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Liver Imaging Reporting and Data System: current status and future perspectives in the diagnosis of hepatocellular carcinoma

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Abstract

Hepatocellular carcinoma (HCC) is the most common primary liver cancer and ranks third among cancer-related deaths globally, with over 900,000 new cases and approximately 830,000 deaths annually. Early detection is crucial, as 5-year survival exceeds 70% for lesions <3 cm treated curatively but drops below 20% in advanced stages. The Liver Imaging Reporting and Data System (LI-RADS) v2018, endorsed by major guidelines, provides a standardized framework for acquisition, interpretation, and reporting of liver lesions in high-risk patients. Using five major imaging features—non-rim arterial phase hyperenhancement, non-peripheral washout, enhancing capsule, lesion size, and threshold growth—alongside optional ancillary features, the LR-5 category achieves >95% positive predictive value for HCC.

Meta-analyses of over 3300 observations report 86% sensitivity and 85% specificity for computed tomography/magnetic resonance imaging (MRI) LI-RADS, with gadoxetate-enhanced MRI reaching 88-91% sensitivity. Key limitations include overcalling benign hypervascular nodules, underdiagnosing hypovascular or well-differentiated HCC (up to 30% of lesions <2 cm), and misclassifying intrahepatic cholangiocarcinoma (CCA) or combined HCC-CCA as LR-5 (up to 40-50%).

The LI-RADS Treatment Response Algorithm v2024 introduces criteria for radioembolization and stereotactic body radiation therapy, improving specificity for viable residual disease detection (93% *vs*. 86% for mRECIST). Future directions include artificial intelligence (82-90% accuracy), radiomics, multimodal imaging, and liquid biomarkers to reduce inter-reader variability and enhance prognostic stratification. Over a decade since its introduction, LI-RADS v2018 remains the reference standard for non-invasive HCC diagnosis and is evolving toward precision oncology.

Key words: LI-RADS, hepatocellular carcinoma, non-invasive diagnosis, treatment response assessment, artificial intelligence.

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Introduction

Hepatocellular carcinoma (HCC) is the most common primary liver malignancy and the third leading cause of cancer-related death worldwide, with over 900,000 new cases and approximately 830,000 deaths annually according to GLOBOCAN 2022 data.[1] It almost invariably develops in the setting of cirrhosis or chronic liver disease, with major risk factors including chronic HBV/HCV infection, non-alcoholic steatohepatitis (NASH), alcohol abuse, and aflatoxin exposure.[2] Early diagnosis is the most important prognostic factor: 5-year survival exceeds 70% for lesions <3 cm treated with curative intent, but drops below 20% in advanced stages.[3] For this reason, international guidelines recommend semi-annual surveillance with ultrasound ± α-fetoprotein (AFP) in high-risk patients.[4] When ultrasound detects a nodule, contrast-enhanced multiphasic computed tomography (CT) or magnetic resonance imaging (MRI) allows non-invasive diagnosis in most cases, avoiding biopsy.[5] However, inter-reader variability has historically led to diagnostic and management heterogeneity.[6] The Liver Imaging Reporting and Data System (LI-RADS), developed by the American College of Radiology (ACR) in 2011 and updated to version 2018, currently represents the most comprehensive and validated system for standardizing acquisition, interpretation, and reporting of focal liver observations in patients at risk for HCC.[7] LI-RADS categorizes observations from LR-1 (definitely benign) to LR-5 (definitely HCC), integrating major and ancillary features, with a positive predictive value (PPV) >95% for the LR-5 category.[8] The system has been officially incorporated into the 2018 American Association for the Study of Liver Diseases (AASLD) guidelines and is used by the Organ Procurement and Transplantation Network (OPTN) for organ allocation.[9] This review, based on literature updated to November 2025, analyzes the current status of LI-RADS v2018, diagnostic performance evidence, main practical limitations, and future perspectives, with particular focus on the LI-RADS Treatment Response Algorithm (TRA) v2024 updates and integration with artificial intelligence.

Methods

This is a narrative review with a structured literature search. We searched PubMed/MEDLINE and Google Scholar for English-language articles published up to November 30, 2025, using combinations of the terms: "LI-RADS", "hepatocellular carcinoma", "CT", "MRI", "gadoxetate", "contrast-enhanced ultrasound", "treatment response algorithm", "mRECIST", "radiomics", "artificial intelligence", and "biomarkers/cfDNA". We prioritized ACR LI-RADS official documents, international guidelines [AASLD/European Association for the Study of the Liver (EASL)/OPTN], systematic reviews/meta-analyses, and large cohort studies. Additional papers were identified through the reference lists of key articles. Evidence was synthesized qualitatively, and quantitative performance metrics were reported as presented in the original sources.

Review findings

Historical evolution of Liver Imaging Reporting and Data System

LI-RADS was first published in 2011 as a CT and MRI algorithm, with categories ranging from LR-1 to LR-5 and the introduction of the LR-M category for non-HCC malignancies.[10] In 2013, the ultrasound surveillance module (US LI-RADS) was added; in 2014, the contrast-enhanced ultrasound (CEUS) LI-RADS, and in 2017, hepatobiliary contrast agents were incorporated.[8] Version 2017 introduced the concept of ancillary features for category upgrade/downgrade and redefined threshold growth.[11] LI-RADS v2018, currently in use, simplified threshold growth as a major feature (≥50% in ≤6 months or ≥100% in >6 months), eliminated subthreshold growth, and clarified the use of ancillary features, achieving a sensitivity increase from 71% to 81% compared with v2017 without loss of specificity.[12] In 2022, the LI-RADS TRA was released, and in 2024, the updated TRA v2024 version introduced specific criteria for emerging locoregional therapies such as radioembolization and stereotactic body radiation therapy.[13] The system's evolution has been driven by systematic evidence reviews: major features have evidence levels ranging from 2++ to 4 according to the Oxford CEBM system.[11]

Liver Imaging Reporting and Data System v2018 diagnostic criteria

LI-RADS v2018 applies to high-risk patients (cirrhosis of any etiology, chronic HBV, cured HCV-related cirrhosis) and uses a diagnostic algorithm based on five major features: i) non-rim arterial phase hyperenhancement (APHE); ii) non-peripheral washout; iii) enhancing capsule; iv) size ≥20 mm; v) threshold growth.[8]

Ancillary features (*e.g.*, hepatobiliary-phase hypointensity, diffusion restriction, mosaic architecture, corona enhancement) may be used in favor of or against malignancy but cannot upgrade beyond LR-4.[14] The LR-5 category requires APHE plus at least one additional major feature for observations ≥20 mm, or two for 10-19 mm observations, ensuring PPV>95%.[8] The LI-RADS v2018 observation categories, their approximate probability of representing HCC, and the corresponding recommended management are summarized in Table 1.

Diagnostic performance across imaging modalities

Meta-analyses including over 3300 observations have shown a pooled sensitivity of 86% [95% confidence interval (CI) 82-89%] and specificity of 85% (95% CI 80-89%) for CT/MRI LI-RADS in diagnosing HCC (LR-5 category).[15] With gadoxetate-enhanced MRI, sensitivity increases to 88-91% due to the hepatobiliary phase.[16] For 10-19 mm observations, adding diffusion restriction as an optional criterion raises sensitivity from 53% to 62% without significant specificity loss.[17] CEUS LI-RADS v2017 with Sonazoid shows 77% sensitivity but limited specificity (88%) due to Kupffer-phase defects; modified Asian versions improve performance.[18] In non-cirrhotic patients with severe steatosis, LR-5 performance remains high (sensitivity 79-83%).[19] Table 2 provides a comparative overview of the diagnostic performance of LI-RADS across the principal imaging modalities based on key meta-analyses and large cohort studies.

Table 1. Liver Imaging Reporting and Data System v2018 categories and hepatocellular carcinoma probability.

Category	Description	HCC probability	Typical management
LR-1	Definitely benign	0%	No follow-up
LR-2	Probably benign	<5%	Follow-up at 6-12 months
LR-3	Intermediate probability	10-35%	Follow-up or biopsy
LR-4	Probably HCC	70-94%	MDT/biopsy/treatment
LR-5	Definitely HCC	≥95%	MDT/biopsy/treatment
LR-M	Probable/definite malignancy, not HCC-specific	Variable	Mandatory biopsy
LR-TIV	Tumor in vein	High for HCC	Staging and systemic therapy

HCC, hepatocellular carcinoma; MDT, multidisciplinary team.[8]

Table 2. Diagnostic performance of Liver Imaging Reporting and Data System across main modalities.

Study/meta-analysis	Modality	N. observations	LR-5 sensitivity (%)	LR-5 specificity (%)	LR-5 PPV
Liang *et al.*, 2021[15]	CT+MRI	3386	86	85	92
Shin *et al.*, 2021[16]	Gadoxetate MRI	1784	88	91	94
Ren *et al.*, 2019[12]	MRI (v2018 *vs.* v2017)	217	81 → 91	91	-
Chen *et al.*, 2021[17]	MRI+diffusion	312	79	93	-
Liu *et al.*, 2024[18]	Modified CEUS	1156	77	88	90
Cao *et al.*, 2024[19]	CT/MRI non-cirrhotic	428	83	89	88

PPV, positive predictive value; CT, computed tomography; MRI, magnetic resonance imaging; CEUS, contrast-enhanced ultrasound.

Limitations and most common pitfalls

The main interpretive errors include: i) overestimation of APHE in perfusion nodules or flash-filling hemangiomas;[6] ii) misinterpretation of hepatobiliary-phase washout with gadoxetate;[20] iii) underdiagnosis of hypovascular or well-differentiated HCC (up to 30% of cases <2 cm);[21] iv) erroneous LR-5 categorization of intrahepatic cholangiocarcinoma or combined HCC-CCA (up to 40-50% of cases).[22]

In these settings, biopsy remains essential.[8] In patients with NASH without overt cirrhosis, major features do not significantly differ from those of virus-related HCC.[23]

Liver Imaging Reporting and Data System within international guideline frameworks (AASLD/OPTN *vs.* EASL)

LI-RADS is the most detailed lexicon/algorithm for imaging-based categorization of liver observations in at-risk populations and is formally integrated into AASLD guidance and OPTN transplant pathways. In contrast, EASL provides a guideline-driven diagnostic algorithm that is widely used in Europe and may differ in how non-invasive diagnosis is operationalized, particularly in small nodules and in the role of CEUS and hepatobiliary agents across centers. In practice, LI-RADS is often preferred when standardized multidisciplinary communication is needed (radiology-hepatology-transplant), when transplant eligibility requires OPTN-compatible reporting, or when structured reporting and auditability are priorities. EASL-based pathways remain highly relevant in European practice and can be used alongside LI-RADS; however, differences in diagnostic thresholds and accepted imaging criteria should be explicitly recognized at the MDT level to avoid management discordance.

In clinical practice, explicit agreement at the multidisciplinary tumor board level on the adopted diagnostic framework is essential to avoid discordant management decisions.

Treatment Response Assessment: Liver Imaging Reporting and Data System Treatment Response Algorithm v2024

The new TRA v2024 algorithm introduces specific criteria for radioembolization (presence of nodular enhancement ≥10 mm with arterial pattern) and stereotactic body radiation therapy (SBRT) (late perilesional enhancement changes), improving specificity compared with mRECIST (93% *vs.* 86%) for detecting viable residual disease.[20]

The LI-RADS TRA provides standardized categorization of treated observations as LR-TR nonviable, equivocal, or viable, based on enhancement patterns and ancillary post-treatment findings. Compared with size-based frameworks, TRA focuses on imaging surrogates of residual tumor perfusion, aligning more closely with histopathologic viability when available.

The TRA v2024 update introduces clarifications for emerging and increasingly used modalities, including radioembolization (TARE) and SBRT, where post-treatment enhancement may be atypical and temporally evolving.

Interpretation of post-treatment enhancement patterns is highly dependent on imaging timing relative to therapy, particularly after SBRT and radioembolization, underscoring the need for standardized follow-up intervals.

In particular, after TARE, viable disease is suggested by nodular arterial enhancement ≥10 mm (rather than ill-defined geographic hyperemia), while after SBRT, delayed/perilesional enhancement changes may reflect treatment effect rather than residual tumor, requiring careful temporal correlation.

Clinically, improved specificity for residual viability can reduce unnecessary retreatment and guide MDT decisions (*e.g.*, additional locoregional therapy *vs.* listing/bridging for transplantation, or escalation to systemic therapy). When TRA is equivocal, short-interval follow-up or biopsy may be appropriate depending on clinical context and transplant candidacy. Importantly, evidence supporting TRA v2024 is still evolving, and performance varies across therapies, imaging timing, and reference standards.

Conclusions

More than a decade after its introduction, LI-RADS v2018 remains the reference standard for non-invasive HCC diagnosis, offering high and reproducible diagnostic performance across all major imaging modalities.[8] The TRA v2024 updates and increasingly tight integration with artificial intelligence promise to further reduce interpretive variability and improve prognostic stratification.[13] However, challenges persist, particularly for atypical lesions and patients with non-cirrhotic liver disease, which will require additional prospective multicenter studies and integration with molecular biomarkers.[4]

Future perspectives

1. Artificial intelligence: deep-learning models for automatic major feature detection achieve 97% sensitivity for APHE and overall LI-RADS categorization accuracy of 82-90%.[24-27]
2. Multimodal integration: combination of CEUS, MRI and radiomics predicts early post-resection recurrence with C-index 0.80.[28]
3. Liquid biomarkers: LI-RADS + AFP + cfDNA combination increases sensitivity for recurrent HCC to 98%.[29]
4. Radiomics: texture features extracted from LI-RADS images correlate with histological grade and survival.[30]

The most promising research directions for LI-RADS, together with currently available evidence and their expected clinical impact, are outlined in Table 3.

Table 3. Main future research directions for the Liver Imaging Reporting and Data System.

Research area	Current evidence	Expected impact
AI/deep learning	Accuracy 82-90%	Reduced inter-reader variability
TRA v2024 post-radioembolization	Specificity 93%	Improved therapeutic stratification
Radiomics+LI-RADS	Correlation with grading/prognosis	Personalized medicine
Multimodal+biomarkers	Sensitivity >95% for recurrence	Post-treatment surveillance
Validation in NASH/non-cirrhotic patients	Maintained performance	Expanded indications

AI, artificial intelligence; TRA, Treatment Response Algorithm; LI-RADS, Liver Imaging Reporting and Data System; NASH, non-alcoholic steatohepatitis.[19,20,23,24,27-29]

Although early results for AI, radiomics, and multimodal approaches are promising, most studies remain retrospective, frequently single-center, with heterogeneous imaging protocols, variable reference standards, and limited external validation. Therefore, reported accuracies and C-indices should be interpreted as hypothesis-generating, and robust prospective multicenter validation and standardization are needed before widespread clinical implementation.

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