Accuracy of Triphasic Magnetic Resonance Imaging in Differentiating Benign and Malignant Liver Lesions

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Abstracts

Background: Precise characterization of focal hepatic lesions (FHL) is essential for appropriate patient management. Triphasic magnetic resonance imaging (MRI) offers superior soft-tissue contrast and dynamic enhancement patterns, making it a cornerstone for non-invasive diagnosis of both benign and malignant hepatic pathologies.

Objectives: To evaluate the diagnostic accuracy of triphasic MRI in characterizing FHL using histopathology as the gold standard.

Methods: This cross-sectional study was conducted from September January to December 2024 at Bangladesh Medical University (BMU). Forty-eight adult patients with sonographically or CT-detected FHL underwent triphasic MRI (pre-contrast, arterial, porto-venous, and equilibrium phases) on a 3.0 Tesla scanner. MRI findings were interpreted by senior radiologists and subsequently correlated with histopathological results from ultrasound-guided biopsy.

Results: The study of 48 patients demonstrated a high overall diagnostic accuracy of 96.6% for triphasic MRI. It showed excellent performance for HCC (sensitivity 92.0%, specificity 91.3%), metastasis (87.5%, 95.0%), and perfect (100%) metrics for hemangioma and cyst. Aggregate sensitivity was 85.9% and specificity 97.2%.

Conclusion: Triphasic MRI is a highly accurate modality for characterizing focal hepatic lesions, providing reliable differentiation between malignant and benign etiologies. Its excellent performance supports its role as a first-line diagnostic tool, potentially reducing unnecessary invasive procedures.

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Introduction

The detection and accurate characterization of focal hepatic lesions (FHL) represent a frequent and significant diagnostic challenge in clinical radiology and hepatology. With the widespread use of cross-sectional imaging, incidental liver findings are increasingly common, necessitating reliable non-invasive methods to distinguish benign entities from malignant neoplasms, which have vastly different management and prognostic implications.[1,2] The clinical presentation of FHL is often non-specific, ranging from asymptomatic incidentalomas to symptoms like abdominal pain, jaundice, or constitutional symptoms in advanced disease. The differential diagnosis is broad, encompassing benign lesions such as hemangioma, focal nodular hyperplasia (FNH), hepatic adenoma, and cysts, as well as malignant tumors, primarily hepatocellular carcinoma (HCC) and metastases.[3,4] HCC, in particular, is a leading cause of cancer-related mortality worldwide, often arising in the context of chronic liver disease and cirrhosis.[5] An accurate and timely diagnosis is therefore critical to guide appropriate therapeutic strategies, which may range from conservative observation for benign lesions to surgical resection, transplantation, or systemic therapy for malignancies. Historically, ultrasonography (USG) serves as the first-line screening tool due to its accessibility and lack of ionizing radiation. However, its utility is limited by operator dependency and suboptimal characterization of many lesions. Computed tomography (CT) provides better anatomical detail and allows for multiphasic contrast enhancement but involves radiation exposure and offers lower soft-tissue contrast compared to magnetic resonance imaging (MRI).[6] Triphasic contrast-enhanced MRI has emerged as a preeminent modality for liver imaging, owing to its unparalleled soft-tissue resolution, lack of ionizing radiation, and unique ability to capture dynamic hemodynamic information across multiple vascular phases. By administering a gadolinium-based contrast agent and obtaining sequential images in the arterial, portal venous, and delayed equilibrium phases, radiologists can analyze specific lesion enhancement patterns that are often pathognomonic.[7] For instance, the classic hallmark of HCC is arterial phase hyperenhancement followed by "washout" in later phases, while hemangiomas typically demonstrate discontinuous peripheral nodular enhancement with progressive centripetal fill-in.[8,9] Despite its established advantages, the definitive diagnostic performance of triphasic MRI must be continually validated against histopathology, the gold standard, especially in diverse clinical populations. Previous studies have demonstrated high accuracy, but local data from specific healthcare contexts are essential to confirm its reliability and identify potential limitations in practice.[10] This study, therefore, aimed to evaluate the diagnostic accuracy of triphasic MRI in the characterization of focal hepatic lesions, with direct histopathological correlation, to establish its definitive role in a tertiary care setting.

Methods

This cross-sectional diagnostic study was conducted at the Department of Radiology and Imaging, Bangladesh Medical University (BMU), Dhaka, from January to December 2024. The study population comprised 48 patients with focal hepatic lesions, irrespective of age and sex.

Inclusion and exclusion criteria

Patients were included if they had a focal hepatic lesion identified on prior ultrasonography or computed tomography. Exclusion criteria encompassed absolute or relative contraindications to MRI (e.g., incompatible implants, renal failure),

pregnancy, known hypersensitivity to contrast media, or having undergone a prior biopsy.

Study procedure

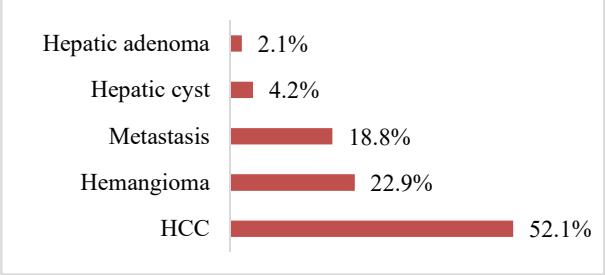
Following ethical approval and informed consent, eligible patients underwent triphasic MRI on a 3.0 Tesla Siemens MAGNETOM Skyra system using a body coil. Dynamic imaging included pre-contrast, arterial (16–20s), porto-venous (45–60s), and equilibrium (3–5 min) phases after an intravenous bolus of gadoterate meglumine. Senior radiologists, blinded to histopathology, interpreted the MRIs. Subsequently, all patients underwent an ultrasound-guided biopsy, with specimens processed using standard hematoxylin and eosin staining for histopathological diagnosis, which served as the reference standard.

Data collection and analysis

A structured questionnaire captured demographic, MRI, and histopathological variables. MRI findings were systematically compared against histopathology reports. Statistical analysis was performed using SPSS version 25.0 to calculate the sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), and overall diagnostic accuracy of triphasic MRI.

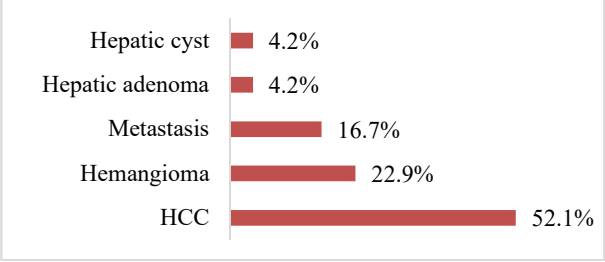
Results

The final study cohort consisted of 48 patients, with a mean age of 49.7 ± 13.8 years (range: 20-73 years). A male predominance was observed, with a male-to-female ratio of 1.8:1. The most common presenting complaint was abdominal pain (95.8%), followed by jaundice (39.6%). On triphasic MRI, single hepatic lesions were found in 56.3% of patients, with the right lobe being the most frequent site of involvement (60.4%). Based on imaging characteristics, 70.8% (n = 34) of the lesions were characterized as malignant, and 29.2% (n = 14) as benign. Histopathological examination served as the reference standard, confirming malignant lesions in 68.8% (n=33) and benign lesions in 31.3% (n=15) of cases. The overall performance of triphasic MRI in differentiating malignant from benign disease was excellent. As illustrated in Table 3, the modality correctly classified 33 of 34 malignant lesions and 13 of 14 benign lesions, resulting in only one false positive and one false negative interpretation. In this study, a lesion-specific analysis of the diagnostic validity of triphasic MRI. The technique demonstrated perfect sensitivity, specificity, and accuracy (100%) for the diagnosis of hepatic hemangioma and simple cyst. For hepatocellular carcinoma (HCC), sensitivity was 92.0% and specificity 91.3%. For metastases, sensitivity was 87.5% with a high specificity of 95.0%. Hepatic adenoma showed perfect specificity (100%) but lower sensitivity (50.0%). Aggregating performance across all lesion types, triphasic MRI demonstrated an average sensitivity of 85.9%, specificity of 97.2%, and an overall diagnostic accuracy of 96.6%.



HCC: Hepatocellular carcinoma

Figure 1. Distribution of focal hepatic lesions by triphasic MRI diagnosis (n=48)



HCC: Hepatocellular carcinoma

Figure 2. Distribution of focal hepatic lesions by histopathological diagnosis (n=48)

Table I: Performance of MRI in differentiating malignant from benign lesions (n=48)

MRI diagnosis	Histopathology: Malignant	Histopathology: Benign	Total
Malignant	33 (True Positive)	1 (False Positive)	34
Benign	1 (False Negative)	13 (True Negative)	14
Total	34	14	48

Table II: Validity of triphasic MRI for specific focal hepatic lesions

Lesion type	Sensitivity	Specificity	Accuracy	PPV	NPV
HCC	92.0%	91.3%	91.7%	92.0%	91.3%
Metastasis	87.5%	95.0%	93.8%	77.8%	97.4%
Hemangioma	100.0%	100%	100%	100%	100%
Hepatic adenoma	50.0%	100%	97.9%	100%	97.9%
Hepatic cyst	100.0%	100%	100%	100%	100%

PPV: Positive Predictive Value; NPV: Negative Predictive Value

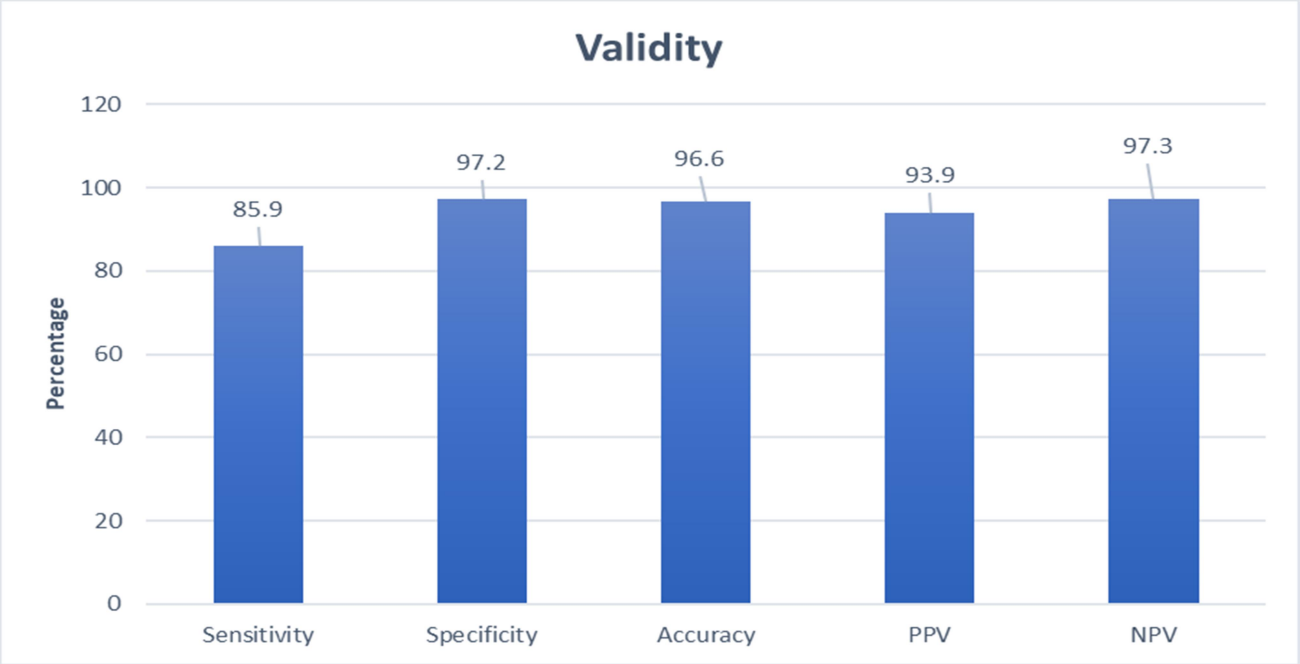


Figure 3. Average validity of triphasic MRI in the evaluation of focal hepatic lesions

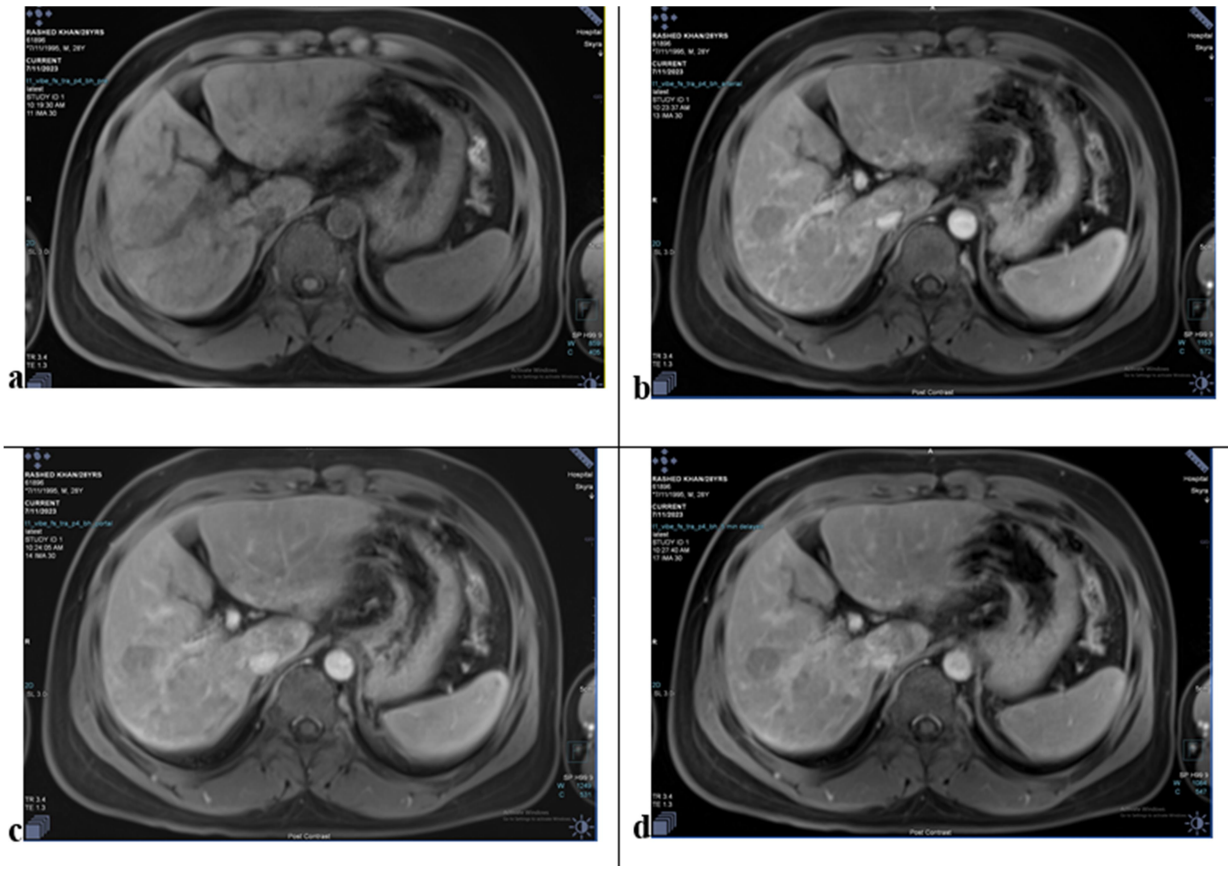


Figure 4. Case of Hepatic Metastases. Hepatic lesions show the following features: hypointense on precontrast T1W (a) image, peripheral enhancement noted at arterial (b)phase, no definite washout at porto-venous (c) and equilibrium (d) phases. (Photo taken from the radiology and imaging department of BMU)

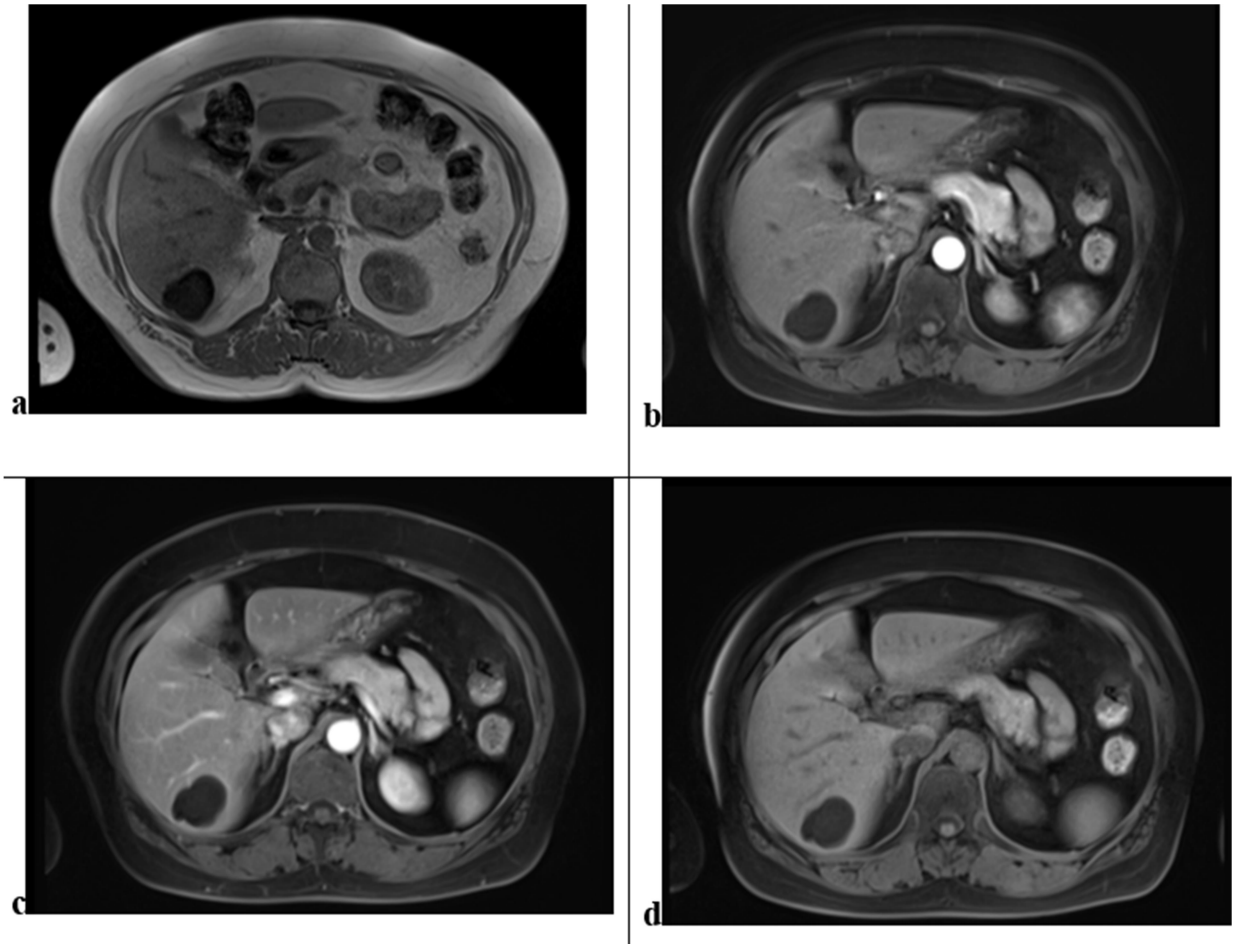


Figure 5. Case of Hepatic Cyst. Hepatic lesion shows following features: hypointense on precontrast T1W (a) image, no enhancement noted at arterial (b), porto-venous (c) and equilibrium (d) phases. (Photo taken from radiology and imaging department of BMU)

Discussions

This prospective, cross-sectional study demonstrates that triphasic MRI is a highly accurate non-invasive modality for the characterization of focal hepatic lesions, with an excellent overall diagnostic concordance of 96.6% when correlated with histopathology. Our findings corroborate and expand upon the established role of dynamic contrast-enhanced MRI in hepatic imaging, providing specific validation within our clinical setting [7]. The demographic profile of our cohort, with a mean age of 49.7 years and a male predominance, aligns with epidemiological patterns of common hepatic pathologies such as HCC, which is frequently associated with chronic liver disease in middle-aged males.[12] The high prevalence of malignancy (68.8% on histopathology) in our study population reflects a tertiary care referral bias but effectively tests the modality's capability in a clinically challenging scenario where accurate differentiation is paramount. The exceptional performance of triphasic MRI for benign lesions, particularly hemangiomas and cysts, achieving 100% sensitivity and specificity, is a key strength. This is attributable to the pathognomonic enhancement patterns these lesions exhibit: progressive peripheral nodular enhancement for hemangiomas and non-enhancement for simple cysts.[13,14] Such definitive characterization can reliably obviate the need for biopsy in these cases, reducing patient morbidity and healthcare

costs. For HCC, the diagnostic sensitivity of 92.0% and specificity of 91.3% are consistent with global literature, which reports sensitivities of 80-95% for MRI in detecting HCC.[15,16] The classic enhancement pattern of arterial hyperenhancement followed by washout in the portal venous or delayed phases remains the cornerstone of non-invasive diagnosis, as reflected in our high accuracy rate of 91.7%.[17] The slightly lower sensitivity (87.5%) but high specificity (95.0%) and NPV (97.4%) for hepatic metastases are noteworthy. While metastases can exhibit variable enhancement patterns depending on the primary tumor, triphasic MRI excelled at correctly identifying the absence of metastatic disease. The two false positives for metastasis (PPV: 77.8%) underscore the challenge in differentiating atypical hyper-vascular metastases from other arterial-phase enhancing lesions like HCC or adenoma, a recognized diagnostic pitfall.[18] Hepatic adenoma presented the greatest diagnostic challenge, with a sensitivity of only 50.0%. This can be explained by its heterogeneous and often non-specific imaging appearance, which may overlap with well-differentiated HCC or focal nodular hyperplasia, especially in the absence of a characteristic central scar or specific hepatobiliary contrast agents.[19,20] The aggregate high specificity (97.2%) and NPV (97.3%) of triphasic MRI are clinically the most significant outcomes. They indicate that a benign characterization of a well-performed and interpreted triphasic MRI is highly reliable. This can prevent unnecessary invasive procedures for benign disease. Conversely, the high PPV (93.9%) supports confident diagnosis and staging of malignancy, facilitating timely therapeutic intervention. Our study has limitations. The sample size, though adequate, is modest, and the use of purposive sampling may limit generalizability. The study did not utilize hepatobiliary phase imaging with liver-specific contrast agents, which has been shown to improve characterization, particularly for nodules in cirrhotic livers and for differentiating hepatic adenoma from FNH.[21,22] Furthermore, the MRI interpretations were performed by senior radiologists at a tertiary center, and results may vary in settings with less expertise. Triphasic MRI demonstrates outstanding diagnostic accuracy in evaluating focal hepatic lesions, serving as a powerful, non-invasive problem-solving tool. Its superior performance in differentiating malignant from benign disease and its near-perfect characterization of common benign lesions like hemangiomas affirm its critical role in clinical decision-making. Future integration with hepatobiliary-specific contrast agents promises to further refine diagnostic confidence, particularly for diagnostically ambiguous lesions.[23]

Limitations:

This study is limited by its modest sample size, single-center design, and the use of standard extracellular contrast agents without hepatobiliary-phase imaging, which may limit generalizability and characterization of certain lesions, such as hepatic adenoma.

Conclusion

Triphasic MRI demonstrates high diagnostic accuracy in characterizing focal hepatic lesions, particularly in distinguishing malignant from benign disease. Its excellent performance for hemangiomas and cysts can obviate unnecessary biopsy. While highly reliable for HCC and metastases, challenges remain with rare entities like adenoma. It is a robust, non-invasive modality essential for clinical decision-making, with future integration of hepatobiliary-specific agents promising further refinement.

Recommendation

Triphasic MRI should be the preferred non-invasive imaging modality for characterizing indeterminate focal hepatic lesions. Future studies should incorporate hepatobiliary-specific contrast agents to improve diagnostic performance for atypical lesions like adenomas, and involve larger, multi-center populations.

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