Nonenhancing capsule refers to subtype of capsule that does not enhacement. On CT, it is seen as hypoattenuating on precontrast study and nonenhancing on postcontrast study. Noncontrast MRI, it is seen as hypointnese on T1WI, hypo- or hyperintense on T2WI, and hyperintense on DWI. On MRI post-contrast sequences, it appears nonenhancing
Nodule-in-nodule	Nodule-in-nodule refers to presence of a smaller inner nodule within a larger outer nodule. The inner nodule shows different imaging features compared with outer nodule, and can be located within the center or periphery of the larger nodule. This feature applies on when both inner and outer nodules are solid
Mosaic architecture	Mosaic architecture refers to presence of any combination of internal nodules, compartments, or septations, within a solid or mostly solid mass. Internal nodules or compartments of lesion have different imaging features. Differential imaging characteristic can be due to presence of fat, fibrosis, blood products, and vascular dynamics
Blood products in mass	Blood products in mass refer to presence of intralesional or perilesional hemorrhage in absence of prior trauma, biopsy or intervention. It should not be applied to nonsolid lesions like hemorrhagic cyst
Fat in mass, more than adjacent liver	Fat in a mass, more than in adjacent liver, refers to excess fat within a mass, in whole or in part, relative to adjacent liver. This fat can be intracellular or extracellular

Abbreviations: CT, computed tomography; DWI, diffusion-weighted imaging; HCC, hepatocellular carcinoma; LI-RADS, Liver Imaging Reporting and Data System; MRI, magnetic resonance imaging; T1WI, T1-weighted imaging.

Table 10 Key aspects of ancillary LI-RADS imaging features favoring benignity on CT and MRI

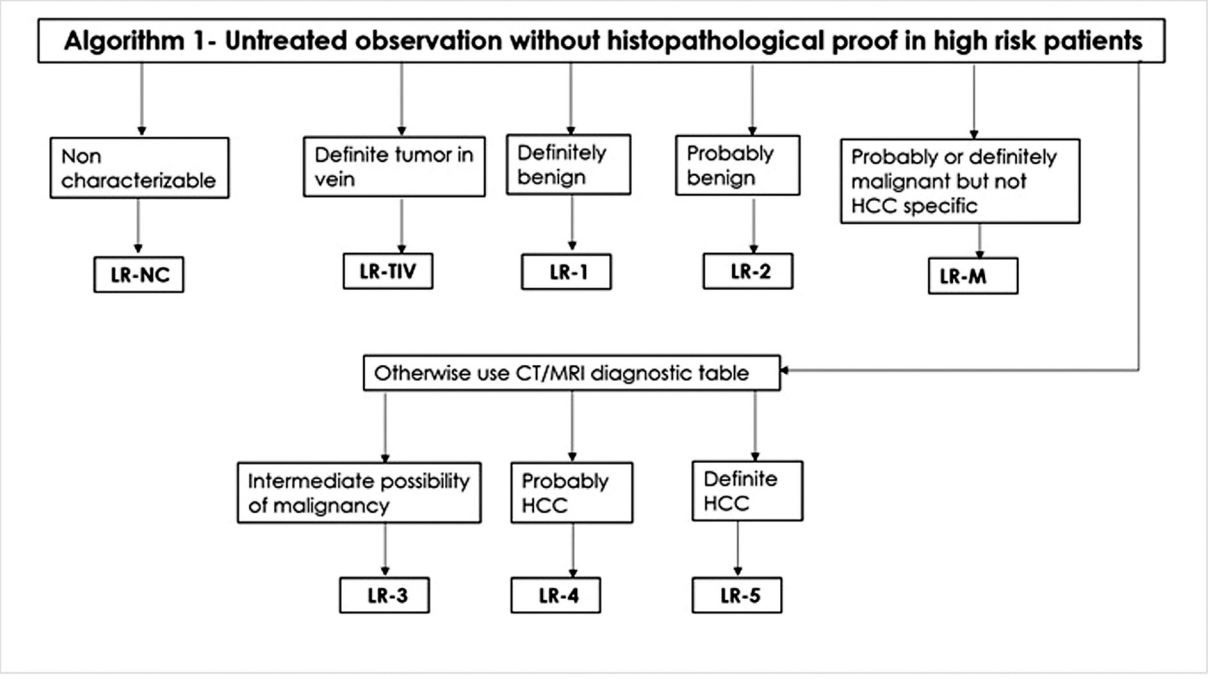
Size stability $\geq$ 2 years	No change size of lesion on serial exams $\geq$ 2 years apart
Size reduction	Spontaneous decrease in size of lesion, and not contributed due to technique differences, artifact, or measurement error
Parallels blood pool	Temporal pattern in which enhancement approximates blood pool in all phases. This enhancement pattern is characteristic but in isolation is not diagnostic of hemangiomas. Other features (i.e., marked T2-hyperintensity and peripheral discontinuous nodular enhancement) may be needed to confirm the diagnosis of hemangioma
Undistorted vessels	Vessels traversing an observation without displacement, deformation, or other alteration. It is usually characteristic of perfusion alterations
Iron in mass, more than liver	More iron in solid mass relative to background iron overloaded liver
Marked T2-hyperintensity	On T2WI, lesion shows higher intensity than non-iron-overloaded spleen and as high as or almost as high as simple fluid. It is characteristic imaging feature of cysts and some hemangiomas
Hepatobiliary phase isointensity	In hepatobiliary phase, lesion shows intensity identical or nearly identical to liver

Abbreviations: CT, computed tomography; LI-RADS, Liver Imaging Reporting and Data System; MRI, magnetic resonance imaging; T2WI, T2-weighted imaging.

Table 11 Key points in the structured reporting of an observation using CT/MRI LI-RADS

Observation numbering	Like 1,2,3, etc.
Location	Hepatic segments I to VIII
Size	Maximum longest dimension, series and image number on which it was measured
TIV	Present or absent and its entire extent if present
LR-M features if applicable	Present or absent
Major features contributing to LI-RADS category	APHE, nonperipheral washout, enhancing capsule and threshold growth should be mentioned
Ancillary features if applicable	Mention the ancillary features responsible for upgrade or downgrade of the category
Final LI-RADS category using LI-RADS 2018 version	LR1 to 5, LR-M, LR-TIV

Abbreviations: APHE, arterial phase hyperenhancement; CT, computed tomography; LI-RADS, Liver Imaging Reporting and Data System; MRI, magnetic resonance imaging; TIV, tumor in vein.



Algorithm 1 Stepwise approach to nontreated observation without histopathological proof in high-risk patients.

Final Check

Scrutiny of all the imaging findings is necessary to allot the final category of any observation. All the nodules need similar optimal assessment for appropriate management recommendations.

Key points in the structured reporting of nontreated observation using CT/MRI LI-RADS are detailed in ►**Table 11**.

Summary

LI-RADS provides unified approach for categorization of liver imaging findings in at-risk patients using standardized lexicon, technique, management, and reporting guidelines. 2018 version of LI-RADS achieved integration with AASLD 2018 HCC clinical practice guidance by adopting the criteria for small (10–19 mm) LR-5 observations and simplifying the definition for threshold growth. In authors experience, knowledge of key concepts of LI-RADS diminishes the errors in reporting, reduces interobserver variability, facilitates communication between radiologists and other clinicians. Details of post-treatment LI-RADS are beyond scope of this article and hence not discussed.

Conflict of Interest
None declared.

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