

The Diagnostic Performance of Non-Rim Arterial Phase Hyperenhancement in LI-RADS 5 Categorization for Hepatocellular Carcinoma: A Histopathological Correlation

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Abstract

Background: Hepatocellular carcinoma (HCC) is the most common primary liver malignancy and a leading cause of cancer-related mortality worldwide. Early and accurate diagnosis is essential for timely treatment and improved prognosis. Triphasic MRI, in combination with the Liver Imaging Reporting and Data System (LI-RADS), allows non-invasive evaluation of liver lesions, with non-rim arterial phase hyperenhancement (APHE) as a key feature for LR-5 categorization.

Objective: To assess the diagnostic performance of non-rim APHE in LI-RADS 5 categorization for HCC, using histopathology as the reference standard.

Methods: A cross-sectional study included 30 patients with suspected hepatic lesions who underwent triphasic MRI. Lesions were categorized according to LI-RADS from April 2024 to September 2025. Criteria, and imaging findings were correlated with histopathology. Diagnostic parameters including sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), likelihood ratios, and accuracy were calculated using SPSS. Statistical significance was determined with Fisher's exact test ($p < 0.05$).

Results: Of 30 lesions, 18 (60%) were confirmed as HCC. Sixteen lesions were categorized as LR-5, of which 15 were true positives and 1 false positive. Sensitivity and specificity of LR-5 for HCC detection were 83.3% and 91.7%, respectively. PPV was 93.8%, NPV 78.6%, and overall accuracy 86.7%. Non-rim APHE was observed in 29 lesions (96.7%), while capsular appearance and washout features were present in 43.3% and 46.7% of lesions, respectively.

Conclusion: Non-rim APHE is a pivotal imaging feature for LI-RADS 5 categorization. Triphasic MRI interpreted using LI-RADS provides high diagnostic accuracy and can guide non-invasive management of HCC, reducing the need for biopsy in most cases.

Introduction

Hepatocellular carcinoma (HCC) is the most common primary malignancy of the liver and represents a major global health burden. It accounts for approximately 75–85% of all primary liver cancers and is currently one of the leading causes of cancer-related mortality worldwide. The incidence of HCC has increased

steadily over the past several decades, largely due to the high prevalence of chronic liver diseases such as hepatitis B virus (HBV), hepatitis C virus (HCV), alcoholic liver disease, and non-alcoholic fatty liver disease. Early and accurate diagnosis of HCC is crucial because prognosis and treatment outcomes are strongly dependent on tumor stage at the time of detection. Patients diagnosed at an early stage

may benefit from curative therapies such as surgical resection, liver transplantation, or local ablative procedures, whereas advanced disease is often associated with limited therapeutic options and poor survival outcomes [1]. Traditionally, histopathological examination has been considered the gold standard for confirming hepatocellular carcinoma. However, biopsy procedures are invasive and carry potential risks such as bleeding, tumor seeding, and sampling error. In addition, small or deeply located lesions may be difficult to access safely. For these reasons, imaging-based diagnostic approaches have become increasingly important in the evaluation of suspected HCC, particularly in patients with cirrhosis or other high-risk conditions. Current international guidelines allow non-invasive diagnosis of HCC based on characteristic imaging findings without the need for histological confirmation in many cases [2]. Multiphasic imaging techniques, particularly triphasic computed tomography (CT) and magnetic resonance imaging (MRI), play a central role in the detection and characterization of focal liver lesions. Among these modalities, MRI is widely recognized for its superior soft tissue contrast and higher sensitivity for detecting small hepatic tumors. Dynamic contrast-enhanced MRI allows visualization of vascular changes within liver lesions during arterial, portal venous, and delayed phases, which provides essential information for differentiating hepatocellular carcinoma from other hepatic malignancies [3]. One of the most important imaging features of HCC is arterial phase hyperenhancement (APHE), which reflects the increased arterial blood supply characteristic of malignant hepatocellular lesions. In particular, non-rim arterial phase hyperenhancement is considered a key diagnostic feature of HCC because malignant hepatocytes develop abnormal arterial vascularization during tumor progression. This enhancement pattern typically appears during the arterial phase and may be followed by washout in the portal venous or delayed phases and the presence of a capsule-like appearance. These dynamic vascular features form the basis for imaging-based diagnostic criteria used in clinical practice [4]. To standardize the interpretation and reporting of liver imaging findings, the American College of Radiology introduced the Liver Imaging Reporting and Data System (LI-

RADS). This structured classification system provides a standardized framework for evaluating hepatic observations in patients at risk for hepatocellular carcinoma. LI-RADS categorizes lesions from LR-1 (definitely benign) to LR-5 (definitely HCC) based on specific major imaging features such as non-rim arterial phase hyperenhancement, washout appearance, capsule enhancement, lesion size, and threshold growth. The system aims to reduce variability in radiological interpretation, improve communication among clinicians, and support consistent clinical decision-making [5]. Among the LI-RADS categories, LR-5 lesions are considered diagnostic of HCC with a very high probability, allowing clinicians to initiate treatment without histopathological confirmation in many clinical settings. Several studies have demonstrated that LR-5 classification has extremely high specificity and positive predictive value for hepatocellular carcinoma, often exceeding 90%. Nevertheless, sensitivity may vary depending on lesion size and the presence of characteristic imaging features. Small or atypical tumors may lack classic vascular patterns and therefore be categorized as LR-4 (probable HCC) rather than LR-5 [6]. Previous research has highlighted the important role of arterial phase hyperenhancement in the identification of hepatocellular carcinoma. Studies have reported that non-rim APHE is the most sensitive imaging feature of HCC and is present in the majority of tumors detected on dynamic MRI. However, arterial hyperenhancement alone is not entirely specific, as certain benign lesions or non-HCC malignancies may occasionally demonstrate similar enhancement patterns. Therefore, correlation with additional imaging features and histopathological findings remains essential for accurate diagnosis [7]. Recent investigations evaluating LI-RADS performance have shown promising results in terms of diagnostic accuracy. Meta-analyses have reported sensitivity values ranging from approximately 70% to 85% and specificity values exceeding 90% for LR-5 lesions when MRI is used as the imaging modality. These findings support the reliability of LI-RADS for non-invasive diagnosis of hepatocellular carcinoma and highlight the importance of dynamic contrast-enhanced imaging in clinical practice [8]. Despite these advances, variability still exists in the diagnostic performance of

individual LI-RADS features, particularly in early-stage disease or atypical tumors. Therefore, continued evaluation of imaging findings in comparison with histopathological results is necessary to better understand the diagnostic value of specific imaging characteristics. In particular, assessing the role of non-rim arterial phase hyperenhancement in LR-5 categorization may help clarify its contribution to accurate identification of hepatocellular carcinoma [9]. The present study was therefore conducted to evaluate the diagnostic performance of non-rim arterial phase hyperenhancement in LI-RADS 5 categorization for hepatocellular carcinoma using triphasic MRI, with histopathological findings as the reference standard. By correlating imaging results with pathological diagnosis, this study aims to determine the reliability of LI-RADS classification and its clinical utility in the non-invasive diagnosis of hepatocellular carcinoma.

Methods

Study design and setting

This cross-sectional observational study was conducted in the Department of Radiology & Imaging in collaboration with the Department of Pathology, BMU. This study was carried out from April 2024 to September 2025. The aim of the study was to evaluate the diagnostic performance of non-rim arterial phase hyperenhancement in LI-RADS 5 categorization for hepatocellular carcinoma using triphasic MRI with histopathological correlation.

Study population

Patients presenting with suspected focal liver lesions who underwent triphasic MRI of the liver were considered for inclusion in the study.

Inclusion criteria

- Patients with suspected hepatic lesions detected on imaging
- Patients who underwent triphasic MRI examination
- Patients with available histopathological diagnosis

Exclusion criteria

- Patients without histopathological confirmation
- Patients with incomplete imaging data
- Patients with contraindications to MRI or contrast agents

Sample size

A total of 30 hepatic observations from eligible patients were included in the final analysis.

Imaging technique

Triphasic MRI examinations were performed using a standard liver imaging protocol including:

- Pre-contrast T1-weighted imaging
- T2-weighted imaging
- Diffusion-weighted imaging
- Dynamic contrast-enhanced imaging during
 1. Arterial phase
 2. Portal venous phase
 3. Delayed phase

Lesions were evaluated according to ACR LI-RADS 2018 criteria, focusing on major imaging features including:

- Non-rim arterial phase hyperenhancement
- Washout appearance
- Capsule appearance
- Lesion size

Each lesion was categorized into LI-RADS categories (LR-1 to LR-5).

Histopathological examination

Histopathological evaluation of liver lesions was performed following biopsy or surgical resection and served as the reference standard for diagnosis.

Data analysis

Data were analyzed using Statistical Package for Social Sciences (SPSS) software. Diagnostic performance was calculated using the following parameters:

- Sensitivity
- Specificity
- Positive predictive value (PPV)
- Negative predictive value (NPV)
- Positive likelihood ratio
- Negative likelihood ratio

Diagnostic accuracy

The association between LI-RADS classification and histopathological findings was assessed using Fisher's exact test, with $P < 0.05$ considered statistically significant.

Results

In this study, a total of 30 patients with liver lesions were evaluated histopathologically and radiologically. The histopathological analysis revealed that the majority of lesions were hepatocellular carcinoma (HCC), accounting for 18 cases (60.0%), followed by metastatic lesions in 4 patients (13.3%). Cholangiocarcinoma was observed in 3 patients (10.0%), while combined HCC-cholangiocarcinoma (HCC-CC) accounted for 2 cases (6.7%). Other less common liver lesions were noted in 3 patients (10.0%) (Table 1). According to the Liver Imaging Reporting and

Table 1 Histopathological distribution of liver lesions (n=30)

Diagnosis	Frequency	Percentage
Hepatocellular carcinoma	18	60.0
Metastasis	4	13.3
Cholangiocarcinoma	3	10.0
Combined HCC-CC	2	6.7
Other lesions	3	10.0
Total	30	100

Data System (LI-RADS) classification, 16 lesions (53.3%) were categorized as LR-5, indicative of definite HCC, while 14 lesions (46.7%) were classified as LR-4, representing probable HCC (Table 2). Triphasic MRI features demonstrated that non-rim arterial phase hyperenhancement was the most frequently observed characteristic, present in 29 lesions (96.7%). Non-peripheral washout was seen in 14 lesions (46.7%), peripheral washout in 4 lesions (13.3%), and no washout was observed in 12 lesions (40.0%). Capsular appearance was identified in 13 lesions (43.3%) (Table 2). The distribution of lesion size indicated that more than half of the lesions (16, 53.3%) measured greater than 5 cm. Lesions between 3 and 5 cm were found in 8 patients (26.7%), while smaller lesions measuring less than 3 cm were observed in 6 cases (20.0%) (Table 2). The diagnostic performance of LI-RADS 5 in identifying HCC was also assessed. The sensitivity of LR-5 for detecting HCC was 83.3% (95% CI: 58.6–96.4), while specificity was 91.7% (95% CI: 61.5–99.8). The positive predictive value was 93.8% (95% CI: 69.4–99.0) and the negative predictive value was 78.6% (95% CI: 56.3–91.3). The positive likelihood ratio was 10.0 (95% CI: 1.51–66.05), and the negative likelihood ratio was 0.18 (95% CI: 0.06–0.52). Overall diagnostic accuracy of LR-5 for

Table 2 LI-RADS classification of observations, imaging features on triphasic MRI, Lesion size

Variables	Frequency	Percentage
LI-RADS Category		
LR-5	16	53.3
LR-4	14	46.7
Total	30	100
Imaging Features on Triphasic MRI		
Non-rim arterial phase hyperenhancement	29	96.7
Non-peripheral washout	14	46.7
Peripheral washout	4	13.3
No washout	12	40.0
Capsule appearance	13	43.3
Lesion size		
<3 cm	6	20.0
3–5 cm	8	26.7
>5 cm	16	53.3
Total	30	100

HCC detection was 86.7% (95% CI: 69.3–96.2) (Table 3). Collectively, these findings indicate that hepatocellular carcinoma was the predominant liver lesion in this cohort, with larger lesions (>5 cm) being more common. Triphasic MRI imaging features, particularly non-rim arterial hyperenhancement and capsular appearance, were frequently observed, and the LI-RADS 5 category demonstrated high diagnostic accuracy for HCC.

Table 3 Diagnostic Performance of LI-RADS 5

Parameter	Value	95% CI
Sensitivity	83.3%	58.6–96.4
Specificity	91.7%	61.5–99.8
Positive Predictive Value	93.8%	69.4–99.0
Negative Predictive Value	78.6%	56.3–91.3
Positive Likelihood Ratio	10.0	1.51–66.05
Negative Likelihood Ratio	0.18	0.06–0.52
Accuracy	86.7%	69.3–96.2

Discussion

This study evaluated the diagnostic performance of non-rim arterial phase hyperenhancement (APHE) in LI-RADS 5 categorization for hepatocellular carcinoma (HCC), using triphasic MRI and histopathological correlation. Among the 30 hepatic lesions analyzed, HCC was the predominant pathology, comprising 60% of lesions. The majority of lesions were larger than 5 cm (53.3%), indicating a relatively advanced disease stage at presentation, which is consistent with other studies from similar

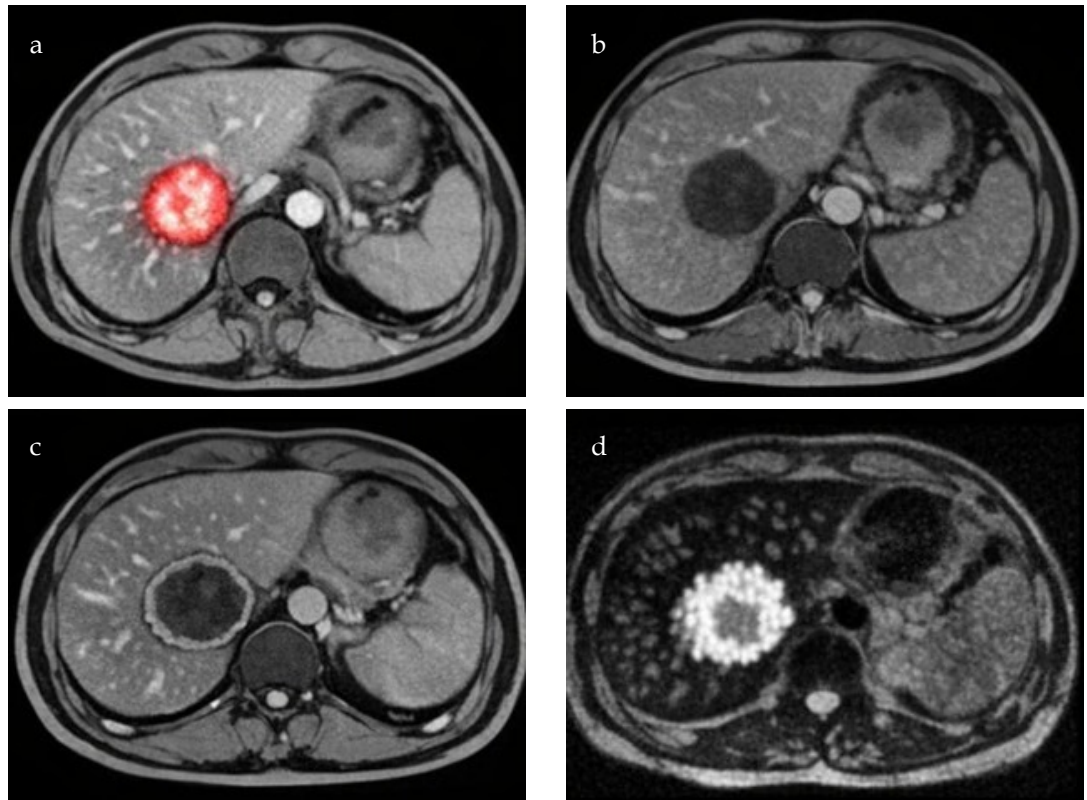


Figure 1 a) Arterial phase MRI showing hyperenhanced hepatic lesion in segment V, b) Portal venous phase MRI showing wash-out of the lesion, c) Delayed phase MRI showing a capsule-like rim around the lesion, d) Diffusion-weighted imaging (DWI) showing restricted diffusion of the lesion.

resource-limited settings where delayed diagnosis is common [10]. The most common MRI finding was non-rim APHE, observed in 29 lesions (96.7%). This underscores its role as a key imaging feature for LR-5 categorization, reflecting the characteristic arterial vascularization of HCC. Capsular appearance was present in 43.3% of lesions, while portal venous or delayed phase washout was seen in less than half of the lesions (46.7% non-peripheral, 13.3% peripheral). The combination

of APHE and these additional features increased confidence in categorizing lesions as definite HCC. These findings are consistent with previous studies reporting that non-rim APHE is highly sensitive for HCC detection, while washout and capsule features contribute to specificity [11]. The LI-RADS 5 category demonstrated high diagnostic accuracy in this study, with sensitivity 83.3%, specificity 91.7%, PPV 93.8%, NPV 78.6%, and overall accuracy 86.7%. This high specificity indicates that lesions classified as LR-5 are highly likely to represent true HCC, allowing clinicians to make non-invasive diagnoses and initiate treatment without the need for biopsy in most cases. However, a few false-negative cases were observed, where three histologically confirmed HCC lesions were categorized as LR-4, likely due to smaller lesion size (<3 cm) or atypical vascular features. Conversely, one false-positive LR-5 lesion corresponded to non-HCC pathology, demonstrating that rare hypervascular non-HCC lesions can mimic APHE patterns [12]. The sensitivity and specificity observed in this study align with reported values in the literature. For example, Liu et al. reported sensitivity of 81% and

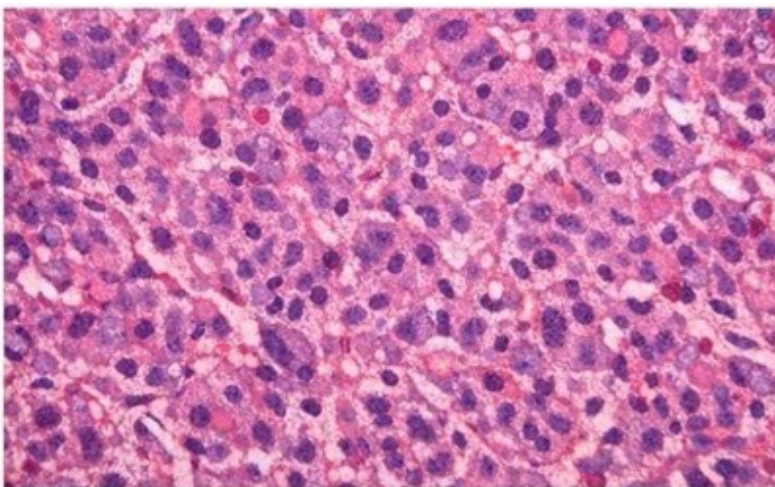


Figure 2 Histopathology (H & E stain) confirming hepatocellular carcinoma

specificity of 82% for LR-5 lesions in MRI, while Clarke et al. reported specificity exceeding 89% in larger cohorts [2, 3]. These findings validate the reliability of non-rim APHE as a key major feature for non-invasive diagnosis of HCC. Meta-analyses have shown that LR-5 categorization generally achieves specificity >90%, emphasizing that imaging-based diagnosis is highly reliable when LI-RADS criteria are applied rigorously [5, 6]. The findings of this study have several clinical implications. Firstly, the high diagnostic accuracy supports non-invasive management, reducing the need for liver biopsy, which is especially beneficial in patients with coagulopathy or lesions in difficult locations. Secondly, structured imaging using LI-RADS enhances communication between radiologists and clinicians, facilitating standardized decision-making for surgery, ablation, or transplantation. Thirdly, recognizing common patterns such as non-rim APHE and capsular appearance may help identify lesions that warrant closer follow-up or intervention, particularly in high-risk cirrhotic populations. Overall, this study demonstrates that non-rim APHE is the most sensitive imaging feature for LR-5 categorization, while capsular appearance and washout enhance specificity. Triphasic MRI interpreted with LI-RADS criteria provides a reliable non-invasive approach for diagnosing hepatocellular carcinoma. These results support the clinical application of LI-RADS in routine imaging protocols and highlight the importance of early recognition of vascular patterns for improving patient management and outcomes [7-9,13-16].

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Conclusion

This study demonstrates that non-rim arterial phase hyperenhancement (APHE) is the most sensitive imaging feature for LR-5 categorization in hepatocellular carcinoma. Triphasic MRI interpreted using LI-RADS 2018 criteria shows high diagnostic accuracy, sensitivity, and specificity, with strong correlation to histopathological findings. The results support the clinical reliability of LI-RADS for non-invasive diagnosis of HCC, allowing early identification and treatment planning, particularly in high-risk patients with chronic liver disease. Additionally, complementary features such as capsular appearance and washout enhance specificity and reinforce confidence in imaging-based diagnosis.

Limitations

Some limitations must be acknowledged. The sample size was relatively small (n=30), which may limit generalizability. Additionally, the study was conducted in a single tertiary care hospital, and patient selection may introduce referral bias, as patients often present with advanced disease. Early or atypical HCC lesions may not demonstrate classic imaging features, which can reduce sensitivity. Furthermore, imaging interpretation was performed by a limited number of radiologists, and inter-observer variability was not formally assessed. Future multicenter studies with larger cohorts and standardized reading protocols could address these limitations and further validate the findings.

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