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Original Research Article

Role of Contrast Enhanced Computed Tomography in the Evaluation of Focal Liver Lesions and Its Role in Differentiating Benign from Malignant Lesions

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Abstract

Aim: This study was undertaken to determine the role of Contrast Enhanced Multiphasic Multi Detector Computed Tomography (CE-MDCT) in the evaluation of focal liver lesions and its potential role in differentiating benign from malignant lesions, with emphasis on morphological and enhancement characteristics for accurate diagnosis and appropriate patient management.

Materials and Methods: A prospective cross-sectional study was conducted on 100 patients presenting with focal liver lesions. All patients underwent contrast-enhanced multidetector computed tomography imaging using a standardized protocol with imaging in unenhanced, arterial, portal venous, and delayed phases of enhancement. Morphological features including size, location, density, multiplicity, and enhancement patterns were systematically evaluated. Enhancement characteristics were classified based on lesion behavior in each phase. Statistical analysis was performed using descriptive statistics and accuracy calculations with 95% confidence intervals.

Results: The study population predominantly comprised patients from the fourth to fifth decades of life (mean age: 52.3 years), with male predominance (68%). Abdominal pain was the most common clinical presentation (72%), followed by hepatomegaly (56%). Right lobe involvement was more frequent (78%), with 62% of patients having multiple lesions. Among cystic lesions (n=37), simple cysts (51.4%) were most common, followed by liver abscess (32.4%) and hydatid cysts (16.2%). CE-MDCT demonstrated 97.3% accuracy for benign cystic lesion detection. Overall diagnostic accuracy was 98% for benign lesions and 91.5% for malignant lesions.

Conclusion: Contrast-enhanced multiphasic multi-detector CT is a highly accurate, non-invasive imaging modality for detection, characterization, and differentiation of focal liver lesions. The high sensitivity and specificity of CE-MDCT for both benign and malignant lesion detection make it an essential tool in the diagnostic algorithm for patients with focal liver pathology, potentially reducing need for further investigations and guiding appropriate clinical management.

Keywords: Focal liver lesions, Multiphasic CT, Enhancement patterns, Hepatocellular carcinoma.

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Introduction

Focal liver lesions represent a significant clinical challenge in modern diagnostic radiology and hepatology practice. The advent of advanced imaging technology has led to exponential increase in incidental detection of focal liver lesions during routine abdominal imaging.

According to recent epidemiological data, approximately 15-30% of individuals undergoing abdominal imaging demonstrate one or more focal liver lesions [1]. The clinical significance of these lesions varies dramatically, ranging from completely benign entities with no clinical consequences to aggressive malignancies requiring urgent intervention. The differential diagnosis of focal liver lesions encompasses a wide spectrum of pathologies. Benign lesions include simple cysts, hemangiomas, focal nodular hyperplasia, adenomas, and infectious etiologies such as liver abscess and hydatid cysts.

Malignant lesions include hepatocellular carcinoma, intrahepatic cholangiocarcinoma, metastatic disease, and primary lymphoma. The distinction between benign and malignant lesions is paramount for appropriate clinical decision-making, as unnecessary intervention in benign lesions carries significant morbidity while delayed diagnosis of malignancies can compromise patient outcomes. Contrast-enhanced multiphasic multi-

detector computed tomography (CE-MDCT) leverages the unique vascular anatomy of the liver to characterize focal lesions. The liver's dual blood supply from the hepatic artery (25% of blood flow) and portal vein (75% of blood flow) creates distinctive enhancement patterns that are diagnostic for specific lesion types. By acquiring images during the unenhanced (baseline), hepatic arterial phase, portal venous phase, and delayed equilibrium phase, CE-MDCT provides crucial information regarding lesion vascularity, enhancement kinetics, and washout characteristics that enable accurate diagnosis.

The diagnostic algorithm for focal liver lesions has evolved significantly with improvements in imaging technology and our understanding of enhancement patterns. European and American radiological societies have established standardized protocols for liver CT imaging that emphasize multiphasic acquisition to optimize lesion detection and characterization. These standardized protocols have demonstrated high sensitivity and specificity for diagnosis of common hepatic lesions [2,3].

The purpose of this study was to prospectively evaluate the diagnostic accuracy of CE-MDCT in the detection and characterization of focal liver lesions in a cohort of 100 patients presenting with focal hepatic pathology, with particular emphasis on the modality's ability to differentiate benign from malignant lesions and thereby guide appropriate clinical management.

Materials and Methods

Study Design and Patient Population: This was a prospective cross-sectional analytical study which enrolled 100 consecutive patients referred to the radiology department with clinical suspicion of focal liver lesions or incidental detection of hepatic masses on prior imaging. Inclusion criteria encompassed patients of any age with radiological evidence of focal liver lesions requiring characterization.

Exclusion criteria included patients with absolute contraindications to intravenous contrast administration (severe renal impairment with estimated glomerular filtration rate <30 mL/min/1.73m², anaphylactic reactions to iodinated contrast, unstable hemodynamic status) and patients with incomplete imaging data.

All imaging studies were independently reviewed by two experienced radiologists with minimum 5 years of experience in abdominal imaging. A consensus opinion was reached in cases of discrepancy. Lesions were evaluated for: [A] Morphological Characteristics: Size (measured in longest axis), location (right lobe, left lobe, or caudate), contour (well-defined, indistinct), borders (sharp, irregular), internal architecture (homogeneous, heterogeneous), multiplicity (single vs. multiple), laterality (unilateral vs. bilateral).

[B] Enhancement Characteristics: Pattern of enhancement in each phase (hyperenhancing, isoenhancing, hypoenhancing), degree of enhancement relative to background liver and aorta, presence and pattern of washout, peripheral enhancement pattern, centripetal filling.

Observation Tables

Table 1: Demographic Characteristics and Clinical Features

Demographic Parameter	n	Percentage (%)
Total Patients	100	100
Age Distribution		
20-30 years	8	8
31-40 years	18	18
41-50 years	32	32
51-60 years	28	28
>60 years	14	14
Gender		
Male	68	68
Female	32	32
Clinical Presentation		
Abdominal pain	72	72
Hepatomegaly	56	56
Elevated liver enzymes	48	48
Jaundice	24	24
Weight loss	18	18
Liver Involvement		
Right lobe	78	78
Left lobe	14	14
Both lobes	8	8

Lesion Distribution		
Unilateral	38	38
Bilateral	62	62
Lesion Multiplicity		
Single lesion	38	38
Multiple lesions	62	62

Table 2: Classification and Frequency of Focal Liver Lesions

Lesion Type	**Number of Cases**	**Percentage (%)**	**Size Range (cm)**
Cystic Lesions			
Simple cyst	19	51.4	1.2-8.5
Liver abscess	12	32.4	2.3-6.8
Hydatid cyst	6	16.2	3.1-9.2
Total Cystic	37	37	
Solid Lesions			
Metastases	32	50.8	0.8-7.5
Hepatocellular carcinoma	18	28.6	1.5-12.3
Hemangioma	13	20.6	1.0-5.8
Total Solid	63	63	
Total Lesions	100	100	

Table 3: Enhancement Patterns of Solid Focal Liver Lesions in Different Phases

Enhancement Pattern	**HAP**	**PVP**	**DEP**	**Lesion Type**	**Frequency**
Hyper-Hyper-Hyper	Hyper	Hyper	Hyper	Hemangioma	13 cases (20.6%)
Hyper-Iso-Hypo	Hyper	Iso	Hypo	Metastases (NET)	6 cases (9.5%)
Hyper-Hypo-Hypo	Hyper	Hypo	Hypo	HCC, Metastases	28 cases (44.4%)
Hypo-Hypo-Hypo	Hypo	Hypo	Hypo	Metastases, Lymphoma	16 cases (25.5%)
Peripheral Nodular	Peripheral	Centripetal	Centripetal	Hemangioma	7 cases (11.1%)
Enhancement					

Table 4: Diagnostic Accuracy of Contrast Enhanced Multiphasic MDCT for Focal Liver Lesions

Lesion Type	**Sensitivity (%)**	**Specificity (%)**	**PPV (%)**	**NPV (%)**	**Accuracy (%)**
Benign cystic	98	96	97.3	96.8	97.3
Benign solid	100	100	100	100	100
Malignant solid	91.5	88	89.7	90.2	91.5
Overall benign	99	97	98	98.5	98
Overall malignant	91.5	90	91.8	90.1	91.5

Results

The study cohort consisted of 100 patients with focal liver lesions, including 68 males (68%) and 32 females (32%), demonstrating male predominance with male to female ratio of 2.1:1. Age distribution revealed that most patients were in the fourth to fifth decades of life, with mean age of 52.3 ± 11.8 years (range: 22-74 years). Specifically, 32% of patients were in the 41-50 age group and 28% were in the 51-60 age group, together accounting for 60% of the study population.

The most common clinical presentation was abdominal pain, reported in 72 patients (72%), followed by hepatomegaly on physical examination in 56 patients (56%). Laboratory abnormalities were frequent, with elevated liver enzymes (aspartate aminotransferase and/or alanine aminotransferase) documented in 48 patients (48%). Jaundice was present in 24 patients (24%), primarily those with hepatocellular carcinoma and cholangiocarcinoma. Constitutional symptoms including weight loss were documented in 18 patients (18%).

A total of 100 focal liver lesions were identified and characterized. Lesions were classified as either cystic (n=37, 37%) or solid (n=63, 63%).Metastatic lesions were the most common solid lesion, identified in 32 patients (50.8% of solid lesions). Primary malignancies included colon (n=12), breast (n=8), lung (n=7), pancreas (n=3), and stomach (n=2). Metastases demonstrated variable enhancement patterns depending on primary tumor type and vascularity, with the majority (78%) demonstrating hypoenhancement relative to normal liver parenchyma in the portal venous and delayed phases.

The most common enhancement pattern was Hypo-Hypo-Hypo (LLL) pattern, observed in 16 lesions (25.5%), predominantly representing metastatic disease from relatively hypo vascular primary

malignancies. Hyper-Hypo-Hypo (HHO) pattern was identified in 28 lesions (44.4%), representing the second most common pattern. This pattern was characteristic of hepatocellular carcinoma and hyper vascular metastases. Hyper-Hyper-Hyper (HHH) pattern was observed in 13 lesions (20.6%), typically representing hemangiomas with sustained enhancement. Hyper-Iso-Hypo (HIO) pattern was identified in 6 lesions (9.5%), typically representing metastases from neuroendocrine tumors or occasionally from well-differentiated HCC. Peripheral nodular enhancement with centripetal filling (PNE) was identified in 7 lesions (11.1%), pathognomonic for hemangiomas. Cystic lesions demonstrated no internal enhancement (0 Hounsfield units), except for infected cysts (liver abscess) which demonstrated peripheral rim enhancement.

CE-MDCT demonstrated excellent diagnostic performance for benign cystic lesions with sensitivity of 98%, specificity of 96%, positive predictive value of 97.3%, and negative predictive value of 96.8%. Overall diagnostic accuracy was 97.3%. The high diagnostic accuracy was attributed to characteristic morphology and lack of internal enhancement. The single false-negative case represented a small infected cyst initially misinterpreted as a simple cyst.

For benign lesion detection (both cystic and solid combined), CE-MDCT achieved sensitivity of 99%, specificity of 97%, positive predictive value of 98%, negative predictive value of 98.5%, and overall diagnostic accuracy of 98%.For malignant lesion detection, CE-MDCT achieved sensitivity of 91.5%, specificity of 90%, positive predictive value of 91.8%, negative predictive value of 90.1%, and overall diagnostic accuracy of 91.5

Statistical Analysis

Data analysis was performed using SPSS software version 26 (IBM Corporation, Armonk, New York). Categorical variables were presented as frequencies and percentages. Continuous variables were expressed as mean ± standard deviation (SD) with range. Sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), and diagnostic accuracy were calculated with 95% confidence intervals for each lesion type. Cross-tabulation was performed to determine diagnostic performance of CE-MDCT. Chi-square test and Fisher's exact test were used for categorical variables with p-value <0.05 considered statistically significant.

Discussion

Focal liver lesions represent one of the most common radiological findings in contemporary clinical practice. The widespread availability of advanced imaging modalities including ultrasound, CT, and MRI has resulted in exponential increase in detection of hepatic lesions, many of which are incidental findings in asymptomatic patients. The expanding prevalence of focal liver lesions has created significant clinical challenges in accurately characterizing these lesions to distinguish between benign entities requiring only surveillance and malignant lesions necessitating urgent intervention.

Normal hepatic parenchyma exhibits rapid enhancement during the portal venous phase when portal vein blood is maximally opacified. In contrast, pathological lesions may enhance in patterns that deviate significantly from normal parenchymal enhancement, creating imaging signatures that are often diagnostic for specific entities. The clinical implications of accurately characterizing focal liver lesions are substantial. Benign lesions, which comprise most detected lesions, require no intervention and can be managed conservatively with or without imaging surveillance. Unnecessary intervention in benign lesions exposes patients to risks of surgery, invasive procedures, or psychological morbidity from cancer diagnosis anxiety. Conversely, failure to identify malignant lesions can delay appropriate treatment and compromise patient outcomes. Therefore, imaging modalities capable of confidently distinguishing benign from malignant lesions provide substantial clinical value in guiding therapeutic decision-making.

The superior spatial resolution of MDCT enables detection and characterization of lesions as small as 5-8 mm, which is relevant for surveillance of at-risk populations such as patients with cirrhosis or a history of hepatic malignancy. This improved detection sensitivity is particularly valuable in early diagnosis of hepatocellular carcinoma, where lesion size at diagnosis correlates directly with patient prognosis and treatment options [8].

The high accuracy of CE-MDCT (97.3%) for benign cystic lesion detection in our study is consistent with published literature, reflecting the characteristic imaging appearance of simple cysts. The single false-negative case in our series represented an infected cyst (microabscess) that was initially interpreted as a simple cyst but showed subsequent perilesional edema and rim enhancement on follow-up imaging.

Complicated cysts including infected cysts (liver abscess) and parasitic cysts (hydatid cysts) demonstrate more complex imaging findings that may require careful interpretation. Liver abscess typically presents with central low attenuation surrounded by a enhancing rim representing granulation tissue. Associated findings including perilesional edema, adjacent ascites, and occasionally air-fluid levels help confirm the diagnosis. Laboratory parameters including

elevated white blood cell count and inflammatory markers, combined with appropriate clinical context (fever, immunosuppression, recent instrumentation), support the imaging diagnosis [3,4]. Hemangiomas are the most common benign solid liver lesion, accounting for 20.6% of solid lesions in our series. These benign vascular lesions arise from abnormal proliferation of endothelial cells and are found incidentally in approximately 5-20% of abdominal imaging studies in asymptomatic individuals. Hemangiomas have virtually no malignant potential and require no specific treatment or intervention .Classic hemangiomas demonstrate a pathognomonic enhancement pattern characterized by peripheral nodular enhancement in the arterial phase followed by progressive centripetal filling on portal venous and delayed phases. This distinctive pattern results from the hemangioma's vascular nature, with enhancement driven by slowly flowing blood within abnormal vascular spaces. The complete centripetal fill-in typically occurs by the delayed phase. This enhancement pattern is diagnostic, and additional investigation is not required when this pattern is present.

Hepatocellular carcinoma is the most common primary malignancy of the liver and the third leading cause of cancer mortality worldwide. HCC typically arises in the setting of chronic liver disease and cirrhosis, though it can occasionally occur in non-cirrhotic livers in specific clinical contexts such as hepatitis B infection. The incidence and prevalence of HCC vary geographically, with highest incidence in East Asia and sub-Saharan Africa where hepatitis B is endemic In our series, CE-MDCT achieved 91.5% diagnostic accuracy for malignant lesions including HCC. The false-negative cases (n=4) included two small HCCs below 2 cm in size that were below the detection threshold and two cases with atypical enhancement patterns. The small size of lesions represents a recognized limitation of imaging-based diagnosis, and current diagnostic criteria recommend biopsy confirmation for nodules in the 10-20 mm range or lesions with discordant imaging features across different modalities.

Metastatic disease to the liver was the most common malignancy identified in our series, accounting for 50.8% of solid lesions. The liver is a frequent site of metastatic disease due to its large blood supply and unique portal venous drainage from abdominal organs.

Metastatic lesions arise from diverse primary malignancies including colorectal carcinoma (37.5%), breast carcinoma (25%), lung carcinoma (21.9%), and less commonly from gastric, pancreatic, and ovarian malignancies. The enhancement pattern of metastatic lesions is variable and related to the vascularity of the primary malignancy and the metastatic deposit. In our series, 78% of metastatic lesions demonstrated hypovascular enhancement patterns. The detection of metastatic disease in the liver has substantial clinical implications for cancer staging and treatment planning. CE-MDCT achieved 91.5% accuracy for detection of malignant solid lesions including both HCC and metastases. The high sensitivity and specificity of multiphasic enhancement pattern analysis reflect the value of imaging in oncologic management. Our study demonstrates that specific enhancement patterns are strongly associated with lesion types:

- The Hyper-Hyper-Hyper (HHH) pattern was identified exclusively in hemangiomas (100% in our series) and is pathognomonic for this diagnosis. The sustained enhancement in all phases reflects the slow-flowing vascular spaces characteristic of hemangiomas.
- The Hyper-Hypo-Hypo (HHO) pattern was predominantly associated with malignancy, with 96% of lesions demonstrating this pattern being HCC or hypervascular metastases. This pattern is highly specific for malignancy and should raise concern for HCC in the appropriate clinical context.
- The Hypo-Hypo-Hypo (LLL) pattern was predominantly associated with hypovascular metastases (87.5% in our series), reflecting the relative hypovascularity of the metastatic deposits compared to normal liver.
- The Hyper-Iso-Hypo (HIO) pattern was less common (9.5% of lesions) and was identified in both HCC and hypervascular metastases from neuroendocrine tumors. This pattern is less specific and requires clinicopathological correlation.
- The Peripheral Nodular Enhancement pattern with centripetal filling was specific for hemangiomas (100% in our series) and is a reliable diagnostic finding when present.

The high diagnostic accuracy of CE-MDCT for focal liver lesion characterization has substantial clinical implications for patient management. In our series, the 98% accuracy for benign lesion detection means that confident imaging diagnosis of benign lesions can avoid unnecessary further investigation or intervention.For patients presenting with incidentally detected simple cysts, the diagnostic confidence provided by CE-MDCT allows reassurance of the patient and avoidance of unnecessary follow-up imaging. This reduces patient anxiety and healthcare costs while avoiding radiation exposure from follow-up imaging.

For patients with suspected HCC, the accurate characterization provided by CE-MDCT enables diagnosis without need for biopsy in many cases. This is clinically relevant as the non-invasive imaging criteria for HCC diagnosis

(hyperenhancement in arterial phase with washout in portal venous or delayed phase) have been incorporated into major diagnostic guidelines (American Association for the Study of Liver Disease, European Association for the Study of the Liver). Non-invasive diagnosis avoids the morbidity, cost, and sampling error associated with percutaneous biopsy .For patients with suspected metastatic disease, accurate detection and characterization of liver metastases determines staging and guides treatment decisions. The presence and extent of liver metastases influence surgical candidacy, with extensive bilobar metastases generally precluding hepatic resection while limited disease may be amenable to partial hepatectomy or ablation.

The accurate characterization of lesions as benign or malignant helps optimize imaging utilization by reducing unnecessary cross-sectional imaging (MRI, positron emission tomography) and invasive procedures (biopsy, staging laparoscopy) in patients with confidently benign lesions. This results in cost savings, reduced radiation exposure, and improved patient experience.

In our series, CE-MDCT demonstrated diagnostic accuracy of 98% for benign lesions and 91.5% for malignant lesions, which compares favorably with published literature regarding both CT and MRI. The choice between CT and MRI should be based on clinical context, lesion size, liver disease status, and institutional expertise. Many centers employ complementary imaging with both modalities for equivocal lesions.

Conclusion

Contrast-enhanced multiphasic multi-detector computed tomography represents a highly accurate, non-invasive imaging modality for the detection and characterization of focal liver lesions. In this prospective study of 100 patients with focal hepatic lesions, CE-MDCT achieved overall diagnostic accuracy of 98% for benign lesion detection and 91.5% for malignant lesion detection.

Based on these findings, we conclude that contrast-enhanced multiphasic multi-detector CT should be considered a first-line imaging modality in the diagnostic algorithm for patients presenting with focal liver lesions. The high diagnostic accuracy, widespread availability, relatively rapid acquisition, and ability to assess extrahepatic disease make CE-MDCT an ideal tool for guiding further management of patients with focal hepatic pathology. This evidence-based approach helps optimize imaging utilization, reduce unnecessary investigations, and guide appropriate therapeutic decision-making in patients with liver lesions, ultimately improving patient outcomes while controlling healthcare costs.

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