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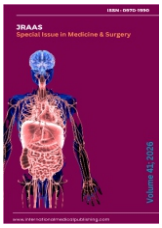

Research Article

Section: Radiodiagnosis

Diagnostic Efficacy of Triple-Phase Multidetector CT in the Evaluation of Focal Hepatic Lesions

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HIGHLIGHTS

- Accurate lesion characterization
- Benign lesions predominated
- Hepatic abscess commonest
- Metastasis commonest malignancy
- Excellent diagnostic accuracy

Key Words:
Triple-phase MDCT
Focal hepatic lesions
Hepatocellular carcinoma
Hepatic hemangioma
Liver metastasis
Contrast-enhanced CT
Hepatic imaging

ABSTRACT

Introduction: Focal hepatic lesions comprise a wide spectrum of benign and malignant pathologies, requiring accurate imaging-based differentiation for appropriate clinical management. Triple-phase Multidetector Computed Tomography (MDCT) plays a vital role in lesion characterization by evaluating dynamic enhancement patterns during different vascular phases. **Aim & Objectives:** To evaluate the diagnostic efficacy of triple-phase MDCT in the characterization and differentiation of focal hepatic lesions and to correlate imaging findings with histopathological examination. **Materials & Methods:** This prospective cross-sectional study was conducted over 12 months in the Department of Radiodiagnosis, Sapthagiri NPS University, Bengaluru. Fifty patients aged >20 years with suspected or ultrasonographically detected focal liver lesions underwent triple-phase MDCT. Lesions were assessed for morphology, enhancement patterns, vascular involvement, and extrahepatic features. Histopathology (FNAC, biopsy, or surgical specimens) served as the reference standard where available. **Results:** Among the 50 patients studied, benign lesions constituted 68% of cases, while malignant lesions accounted for 32%. Hepatic abscess was the most common benign lesion (36%), whereas metastasis was the most common malignant lesion (18%). Hemangiomas demonstrated characteristic peripheral nodular enhancement with centripetal fill-in, while hepatocellular carcinoma showed arterial hyperenhancement with portal venous washout. Triple-phase MDCT correctly characterized 43 out of 44 histopathologically correlated cases, yielding an overall diagnostic accuracy of 97.5%. Additional findings such as portal vein thrombosis, inflammatory hyperemia, and metastatic spread were effectively demonstrated. **Conclusion:** Triple-phase MDCT is a highly sensitive, rapid, & reliable imaging modality for evaluating focal hepatic lesions. Characteristic enhancement patterns enable accurate differentiation of benign and malignant lesions and provide essential information for diagnosis, staging, and treatment planning.

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INTRODUCTION

The liver is one of the most common organs affected by a wide spectrum of pathological lesions, ranging from benign entities such as cysts, hemangiomas, and abscesses to malignant neoplasms, including hepatocellular carcinoma (HCC), cholangiocarcinoma, and metastatic deposits. Accurate characterization of focal hepatic lesions is essential because therapeutic strategies and prognostic outcomes differ substantially between benign and malignant conditions. Early and reliable differentiation helps clinicians determine the need for conservative management, surgical intervention, chemotherapy, or locoregional therapies. Conventional ultrasonography (USG) is often used as the initial imaging modality because of its accessibility, low cost, and non-invasive nature; however, it is limited by operator dependency, patient body habitus, bowel gas interference, and inadequate characterization of lesion vascularity and enhancement patterns [1,2]. The development of Multidetector Computed Tomography (MDCT) has significantly advanced hepatic imaging by enabling rapid volumetric acquisition with excellent spatial and temporal resolution. Compared with conventional single-slice CT, MDCT permits thin-section imaging during a single breath-hold, thereby reducing motion artifacts and improving lesion detection and characterization [3]. The introduction of helical and multidetector technology has further enhanced the ability of CT to evaluate hepatic lesions dynamically following intravenous contrast administration [4].

The diagnostic capability of triple-phase MDCT is based on the unique dual blood supply of the liver. Approximately 75% of hepatic blood flow is supplied by the portal vein, while the hepatic artery contributes the remaining 25% [1]. Normal hepatic parenchyma predominantly enhances during the portal venous phase, whereas many malignant lesions, especially hepatocellular carcinoma and hypervascular metastases, derive most of their vascular supply from the hepatic artery. As a result, these lesions show intense enhancement during the arterial phase and relative washout during the portal venous or delayed phases. This differential enhancement behavior forms the basis of "vascular fingerprinting," which is crucial for lesion characterization [5]. Triple-phase MDCT consists of arterial, portal venous, and delayed imaging phases. The arterial phase is particularly useful for detecting hypervascular lesions such as HCC, focal nodular hyperplasia, and certain metastases. The portal venous phase optimally demonstrates hypovascular metastases and provides excellent delineation of hepatic parenchyma. Delayed phase imaging aids in evaluating fibrous lesions, hemangiomas, and lesions exhibiting contrast retention or washout. This multiphasic evaluation improves diagnostic confidence and helps distinguish lesions that may appear similar on non-contrast imaging [6,7].

Recent advances in contrast administration protocols, scan timing optimization, and multidetector technology have further improved lesion conspicuity and diagnostic accuracy [8–10]. MDCT also provides valuable information regarding lesion size, number, vascular invasion, biliary involvement, lymphadenopathy & extrahepatic spread, making it indispensable for staging and treatment planning. Despite these advantages, histopathological examination remains the gold standard for definitive diagnosis, especially in lesions with atypical imaging appearances [11]. Schematic representation of triple-phase MDCT for evaluation of focal hepatic lesions **(Figure 1)**.

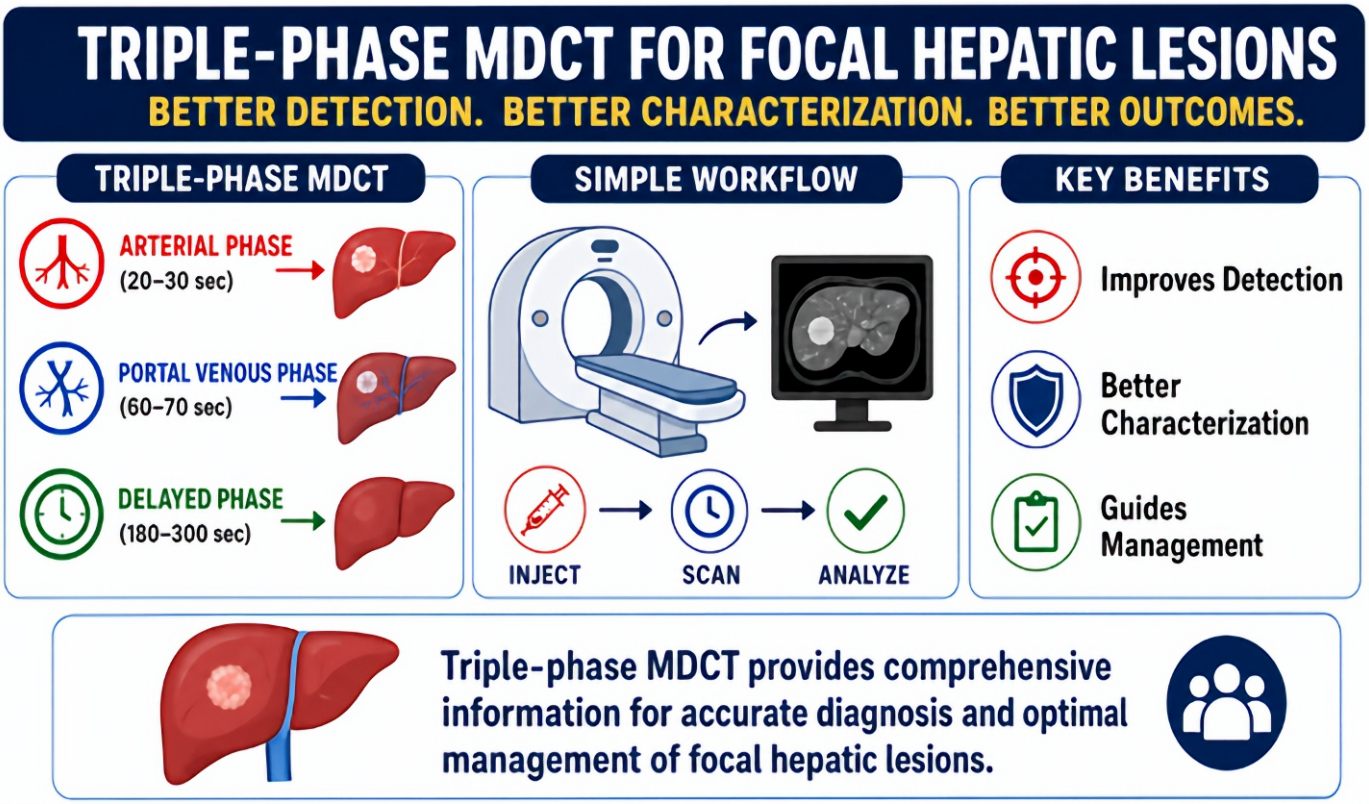

Figure 1: Triple-phase MDCT protocol showing arterial, portal venous, and delayed phases and their role in accurate diagnosis and management of focal hepatic lesions.

In view of the increasing prevalence of hepatic lesions and the growing importance of accurate imaging-based diagnosis, the present study was undertaken at Rajah Muthiah Medical College and Hospital to evaluate the role of triple-phase MDCT in differentiating focal hepatic lesions and to correlate radiological findings with histopathological diagnosis wherever possible.

MATERIALS & METHODS

This prospective cross-sectional study was conducted over a period of twelve months in the Department of Radiodiagnosis at Sapthagiri NPS University, Bengaluru. Institutional Ethics Committee approval was obtained before commencement of the study, and written informed consent was secured from all participants after explaining the procedure in detail. The study included 50 adult patients aged above 20 years who presented with clinical suspicion of focal hepatic lesions, including symptoms such as abdominal pain, jaundice, and weight loss, or had incidentally detected liver masses on screening ultrasonography. Patients younger than 20 years, those with acute hepatic trauma, known hypersensitivity to iodinated contrast media, and individuals with impaired renal function evidenced by elevated serum creatinine and urea levels were excluded from the study. All patients underwent imaging using a Toshiba 4-slice Multidetector Computed Tomography (MDCT) scanner. Initially, an unenhanced CT scan of the abdomen was performed, followed by a dynamic triple-phase contrast-enhanced study. A non-ionic iodinated contrast agent was administered intravenously at a dose of 1 mL/kg body weight using an automated power injector at a flow rate of 4–6 mL/sec to achieve optimal vascular opacification. Imaging acquisition was performed during a single breath-hold to minimize motion artifacts. Triple-phase imaging included the late arterial phase (10–25 seconds), optimized for detecting hypervascular lesions supplied predominantly by the hepatic artery; the portal venous phase (25–60 seconds), which demonstrated peak hepatic parenchymal enhancement; and the delayed phase (120–180 seconds), used for evaluating washout patterns and delayed contrast retention in fibrotic lesions.

CT images were systematically analyzed for lesion number, size, segmental location, calcification, hemorrhage, vascular involvement, enhancement characteristics, and associated extrahepatic findings such as ascites, splenomegaly, and lymphadenopathy. Enhancement patterns were categorized as peripheral globular, central, rim, or diffuse across the three imaging phases. A provisional radiological diagnosis was established based on MDCT findings and subsequently correlated with histopathological examination (HPE), which served as the reference standard. Histopathological confirmation was obtained through USG-guided fine needle aspiration cytology (FNAC), core needle biopsy, or surgical pathology specimens. Diagnostic performance parameters, including sensitivity, specificity, and overall accuracy of triple-phase MDCT, were calculated by comparing imaging diagnoses with definitive pathological outcomes.

RESULTS

The present study analyzed 50 patients who underwent Triple-Phase MDCT for the evaluation of focal hepatic lesions. Out of these, 34 patients (68%) were diagnosed with benign pathologies and 16 patients (32%) with malignant conditions **(Table 1)**. Benign lesions were more commonly observed in younger age groups, particularly between 31–50 years, whereas malignant lesions showed a relatively higher frequency in patients aged above 50 years. Pie chart showing the distribution of benign and malignant hepatic lesions **(Figure 2)**. The age-wise distribution of focal liver lesions demonstrated that the highest number of cases was observed in the 41–50 years age group, comprising 16 patients (32%), followed by the 31–40 years age group with 12 patients (24%). Patients aged 51–60 years accounted for 10 cases (20%), while the 21–30 years and >60 years age groups each contributed 6 cases (12%) **(Figure 3)**. Benign lesions were more commonly encountered in younger and middle-aged individuals, particularly in the 31–50 years age group, where 22 of the 34 benign lesions were identified. In contrast, malignant lesions showed a relatively higher prevalence among older patients, especially in the 51–60 years and >60 years age groups, accounting for 10 out of 16 malignant cases. These findings suggest an increasing tendency for malignant hepatic lesions with advancing age, whereas benign lesions were predominantly observed in younger patients. The study population consisted predominantly of male patients, who accounted for 31 cases (62%), while female patients comprised 19 cases (38%). The male-to-female ratio was approximately 1.6:1, indicating a higher prevalence of focal hepatic lesions among males in the present study **(Table 3)**. Among the 50 patients evaluated with triple-phase MDCT, benign lesions constituted the majority, accounting for 34 cases (68%), while malignant lesions were observed in 16 cases (32%). Hepatic abscess was the most common benign lesion, identified in 18 patients (36%), followed by hemangioma in 9 cases (18%) and simple cysts/other benign lesions in 7 cases (14%). Among malignant lesions, metastases were the predominant pathology, detected in 9 patients (18%), followed by hepatocellular carcinoma (HCC) in 6 cases (12%). Cholangiocarcinoma was the least common malignant lesion, observed in only 1 patient (2%). These findings demonstrate that benign hepatic lesions were more prevalent than malignant lesions in the present study population **(Figure 4 & Table 4)**.

Characterisation of Specific Lesions

Hepatic hemangiomas were identified in 9 cases & demonstrated characteristic enhancement kinetics on triple-phase MDCT. On non-contrast CT scans, 71% of hemangiomas appeared hypodense, while the remaining 29% were isodense relative to the surrounding liver parenchyma. The typical imaging pattern consisted of early peripheral globular enhancement during the arterial phase, followed by progressive centripetal filling during the portal venous phase and persistent complete central enhancement on delayed phase images. These enhancement characteristics were highly suggestive of cavernous hemangioma.

Hepatocellular carcinoma (HCC) was diagnosed in 6 patients, and all lesions appeared hypodense on non-contrast CT imaging. Dynamic contrast-enhanced imaging revealed intense arterial phase enhancement with rapid washout during the portal venous phase in all cases, representing the classic vascular pattern of HCC. Additional associated findings included portal vein thrombosis in 33% of cases, along with the presence of intratumoral vessels and capsular enhancement. One lesion initially interpreted radiologically as HCC was subsequently proven on histopathology to be metastatic adenocarcinoma, highlighting the potential overlap in enhancement characteristics between hypervascular metastases and primary hepatic malignancies. Liver abscesses constituted the most common benign lesion, identified in 18 patients. These lesions typically appeared as ill-defined hypodense masses on CT imaging. The characteristic "double-target sign," comprising a central hypodense area surrounded by an inner hyperdense ring and an outer hypodense rim, was observed in 35% of cases. In addition, 57% of patients demonstrated transient wedge-shaped or segmental hepatic enhancement during the arterial phase, likely secondary to regional inflammatory hyperemia adjacent to the abscess cavity. Metastatic lesions were identified in 9 patients and most commonly presented as multiple hepatic lesions. The majority of metastases were hypovascular and demonstrated peripheral rim enhancement during the portal venous phase, particularly in patients with primary gastrointestinal malignancies such as gastric or colonic carcinoma. Hypervascular metastases were observed in two cases, both of which showed intense arterial phase enhancement and were associated with primary tumors arising from the kidney and stomach.

Triple-phase MDCT demonstrated characteristic enhancement patterns that aided in the differentiation of focal hepatic lesions. Hemangiomas showed peripheral globular enhancement during the arterial phase with progressive centripetal filling in the portal venous phase and complete delayed fill-in, consistent with persistent enhancement. Hepatocellular carcinoma (HCC) characteristically exhibited intense arterial enhancement followed by rapid washout in the portal venous and delayed phases, producing the classical "wash-in and wash-out" appearance. Liver abscesses demonstrated peripheral rim enhancement with the characteristic double-target sign in the portal venous phase and absence of delayed enhancement, suggestive of inflammatory hyperemia. Metastatic lesions displayed variable enhancement patterns, most commonly peripheral rim enhancement with persistent hypodensity on delayed imaging. Cholangiocarcinoma appeared predominantly hypodense in both arterial and portal venous phases with delayed contrast pooling, reflecting the presence of abundant desmoplastic stroma **(Table 5)**. A high degree of correlation was observed between triple-phase MDCT findings and Histopathological Examination (HPE). Out of the total 50 patients included in the study, histopathological confirmation was available in 44 cases. Among these, MDCT correctly identified and characterized focal hepatic lesions in 43 patients, resulting in an overall diagnostic accuracy of 97.5%. These findings demonstrate the high reliability and effectiveness of triple-phase MDCT in the evaluation and differentiation of focal liver lesions **(Table 6)**.

Table 1: Distribution of Benign and Malignant Hepatic Lesions

Lesion Type	Frequency (n)	Percentage (%)
Benign	34	68%
Malignant	16	32%
Total	**50**	**100%**

Table 2: Frequency of Focal Liver Lesions Across Various Age Groups

Age Group (Years)	Benign (n=34)	Malignant (n=16)	Total (n=50)	Percentage (%)
21–30	6	0	6	12%
31–40	10	2	12	24%
41–50	12	4	16	32%
51–60	4	6	10	20%
> 60	2	4	6	12%

Table 3: Gender Distribution of the Study Population

Gender	Number of Cases	Percentage (%)
Male	31	62%
Female	19	38%
Total	**50**	**100%**

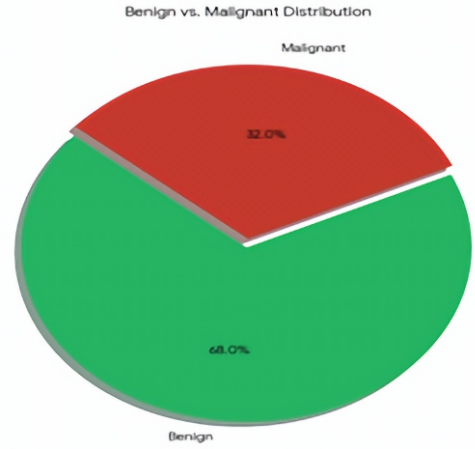

Table 2: Frequency of Focal Liver Lesions Across Various Age Groups

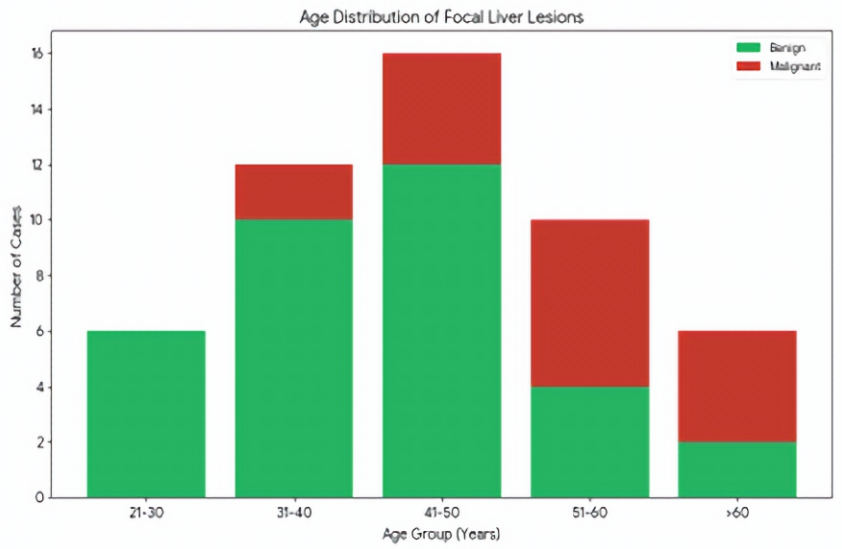

Figure 3: Age-wise distribution of benign and malignant focal liver lesions among the study population.

Table 4: Characterisation of Specific Lesions

Category	Type of Lesion	Number of Cases (n=50)	Percentage (%)
Benign (n=34)	Hepatic Abscess	18	36%
	Hemangioma	9	18%
	Simple Cysts/Others	7	14%
Malignant (n=16)	Metastasis	9	18%
	Hepatocellular Carcinoma (HCC)	6	12%
	Cholangiocarcinoma	1	2%
Total		**50**	**100%**

Table 5: Enhancement Patterns of Focal Liver Lesions on Triple-Phase MDCT

Type of Lesion	Arterial Phase	Portal Venous Phase	Delayed Phase	Characteristic Pattern
Hemangioma	Peripheral globular	Centripetal filling	Complete fill-in	Persistent enhancement
HCC	Intense/Diffuse	Rapid Washout	Hypodense	"Wash-in & Wash-out"
Abscess	Peripheral rim	Double-target sign	No enhancement	Inflammatory hyperemia
Metastasis	Variable/Rim	Peripheral rim	Hypodense	Low attenuation
CCC	Hypodense	Hypodense	Delayed pooling	Desmoplastic stroma

Table 6: Correlation of MDCT Findings with Histopathological Examination (HPE)

Feature	Value
Total Study Population (n)	50
Cases with Histopathological Correlation	44
Correct Radiological Diagnosis	43
Diagnostic Accuracy	**97.5%**

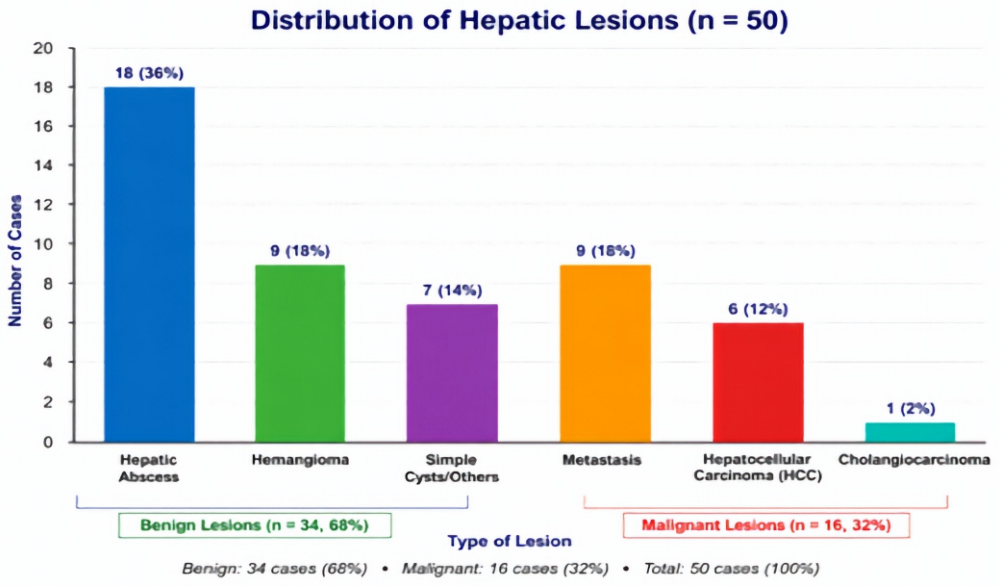

Figure 4: Bar graph showing the distribution of focal hepatic lesions among the study population (n = 50). Hepatic abscess was the most common lesion identified, followed by hemangioma and metastatic lesions. Benign lesions constituted the majority of cases (68%), while malignant lesions accounted for 32% of the study population.

DISCUSSION

Accurate characterization of focal liver lesions is essential for determining appropriate clinical management and improving patient outcomes. In the present study, triple-phase Multidetector Computed Tomography (MDCT) demonstrated a diagnostic accuracy of 97.5% when correlated with histopathological findings, confirming its reliability in differentiating benign from malignant hepatic lesions. The high accuracy achieved in our study can be attributed to the excellent temporal and spatial resolution of MDCT, which enables dynamic assessment of hepatic vascularity during arterial, portal venous, and delayed phases. Sahani and Kalva et al. emphasized that multiphasic MDCT has become a cornerstone in liver imaging because it provides both anatomical and hemodynamic information essential for lesion characterization [6]. Similarly, Horton et al. reported that multidetector CT technology significantly improves lesion detection through rapid volumetric acquisition and optimal contrast enhancement [9].

Benign lesions constituted most lesions in our study, with hepatic abscesses being the most common pathology. Most abscesses appeared as ill-defined hypodense lesions with peripheral rim enhancement and the characteristic "double-target sign." Perilesional transient hepatic enhancement was observed in a significant number of cases, likely representing inflammatory hyperemia. Mathieu et al. described similar findings and noted that these enhancement characteristics are valuable in distinguishing abscesses from necrotic malignant lesions [12]. The ability of MDCT to detect associated inflammatory changes and extrahepatic involvement makes it highly useful in the evaluation of infective hepatic lesions. Hepatic hemangioma was the second most common benign lesion identified in our study. The lesions demonstrated typical peripheral globular enhancement during the arterial phase with progressive centripetal filling during the portal venous and delayed phases.

Hanafusa et al. and Yashimata et al. previously described this enhancement pattern as virtually pathognomonic for cavernous hemangioma [13,14]. Delayed phase imaging was particularly useful in confirming persistent contrast retention and complete fill-in, thereby increasing diagnostic confidence and reducing unnecessary biopsies.

Among malignant lesions, metastases were more frequent than primary hepatic malignancies. Most metastatic lesions appeared as multiple hypovascular lesions showing peripheral rim enhancement in the portal venous phase. Ward et al. similarly reported that contrast-enhanced CT plays a crucial role in detecting metastatic liver disease & assessing resectability [2]. Hypervascular metastases observed in two of our patients showed strong arterial enhancement, emphasizing the importance of arterial phase imaging in lesion characterization.

Hepatocellular carcinoma (HCC) demonstrated the classic "wash-in and wash-out" enhancement pattern characterized by arterial phase hyperenhancement followed by rapid washout in the portal venous phase. Baron and Brancatelli et al. identified this vascular profile as the hallmark feature of HCC on dynamic CT imaging [7]. In addition, portal vein thrombosis was observed in one-third of HCC cases in our study, comparable to findings reported by Honda et al. and Baron et al., who highlighted the role of MDCT in evaluating vascular invasion and tumor staging [4,15]. One lesion initially interpreted radiologically as HCC was later confirmed histopathologically as metastatic adenocarcinoma, illustrating the overlap in enhancement patterns between hypervascular metastases & primary hepatic tumors. Optimized scan timing and contrast administration are essential for accurate lesion characterization. Goshima et al. demonstrated that precise bolus tracking techniques significantly improve hepatic arterial and portal venous phase imaging [8]. Likewise, Heiken et al. emphasized that appropriate contrast injection protocols enhance lesion conspicuity and diagnostic yield [10].

Despite the excellent diagnostic performance of MDCT, histopathological examina-tion remains the definitive gold standard, particularly in lesions with atypical imaging findings or overlapping vascular charact-eristics [11]. Overall, the present study confirms that triple-phase MDCT is a rapid, non-invasive, and highly sensitive imaging modality for the comprehensive evaluation of focal hepatic lesions.

CONCLUSION

Suprapatellar intramedullary nailing is a safe and effective technique for the management of proximal tibial and tibial shaft fractures. The semi-extended position facilitates improved fracture alignment and provides satisfactory radiological union and functional outcomes with minimal complications. The supra-patellar approach also demonstrated low incidence of anterior knee pain and minimal patellofemoral cartilage morbidity when appropriate protective instrumentation was used.

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 focus on integrating artificial intelligence and radiomics with MDCT to improve the characterization of indeterminate or isodense lesions. Research into low-dose CT protocols and iterative reconstruction techniques may help reduce radiation exposure while preserving image quality. The role of Dual-Energy CT (DECT) in detecting subtle hepatic lesions should also be further explored. In equivocal cases, early correlation with hepatobiliary specific MRI may improve diagnostic confidence and reduce the need for invasive biopsy. Larger multicentric studies with longer follow up are recommended to evaluate the prognostic significa-nce of enhancement patterns and treatment response assessment in hepatic malignancies.

CLINICAL SIGNIFICANCE

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

ABBREVIATIONS

MDCT: Multidetector Computed Tomography
HCC: Hepatocellular Carcinoma
CT: Computed Tomography

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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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None

ETHICAL APPROVAL & CONSENT TO PARTICIPATE

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 thewriting or editing of the manuscript, and no images were alt-ered or manipulated using AI & LLM.

AUTHOR'S NOTE

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

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