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Hepatobiliary MRI Contrast Agent: Pattern Recognition Approach to Focal Hepatic Lesions & Comparison with Ultrasound Findings

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HIGHLIGHTS

- MRI characterizes hepatic lesions.
- MRI improves sensitivity.
- Metastases predominate.
- Diffusion aids differentiation.
- MRI outperforms USG.

Key Words:

Hepatic lesions
Magnetic resonance imaging
Gadobenate dimeglumine
Ultrasonography
Hepatobiliary contrast agent

ABSTRACT

Introduction: Accurate detection and characterization of focal hepatic lesions are essential for appropriate clinical management. Ultrasonography (USG) is commonly used as an initial investigation; however, magnetic resonance imaging (MRI), particularly with hepatobiliary-specific contrast agents, provides superior soft-tissue characterization and functional information. **Aim & Objective:** This study evaluated the diagnostic utility of gadobenate dimeglumine-enhanced multiparametric MRI in the characterization of focal hepatic lesions and compared its findings with USG and histopathology. **Material & Methods:** Forty patients with focal hepatic lesions detected on USG were included. Patients with contraindications to MRI, pregnancy, clinical instability, or severe claustrophobia were excluded. Lesion morphology, location, size, enhancement pattern, and diffusion characteristics were assessed on MRI and compared with USG and histopathological findings. Diagnostic performance was evaluated using sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV). **Results:** Among 40 patients, 26 (65%) were male and 14 (35%) female, with a mean age of 48.28 ± 12.39 years. MRI demonstrated 20 (50%) hypervascular and 20 (50%) hypovascular lesions, while true diffusion restriction was observed in 27 (67.5%). Metastases were the most common lesions (47.5%), followed by haemangiomas (17.5%) and intrahepatic cholangiocarcinoma (12.5%). MRI correctly characterized 38 lesions compared with 28 on USG. MRI demonstrated sensitivity of 97.14%, specificity of 100%, PPV of 100%, and NPV of 99.30%, compared with 65.71%, 100%, 100%, and 92.10%, respectively, for USG. **Conclusion:** Gadobenate dimeglumine-enhanced multiparametric MRI demonstrated high diagnostic performance in the detection and characterization of focal hepatic lesions and showed greater sensitivity and negative predictive value than USG. Its dynamic and hepatobiliary imaging capabilities provide valuable information for differentiating benign, malignant, and infective hepatic lesions.



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INTRODUCTION

Magnetic resonance imaging (MRI) has increasingly emerged as an important imaging modality for the evaluation of liver diseases because of its superior soft-tissue contrast, multiplanar capability, and ability to provide detailed anatomical and functional information [1,2]. The incorporation of contrast agents has further improved the diagnostic performance of MRI, particularly for the detection and characterization of focal hepatic lesions [3,4]. Conventional extracellular fluid gadolinium-based agents have been widely used, while hepatobiliary-specific contrast agents have provided additional information regarding hepatocyte function and biliary excretion [5,6].

Focal hepatic lesions encompass a broad spectrum of benign and malignant conditions, and accurate characterization is essential for appropriate clinical management, prognostication, and treatment planning [1,7]. Over the past two decades, ultrasonography (USG), contrast-enhanced computed tomography (CECT), and MRI have become established modalities for liver imaging [8]. USG is commonly used as the initial screening investigation because of its accessibility, lack of ionizing radiation, and relatively low cost. CECT has traditionally been used for comprehensive hepatic assessment because multidetector CT permits rapid volumetric acquisition and multiplanar reconstruction [9]. However, its use involves ionizing radiation and iodinated contrast administration, which may limit its application in certain clinical situations [10].

Technological advances have transformed MRI from a complementary problem-solving investigation into a major modality for hepatic imaging [1,2]. Improvements in rapid acquisition techniques, image processing, and multiparametric sequences have enhanced visualization of hepatic anatomy and lesion-to-liver contrast [11]. Dynamic contrast-enhanced MRI provides valuable information regarding lesion vascularity and enhancement characteristics and can improve differentiation between various focal hepatic lesions [4–6].

Hepatobiliary contrast agents such as gadobenate dimeglumine (Gd-BOPTA) offer additional diagnostic information through partial hepatocellular uptake and subsequent biliary excretion, thereby improving lesion detection and characterization. The present single-centre pilot study was therefore undertaken to evaluate the effectiveness of Gd-BOPTA-enhanced MRI in differentiating focal hepatic lesions using multiparametric and hepatobiliary-phase imaging techniques [5,12]. **Figure 1.** Schematic Representation of the Diagnostic Workflow and Contrast Enhancement Mechanism of Gd-BOPTA–Enhanced Hepatobiliary MRI for Focal Hepatic Lesion Detection and Characterization.

The present study aimed to evaluate the diagnostic accuracy and clinical utility of triphasic liver magnetic resonance imaging (MRI) using a hepatobiliary-specific contrast agent for the detection and characterization of focal hepatic lesions. The objectives were to review the currently available hepatobiliary-specific contrast agents, assess techniques for optimizing triphasic liver MRI using these agents, and evaluate the imaging characteristics of various focal hepatic lesions, with particular emphasis on their detection and characterization during hepatobiliary contrast-enhanced MRI.

MATERIALS & METHODS

This prospective observational study was conducted at the Department of Radiology, Medical College Vadodara, Vadodara from September 2024 to June 2025. Ethical approval has been obtained from the Ethical Approval Committee of Medical College Vadodara, Vadodara.

Study Population

The study population comprised patients with focal hepatic lesions identified on ultrasonography. Patients were included after providing informed consent. Those who were clinically

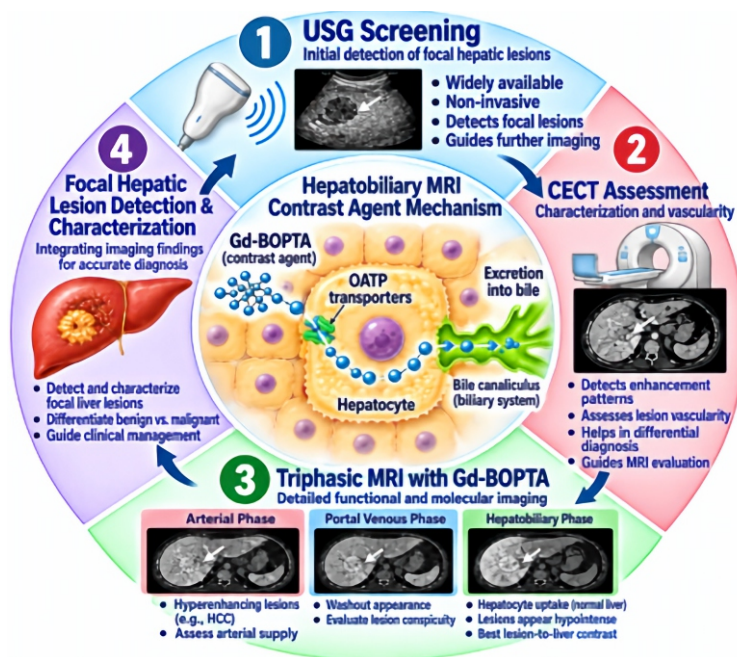


Figure 1: Diagnostic Workflow and Contrast Mechanism of Gd-BOPTA–Enhanced Hepatobiliary MRI.

unstable, pregnant, or had contraindications to magnetic resonance imaging (MRI), including MR-incompatible implants, were excluded. Patients with severe claustrophobia or those requiring sedation to complete the MRI examination were also excluded from the study.

Data Analysis

Ultrasound and MRI findings were reviewed and compared for focal hepatic lesions, documenting lesion size, location, morphology, and relevant imaging features. MRI findings were correlated with ultrasound & histopathology to assess diagnostic concordance and lesion characterization. For biopsied lesions, histopathological findings served as the reference standard. Sensitivity, specificity, positive predictive value, and negative predictive value of MRI were calculated, while descriptive statistics summarized demographic, imaging, and histopathological findings.

RESULTS

The study included 40 patients, with a mean age of 48.28 ± 12.39 years (range, 16–81 years). Most participants were aged 41–60 years (26, 65%), followed by 21–40 years (9, 22.5%), >60 years (4, 10%), and ≤ 20 years (1, 2.5%). Males constituted the majority of the study population (26, 65%), while females accounted for 14 (35%). On contrast-enhanced MRI, focal hepatic lesions showed an equal distribution of hypervascular and hypovascular enhancement patterns, with 20 lesions (50%) in each category. Hypervascular lesions demonstrated earlier and more intense enhancement than the surrounding liver parenchyma, emphasizing the importance of dynamic arterial-phase imaging for their detection and characterization. In the present study, contrast-enhanced MRI identified 20 hypervascular lesions compared with 11 detected by ultrasound, demonstrating its greater ability to characterize vascular enhancement patterns. These findings highlight the importance of a systematic multiparametric MRI approach for differentiating common hypervascular lesions, including haemangioma, focal nodular hyperplasia, hepatic adenoma, hepatocellular carcinoma, regenerative nodules, and hypervascular metastases.

Among 40 hepatic lesions, MRI identified 20 (50%) as hypervascular compared with 11 (27.5%) on USG, while 26 (65%) were single and 14 (35%) multifocal; true diffusion restriction was observed in 27 (67.5%) lesions (Table 1). Among 40 focal hepatic lesions, true diffusion restriction was present in 27 (67.5%), including all 24 malignant lesions and 3 of 4 infective lesions, whereas none of the 12 benign lesions showed

restriction; thus, diffusion restriction was predominantly associated with malignant lesions, although other MRI features and enhancement characteristics are required for accurate lesion characterization (Table 2).

Comparison of MRI-based LI-RADS scores with histopathological findings showed that all 7 LI-RADS I lesions were benign haemangiomas, while all 4 LI-RADS II lesions were infective; LI-RADS III lesions were benign, with focal nodular hyperplasia identified on histopathology. Of the 3 LI-RADS V lesions, 2 were hepatocellular carcinomas and 1 was hepatic adenoma, whereas all 24 LI-RADS M lesions were malignant, comprising 19 metastases and 5 intrahepatic cholangiocarcinomas (Figure 2). MRI characterization of 40 focal hepatic lesions showed metastasis as the most common lesion, accounting for 19 (47.5%) cases, followed by haemangioma in 7 (17.5%), intrahepatic cholangiocarcinoma in 5 (12.5%), abscess in 3 (7.5%), hepatocellular carcinoma in 2 (5%), and focal nodular hyperplasia, hepatic adenoma, low-grade regenerative nodule, and cyst in 1 (2.5%) case each (Table 3).

Among 40 focal hepatic lesions, MRI correctly characterized 38 lesions compared with 28 on USG, while 2 lesions remained indeterminate on both modalities; MRI accurately identified all haemangiomas, focal nodular hyperplasia, hepatic adenoma, low-grade regenerative nodule, cysts, intrahepatic cholangiocarcinoma, and abscesses (Table 4).

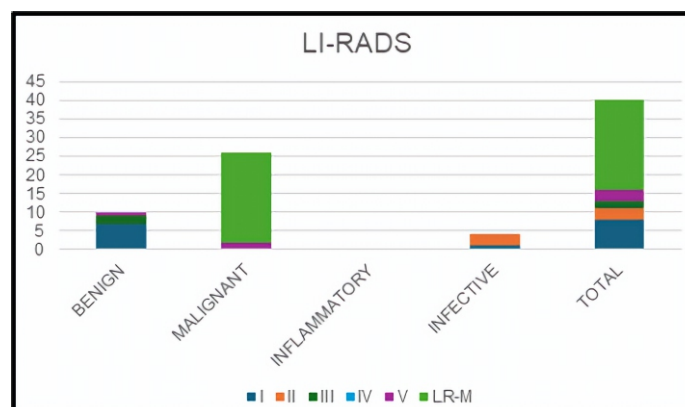
In the analysis of diagnostic performance for focal hepatic lesions, MRI demonstrated a sensitivity of 97.14%, specificity of 100%, PPV of 100%, and NPV of 99.30%, whereas USG showed a sensitivity of 65.71%, specificity of 100%, PPV of 100%, and NPV of 92.10%. Thus, MRI showed higher sensitivity and NPV than USG, while both modalities demonstrated identical specificity and PPV. On comparative analysis, MRI correctly characterized all 12 benign and 26 malignant lesions, whereas USG correctly identified 9 benign lesions and misclassified 3 benign lesions as malignant, although all 26 malignant lesions were correctly detected. Overall, the findings demonstrate the greater diagnostic performance of contrast-enhanced MRI with hepatobiliary-specific gadobenate dimeglumine for characterization of focal hepatic lesions compared with USG. Ultrasound analysis showed that non-circumscribed margins, heterogeneous and hypoechoic echopatterns, and internal vascularity were more frequently associated with malignant lesions, whereas anechoic and complex cystic/solid patterns were predominantly seen in infective lesions; however, considerable overlap among categories indicates that USG findings should be correlated with MRI & histopathology for definitive characterization (Table 5).

Table 1: Comparative MRI and USG Findings of Focal Hepatic Lesions (N = 40)

Parameter	Category / Finding	MRI n (%)	USG n (%)
Enhancement pattern	Hypervascular	20 (50.0)	11 (27.5)
	Hypovascular	20 (50.0)	29 (72.5)
	Total	40 (100)	40 (100)
Focality	Single	26 (65.0)	-
	Multifocal	14 (35.0)	-
	Total	40 (100)	-
True diffusion restriction	Yes	27 (67.5)	-
	No	13 (32.5)	-
	Total	40(100)	-

Table 2: Comparative Analysis of hepatic lesion giving true restriction diffusion

TRUE RESTRICTION DIFFUSION	FREQUENCY	MALIGNANT	BENIGN	INFECTIVE
YES	27	24	0	3
NO	13	0	12	1
TOTAL	40	24	12	4

**Figure 2: Comparative Analysis of LI-RADS Scores from MRI Findings****Table 3: Comparative Analysis of type of focal hepatic lesions on MRI**

TYPE OF HEPATIC MASS	NO OF PATIENT	PERCENTAGE
Haemangioma	7	17.5
Focal Nodular hyperplasia	1	2.5
Hepatic adenoma	1	2.5
Low grade regenerative nodule	1	2.5
Cyst	1	2.5
Hepatocellular carcinoma	2	5
Intrahepatic cholangiocarcinoma	5	12.5
Metastasis	19	47.5
Abscess	3	7.5
Total	40	100

Table 4: Diagnostic accuracy of MRI and Sonography in focal hepatic lesion

TYPE OF HEPATIC MASS	NO OF PATIENT	PERCENTAGE
Haemangioma	7	17.5
Focal Nodular hyperplasia	1	2.5
Hepatic adenoma	1	2.5
Low grade regenerative nodule	1	2.5
Cyst	1	2.5
Hepatocellular carcinoma	2	5
Intrahepatic cholangiocarcinoma	5	12.5
Metastasis	19	47.5
Abscess	3	7.5
Total	40	100

Table 4: Diagnostic accuracy of MRI and Sonography in focal hepatic lesion

Etiology	Total (HPE diagnosis)	USG Diagnosis	MRI Diagnosis	Both indeterminate
Haemangioma	7	7	7	0
Focal Nodular hyperplasia	1	0	1	0
Hepatic adenoma	1	0	1	0
Low grade regenerative nodule	1	0	1	0
Cyst	1	1	1	0
Hepatocellular carcinoma	2	0	1	1
Intrahepatic cholangiocarcinoma	5	1	5	0
Metastasis	18	16	18	0
Abscess	3	3	3	0
Spindle cell neoplasm	1	0	0	1
Total	40	28	38	2

Table 5: USG characteristics across different categories

USG	BENIGN	MALIGNANT	INFECTIVE
MARGIN			
CIRCUMSCRIBED	9	19	3
NON CIRCUMSCRIBED	0	8	1
ECHOPATTERN			
ANECHOIC	0	0	1
COMPLEX CYSTIC/SOLID	0	1	3
HETEROGENOUS	0	6	0
HYPERECHOIC	7	9	0
HYPOECHOIC	0	12	0
ISOECHOIC	1	0	0
INTERNAL VASCULARITY			
PRESENT	2	9	0
ABSENT	7	18	1
PERIPHERAL	0	0	3

DISCUSSION

The present study evaluated the effectiveness of liver MRI using a hepatobiliary-specific contrast agent for the detection and characterization of focal hepatic lesions, with particular emphasis on comparison with ultrasonography (USG) and histopathology. The mean age of patients was 48 ± 12 years (range, 17–81 years), comparable with the findings of Quillin SP, et. al; 1997 and Mortelet KJ & Ros PR. 2001, who reported a mean age of 47.71 ± 12.15 years, and Mortelet KJ & Ros PR. 2001, who reported a mean age of 46.7 years [13,14]. The similarity in age distribution suggests comparable demographic characteristics among the studied populations.

Comparison of MRI LI-RADS categories with histopathology demonstrated an increasing likelihood of malignancy with higher-risk categories. All seven LI-RADS I lesions were benign haemangiomas, while the four LI-RADS II lesions were infective. Among LI-RADS III lesions, histopathology demonstrated focal nodular hyperplasia and regenerative nodular hyperplasia. Of three LI-RADS V lesions, two were hepatocellular carcinomas (HCCs) and one was hepatic adenoma. Among 24 LI-RADS-M lesions, 19 were metastases and five were intrahepatic cholangiocarcinomas. These findings demonstrated the value of MRI-based categorization in stratifying focal liver lesions according to their probability of malignancy [13,14].

MRI demonstrated superior diagnostic performance compared with USG. The sensitivity, specificity, PPV, and NPV of MRI were 97.14%, 100%, 100%, and 99.3%, respectively, compared with 65.71%, 100%, 100%, and 92.1% for USG. These findings indicate the higher sensitivity of MRI for lesion detection and characterization. Chander R, et. al; 2019, reported MRI sensitivity, specificity, PPV, and NPV of 90.48% each [17]. Maurea S, et. al; 2014 [15], reported sensitivity of 79%, specificity of 99%, PPV of 96%, and NPV of 90%, while Kim YK, et. al; 2010 [16], reported sensitivity of 91.4% and PPV of 88.1%. Chander R, et. al; 2019 [17], reported sensitivity and specificity of 84.5% and 86.6%, respectively, for MRI, compared with 68% and 74% for USG [15-17]. Correlation with histopathology further demonstrated the diagnostic value of MRI. MRI correctly identified all 26 malignant lesions, although one lesion interpreted as metastasis was subsequently diagnosed as a spindle-cell neoplasm on histopathology. USG correctly identified nine of 12 benign lesions but misclassified three as malignant, whereas all 26 malignant lesions

were identified correctly in the present dataset. Ramesh Chander R, et. al; 2019, reported false-positive and false-negative classifications with USG, supporting the need for further characterization of indeterminate lesions using cross-sectional imaging [17].

Specific ultrasound features associated with malignancy included irregular morphology, non-circumscribed margins, heterogeneous or hypoechoic echotexture, and internal vascularity. KOTNIS S, et. al; 2021, who described irregular margins, complex echogenicity, and microlobulated morphology as suspicious findings. MRI provided more specific characterization through enhancement kinetics & tissue signal characteristics. Non-rim arterial enhancement and non-peripheral washout were important malignant features, particularly for HCC, while progressive enhancement was characteristic of cholangiocarcinoma [18]. Among malignant lesions, HCC commonly demonstrated arterial phase hyperenhancement followed by washout. In the present study, six of seven HCCs in cirrhotic livers showed this characteristic pattern. Lin DJ, et. al; 2019, demonstrated arterial enhancement and delayed washout as important diagnostic features of HCC, with reported sensitivity and specificity approaching 89% and 96%, respectively [19]. Metastases were predominantly T1 hypointense and T2 hyperintense, consistent with previously described MRI appearances. Four of five cholangiocarcinomas demonstrated peripheral enhancement followed by progressive centripetal enhancement, consistent with findings reported by Maetani et al. [11,12,19]. Benign lesions also demonstrated characteristic MRI patterns. All seven haemangiomas were T1 hypointense and T2 hyperintense with characteristic enhancement, allowing accurate diagnosis in the present study. Similar enhancement patterns have been described previously. Hepatic adenoma demonstrated characteristic signal and enhancement features, while focal nodular hyperplasia showed arterial enhancement with progressive filling. Regenerative nodules demonstrated relatively characteristic signal and enhancement patterns in cirrhotic liver. Hydatid cysts and abscesses showed characteristic T1/T2 signal abnormalities, peripheral rim features, and diffusion restriction, consistent with previously reported findings. Overall, dynamic contrast-enhanced MRI with hepatobiliary-specific contrast enhancement provided valuable information for differentiating benign, malignant, and infective lesions and was particularly useful in distinguishing HCC, intrahepatic cholangiocarcinoma, hepatic adenoma, and focal nodular hyperplasia [20-22].

CONCLUSION

The study evaluated the diagnostic accuracy and clinical utility of dynamic contrast-enhanced MRI using gadobenate dimeglumine for characterizing focal hepatic lesions. MRI demonstrated superior sensitivity, specificity, PPV, and NPV compared with ultrasound, with strong correlation with histopathology. Its high spatial resolution and multiparametric sequences enabled detailed assessment of lesion morphology, margins, vascularity, haemorrhage, and fat content. MRI therefore provided improved characterization of benign and malignant lesions and valuable additional information for lesions initially detected on ultrasound, supporting its role in accurate diagnosis and clinical decision-making.

LIMITATIONS & FUTURE PERSPECTIVES

The study's limitations include a single-centre setting, a relatively small sample size, and a short study duration, which may limit the broader applicability of the results. Future studies should incorporate multi-centre designs with larger populations to enhance validity, assess long-term outcomes, & investigate advanced diagnostic & management approaches. Such efforts will improve overall patient care & help minimize complications.

CLINICAL SIGNIFICANCE

The clinical significance of this study lies in its potential to bridge the gap between research findings and practical health-care, diagnosis, and treatment outcomes. By highlighting real-care applications. It emphasizes the importance of translating scientific observations into meaningful improvements in patient world relevance, the study contributes to evidence based medical practice and supports informed clinical decision making. Ultimately, the findings aim to enhance patient quality of life, optimize therapeutic strategies, and promote better disease management in clinical settings.

ABBREVIATIONS

MRI: Magnetic Resonance Imaging

PPV: Positive Predictive Value

NPV: Negative Predictive Value

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AUTHOR CONTRIBUTIONS

All authors significantly contributed to the study conception and design, data acquisition, or data analysis and interpretation. They participated in drafting the manuscript or critically revising it for important intellectual content, consented to its submission to the current journal, provided final approval for the version to be published, and accepted responsibility for all aspects of the work.

Additionally, all authors meet the authorship criteria outlined by the International Committee of Medical Journal Editors (ICMJE) guidelines.

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CONFLICT OF INTEREST

Authors declared that there is no conflict of interest.

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All necessary consent & approval was obtained by authors.

CONSENT FOR PUBLICATION

All necessary consent for publication was obtained by authors.

DATA AVAILABILITY

All data generated and analyzed are included within this research article. The datasets utilized and/or analyzed in this study can be obtained from the corresponding author upon a reasonable request.

USE OF ARTIFICIAL INTELLIGENCE (AI) & LARGE LANGUAGE MODEL (LLM)

The authors confirm that no AI & LLM tools were used in the writing or editing of the manuscript, and no images were altered or manipulated using AI & LLM.

AUTHOR'S NOTE

This article serves as an important educational tool for the scientific community, offering insights that may inspire future research directions. However, they should not be relied upon independently when making treatment decisions or developing public health policies.

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