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ORIGINAL RESEARCH

Comparison of Contrast-Enhanced Ultrasound and CT for Characterization of Focal Liver Lesions in Cirrhotic Patients

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ABSTRACT

Background: Cirrhosis predisposes patients to focal liver lesions (FLLs), including benign nodules and hepatocellular carcinoma (HCC), necessitating early and accurate imaging for timely diagnosis and management. Contrast-enhanced computed tomography (CECT) is widely used for liver lesion characterization, but contrast-enhanced ultrasound (CEUS) has gained attention as a real-time, radiation-free alternative with superior vascular assessment. This study compares CEUS and CECT in diagnosing focal liver lesions in cirrhotic patients, assessing their diagnostic accuracy, sensitivity, and clinical utility. **Objectives:** To compare the efficacy, diagnostic accuracy, and limitations of CEUS and CECT in characterizing focal liver lesions in cirrhotic patients, differentiating benign from malignant lesions, and evaluating their clinical role in liver lesion detection and staging. **Methods:** A prospective comparative study was conducted on 120 cirrhotic patients with suspected focal liver lesions at a tertiary care center. All patients underwent both CEUS and CECT within one week for lesion characterization based on vascular phases, washout kinetics, and enhancement patterns. Lesion classification was compared with histopathology, MRI confirmation, or follow-up imaging over six months. Statistical analysis included sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), and diagnostic accuracy for both imaging modalities, using receiver operating characteristic (ROC) curves and McNemar's test. **Result:** Among 120 patients, 80 (66.7%) had malignant lesions (HCC, cholangiocarcinoma, metastases) and 40 (33.3%) had benign lesions (regenerative nodules, hemangiomas, focal nodular hyperplasia). CEUS demonstrated a sensitivity of 91.2%, specificity of 87.5%, and overall accuracy of 89.6%, while CECT showed a sensitivity of 94.6%, specificity of 83.3%, and accuracy of 90.8%. CEUS outperformed CECT in characterizing small lesions (<2 cm) and detecting arterial phase hyperenhancement, while CT was superior in identifying multifocal lesions, extrahepatic spread, and portal vein thrombosis. The concordance rate between CEUS and CECT was 88.4%, with CEUS misclassifying 8 cases and CECT misclassifying 10 cases due to overlapping enhancement patterns and lesion heterogeneity. **Conclusion:** Both CEUS and CECT exhibit high diagnostic accuracy in differentiating benign and malignant focal liver lesions in cirrhotic patients. CEUS excels in real-time vascular assessment and detecting early arterial-phase enhancement, particularly in small lesions, while CECT remains superior for staging, detecting multifocal disease, and assessing extrahepatic involvement. A combined imaging approach may enhance diagnostic precision, especially for indeterminate lesions or high-risk cirrhotic patients. Future research should explore the integration of CEUS in routine liver imaging protocols and its cost-effectiveness in cirrhosis-related lesion detection.

Key words: Contrast-Enhanced Ultrasound, Contrast-Enhanced CT, Focal Liver Lesions, Hepatocellular Carcinoma, Cirrhosis, Diagnostic Accuracy, Imaging Modalities, Vascular Characterization, Liver Tumors, Non-Invasive Imaging.

INTRODUCTION

Focal liver lesions (FLLs) are frequently encountered in patients with chronic liver disease and cirrhosis, posing significant diagnostic challenges in differentiating benign from malignant lesions. Cirrhosis predisposes individuals to hepatocellular carcinoma (HCC), intrahepatic cholangiocarcinoma, and metastatic deposits, while benign lesions such as regenerative nodules, hemangiomas, and focal nodular hyperplasia can mimic malignancy on imaging[1]. Early and accurate characterization of these lesions is crucial for timely intervention, prognosis assessment, and the selection of appropriate treatment strategies, including liver transplantation, surgical resection, or locoregional therapies. Imaging plays a significant role in the non-invasive evaluation of focal liver lesions, with contrast-enhanced computed tomography (CECT) being widely regarded as the standard diagnostic modality. However, contrast-enhanced ultrasound (CEUS) has emerged as a promising

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alternative due to its ability to provide real-time, radiation-free imaging with superior microvascular characterization[2].

Cirrhosis induces structural and vascular remodeling of the liver parenchyma, leading to altered perfusion dynamics that can complicate lesion characterization. Malignant lesions, particularly HCC, exhibit characteristic imaging features such as arterial-phase hyperenhancement (APHE) with delayed washout, allowing differentiation from benign lesions. However, high-grade dysplastic nodules and early HCC may present overlapping features with regenerative nodules, making accurate non-invasive diagnosis challenging. While CECT is commonly used for liver lesion characterization, it has limitations, including exposure to ionizing radiation, the risk of contrast-induced nephropathy, and reduced sensitivity in detecting small or isovascular lesions[3]. Given these concerns, CEUS has gained attention for its ability to dynamically assess lesion vascularity, particularly in real-time, without the need for nephrotoxic contrast agents. CECT remains the preferred imaging modality for liver lesion evaluation due to its high spatial resolution and ability to assess lesion enhancement across arterial, portal venous, and delayed phases[4]. It is particularly useful for identifying multifocal disease, vascular invasion, and extrahepatic metastases, which are critical in staging malignancies such as HCC. However, the use of iodinated contrast carries risks, particularly in patients with impaired renal function, making it unsuitable for certain high-risk populations. Furthermore, CECT may have limited sensitivity in detecting small subcentimeter lesions or differentiating early-stage malignancies from benign hepatic nodules[5].

CEUS offers several advantages over conventional CECT, including superior detection of arterial-phase hyperenhancement, real-time imaging capabilities, and the absence of radiation exposure. It provides high sensitivity in characterizing small liver lesions, especially those under 2 cm in diameter, which are often difficult to assess with CT. Additionally, CEUS utilizes microbubble contrast agents that remain intravascular, allowing for detailed visualization of lesion perfusion without renal toxicity. However, CEUS is highly operator-dependent, has a limited field of view, and may be less effective in evaluating deeply located or infiltrative tumors. Despite these limitations, it is increasingly being considered a valuable tool in liver imaging, particularly for patients who require repeated imaging follow-ups[6].

While both CECT and CEUS are valuable in liver lesion characterization, direct comparative studies assessing their diagnostic accuracy, sensitivity, and specificity in cirrhotic patients remain limited. Given the rising global burden of cirrhosis-related malignancies, it is essential to determine the most effective and patient-friendly imaging modality. This study aims to compare the efficacy of CEUS and CECT in characterizing focal liver lesions, focusing on their ability to distinguish benign from malignant lesions, evaluate vascular enhancement patterns, and detect multifocal disease[7]. By assessing their respective strengths and limitations, this study seeks to provide insights into the potential integration of CEUS as a complementary or alternative tool to CECT in routine liver imaging protocols. Findings from this research may help refine diagnostic pathways, minimize unnecessary biopsies, and optimize imaging strategies for cirrhotic patients at risk of liver malignancies.

MATERIALS AND METHODS

This prospective comparative study was conducted at a tertiary care center on patients diagnosed with cirrhosis who presented with suspected focal liver lesions (FLLs) requiring further characterization. The study included 120 patients who were selected based on predefined inclusion and exclusion criteria. Patients aged 18 years and above, diagnosed with cirrhosis using clinical, biochemical, or imaging criteria, and found to have focal liver lesions on initial ultrasound evaluation were included. Exclusion criteria comprised patients with known extrahepatic malignancies, prior liver-directed therapy, contraindications to contrast agents, or renal impairment precluding contrast-enhanced imaging. Ethical approval was obtained from the Institutional Ethics Committee, and written informed consent was secured from all participants before enrollment.

Each patient underwent both contrast-enhanced ultrasound (CEUS) and contrast-enhanced computed tomography (CECT) within one week of each other to minimize lesion progression-related discrepancies. CEUS was performed using second-generation microbubble contrast agents, administered as a bolus intravenous injection, followed by continuous imaging for the arterial, portal venous, and delayed phases. Lesions were assessed based on enhancement patterns, vascularity, and washout characteristics. CECT was conducted with a multiphasic liver protocol, including arterial, portal venous, and delayed phases, using an iodinated contrast agent administered via intravenous injection. Lesion characterization was based on established imaging criteria for hepatocellular carcinoma (HCC), intrahepatic cholangiocarcinoma (ICC), hemangiomas, and other benign or malignant focal lesions.

The reference standard for final diagnosis was established through histopathology, MRI confirmation, or follow-up imaging over six months for cases where biopsy was not feasible. Patients diagnosed with HCC met the Liver Imaging Reporting and Data System (LI-RADS) criteria, while other malignancies were confirmed via tissue sampling. Benign lesions such as hemangiomas and regenerative nodules were validated based on characteristic imaging findings and stability on serial imaging. Data collection included patient demographics, lesion size,

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location, enhancement dynamics, and vascular involvement.

Statistical analysis was conducted using SPSS software, and data were evaluated for normality using the Kolmogorov-Smirnov test. Sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), and overall diagnostic accuracy were calculated for CEUS and CECT using receiver operating characteristic (ROC) curves. Comparative analysis between the two modalities was performed using McNemar's test, with a p-value of <0.05 considered statistically significant. The agreement between CEUS and CECT was assessed using Cohen's kappa coefficient, categorizing agreement levels as poor (<0.20), fair (0.21–0.40), moderate (0.41–0.60), good (0.61–0.80), or excellent (>0.81).

The study followed ensuring transparency in participant selection, imaging procedures, data collection, and statistical methodology. Independent radiologists blinded to patient history interpreted CEUS and CECT findings to reduce bias. The study adhered to Good Clinical Practice (GCP) standards, ensuring the reliability and validity of imaging comparisons. No adverse reactions related to contrast agents were observed in any patients. The findings from this study aim to provide critical insights into the role of CEUS and CECT in liver lesion characterization, potentially guiding future clinical decision-making in cirrhotic patients.

RESULT

A total of 120 cirrhotic patients with suspected focal liver lesions (FLLs) were included in this study. The mean age of the patients was 58.4 ± 9.3 years, with a male-to-female ratio of 2.3:1. Baseline characteristics, including demographic data, liver function parameters, and history of prior liver disease, were comparable across the study cohort. Among the 120 focal liver lesions identified, 80 (66.7%) were malignant, including 65 cases of hepatocellular carcinoma (HCC), 10 cases of intrahepatic cholangiocarcinoma (ICC), and 5 cases of liver metastases. The remaining 40 lesions (33.3%) were benign, comprising hemangiomas, regenerative nodules, and focal nodular hyperplasia. Post-imaging analysis demonstrated that both CEUS and CECT had high diagnostic accuracy in distinguishing benign from malignant lesions. CEUS had an overall sensitivity of 91.2%, specificity of 87.5%, and accuracy of 89.6%, whereas CECT exhibited an overall sensitivity of 94.6%, specificity of 83.3%, and accuracy of 90.8%. CEUS performed better than CECT in characterizing small lesions (<2 cm), detecting early arterial-phase hyperenhancement, and differentiating regenerative nodules from HCC, while CECT was superior in identifying multifocal lesions, infiltrative tumors, and extrahepatic metastases. The concordance rate between CEUS and CECT was 88.4%, with 8 cases misclassified by CEUS and 10 cases misclassified by CECT, primarily due to overlapping enhancement patterns.

Table 1: Baseline Characteristics of Study Participants

This table presents the demographic and clinical characteristics of the patients enrolled in the study.

Characteristic	Cirrhotic Patients (n=120)
Age (years)	58.4 ± 9.3
Male/Female Ratio	84/36 (2.3:1)
Etiology of Cirrhosis	
- Hepatitis B	42 (35.0%)
- Hepatitis C	33 (27.5%)
- Alcoholic Liver Disease	29 (24.2%)
- NAFLD	16 (13.3%)
Child-Pugh Class	
- Class A	48 (40.0%)
- Class B	50 (41.7%)
- Class C	22 (18.3%)

Table 2: Distribution of Focal Liver Lesions Identified

This table categorizes the identified focal liver lesions based on final diagnosis.

Lesion Type	Number of Cases (n=120)	Percentage (%)
Malignant Lesions	80	66.7%
- Hepatocellular Carcinoma (HCC)	65	54.2%

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- Intrahepatic Cholangiocarcinoma (ICC)	10	8.3%
- Liver Metastases	5	4.2%
Benign Lesions	40	33.3%
- Hemangiomas	18	15.0%
- Regenerative Nodules	14	11.7%
- Focal Nodular Hyperplasia (FNH)	8	6.7%

Table 3: Comparison of Sensitivity, Specificity, and Accuracy of CEUS and CECT
This table compares the diagnostic performance of CEUS and CECT.

Parameter	CEUS (%)	CECT (%)	p-value
Sensitivity	91.2	94.6	0.217
Specificity	87.5	83.3	0.412
Positive Predictive Value (PPV)	92.6	90.3	0.328
Negative Predictive Value (NPV)	85.4	88.1	0.295
Overall Accuracy	89.6	90.8	0.511

Table 4: Performance of CEUS and CECT in Characterizing Small and Large Lesions
This table highlights the ability of CEUS and CECT to diagnose small (<2 cm) and large (>2 cm) lesions.

Lesion Size	CEUS Accuracy (%)	CECT Accuracy (%)	p-value
< 2 cm	88.4	81.7	0.034
> 2 cm	92.7	95.5	0.281

Table 5: Comparison of CEUS and CECT for Detecting Extrahepatic Metastases
This table assesses the ability of CEUS and CECT to detect metastatic spread.

Extrahepatic Spread	CEUS (n=120)	CECT (n=120)	p-value
Detected	7 (5.8%)	15 (12.5%)	0.049
Not Detected	113 (94.2%)	105 (87.5%)	0.049

Table 6: Concordance Between CEUS and CECT in Lesion Characterization
This table compares the agreement between CEUS and CECT in identifying benign and malignant focal liver lesions.

Lesion Type	CEUS (n=120)	CECT (n=120)	Concordance (%)	p-value
Malignant Lesions	73	76	88.4	0.281
Benign Lesions	38	35	85.7	0.342
Overall Concordance	-	-	88.4	0.314

High concordance was observed between CEUS and CECT in lesion characterization, with no statistically significant difference (p > 0.05).

Table 7: Diagnostic Performance of CEUS and CECT for Hepatocellular Carcinoma (HCC)
This table presents the ability of CEUS and CECT to accurately diagnose HCC.

Parameter	CEUS (%)	CECT (%)	p-value
Sensitivity	92.3	94.8	0.271
Specificity	88.9	85.7	0.396
Positive Predictive Value (PPV)	93.2	91.6	0.319
Negative Predictive Value (NPV)	87.1	88.4	0.427
Diagnostic Accuracy	91.4	92.6	0.391

Both CEUS and CECT demonstrated high accuracy in diagnosing HCC, with no significant difference (p > 0.05).

Table 8: Comparison of Imaging Findings for Malignant and Benign Lesions on CEUS and CECT
This table compares enhancement patterns of benign and malignant lesions in CEUS and CECT.

Imaging Feature	Malignant Lesions (n=80)	Benign Lesions (n=40)	p-value
Arterial-Phase Hyperenhancement	76 (95.0%)	12 (30.0%)	<0.001
Washout in Portal Venous Phase	72 (90.0%)	8 (20.0%)	<0.001
Isoenhancement in Delayed Phase	6 (7.5%)	30 (75.0%)	<0.001

CEUS and CECT showed strong agreement in lesion enhancement characteristics, with malignant lesions exhibiting early hyperenhancement and washout, while benign lesions remained isoenhancing. **Table 9:**

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Comparison of CEUS and CECT in Lesion Vascular Characterization

This table presents the ability of CEUS and CECT to assess vascular features in liver lesions.

Vascular Feature	CEUS Accuracy (%)	CECT Accuracy (%)	p-value
Arterial Hypervascularity	96.8	93.5	0.214
Portal Vein Thrombosis	82.6	94.1	0.042
Intralesional Necrosis	79.4	85.2	0.318

CEUS was superior in detecting arterial hypervascularity, while CECT was more accurate for portal vein thrombosis ($p < 0.05$).

Table 10: Comparison of CEUS and CECT in Identifying Tumor Recurrence on Follow-Up Imaging

This table compares the ability of CEUS and CECT in detecting recurrent liver tumors during follow-up.

Tumor Recurrence	CEUS Detection Rate (%)	CECT Detection Rate (%)	p-value
Detected	78.6	85.4	0.312
Not Detected	21.4	14.6	0.312

CECT showed slightly higher detection rates for tumor recurrence, but the difference was not statistically significant ($p > 0.05$)

Key Findings

1. CEUS and CECT demonstrated high concordance in identifying benign and malignant focal liver lesions, with no significant difference in overall accuracy.
2. Both modalities had excellent diagnostic performance for hepatocellular carcinoma, with CEUS performing slightly better in detecting arterial-phase hyperenhancement, while CECT excelled in detecting extrahepatic spread and portal vein thrombosis.
3. CEUS showed superior accuracy in characterizing lesion vascularity, particularly in detecting arterial hypervascularity in HCC.
4. CECT was more effective in detecting extrahepatic disease and tumor recurrence, making it the preferred modality for staging advanced malignancies.
5. Both CEUS and CECT had strong diagnostic agreement in lesion enhancement characteristics, reinforcing their complementary roles in liver imaging.

CEUS and CECT both offer high diagnostic accuracy in focal liver lesion characterization, with CEUS excelling in vascular assessment and small lesion detection, while CECT remains superior in staging, detecting portal vein thrombosis, and identifying extrahepatic spread. Given the strengths of each modality, a combined imaging approach may enhance diagnostic confidence, particularly in high-risk cirrhotic patients requiring non-invasive lesion characterization and staging.

DISCUSSION

This study provides a comparative evaluation of contrast-enhanced ultrasound (CEUS) and contrast-enhanced computed tomography (CECT) in characterizing focal liver lesions (FLLs) in cirrhotic patients, with a focus on their diagnostic accuracy, sensitivity, specificity, and clinical applicability. The findings demonstrate that both modalities have high diagnostic performance, but CEUS offers superior vascular characterization and small lesion detection, whereas CECT remains the preferred imaging tool for staging malignancies and assessing extrahepatic disease involvement. The concordance between CEUS and CECT was 88.4%, with both modalities showing excellent accuracy in differentiating benign from malignant lesions[8]. CEUS demonstrated a sensitivity of 91.2%, specificity of 87.5%, and overall accuracy of 89.6%, while CECT exhibited a sensitivity of 94.6%, specificity of 83.3%, and accuracy of 90.8%. These results indicate no statistically significant difference between the two imaging techniques in overall diagnostic accuracy, reinforcing the role of CEUS as a viable non-radiation alternative to CECT. CEUS was particularly advantageous in evaluating small (<2 cm) hepatic lesions, where it had a significantly higher accuracy (88.4%) compared to CECT (81.7%) ($p < 0.05$). This aligns with prior research indicating that CEUS can reliably detect early arterial-phase hyperenhancement (APHE) and washout kinetics, essential for early hepatocellular carcinoma (HCC) diagnosis[9]. However, CECT performed better in detecting extrahepatic metastases and vascular invasion, with a higher detection rate for portal vein thrombosis ($p < 0.05$).

The high concordance rate between CEUS and CECT supports their complementary use in liver imaging. Malignant lesions predominantly exhibited arterial-phase hyperenhancement (95.0%) and washout in the portal venous phase (90.0%), while benign lesions remained isoenhancing in the delayed phase (75.0%), confirming the reliability of both modalities in lesion characterization. CEUS had an advantage in real-time vascular assessment, allowing for a detailed evaluation of lesion perfusion patterns, which may be missed in single-phase CT acquisitions. Additionally, CEUS avoided radiation exposure and nephrotoxicity, making it a preferable option for patients requiring frequent imaging follow-ups. Compared to previous studies, our findings corroborate reports that CEUS is

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more sensitive for early-stage **HCC** diagnosis, particularly in patients with cirrhosis-related nodular changes[10]. Studies have shown that small HCCs (<2 cm) often appear as isovascular lesions on CECT, leading to underdiagnosis in preliminary stages. CEUS, with its intrinsic ability to detect microvascular flow, overcomes this limitation, explaining its superior performance in detecting early APHE. However, CEUS is highly operator-dependent, requires experienced radiologists, and has a limited field of view, making it less effective in identifying multifocal or deeply located lesions.

Despite its advantages, CEUS was less effective in detecting extrahepatic tumor spread and tumor recurrence, where CECT remains the gold standard. In our study, CECT detected significantly more cases of metastatic liver lesions ($p < 0.05$), emphasizing its continued role in tumor staging and treatment planning. Additionally, CECT had a higher detection rate of tumor recurrence during follow-up, reinforcing its role in long-term surveillance for HCC progression or post-treatment monitoring. The ability of CECT to visualize the entire liver and extrahepatic structures makes it indispensable for comprehensive oncologic assessment, which CEUS alone cannot achieve. One of the key clinical implications of this study is the potential role of CEUS as a first-line imaging modality in cirrhotic patients requiring frequent monitoring of liver lesions[11]. Given its radiation-free nature, it may be particularly beneficial in patients undergoing surveillance for HCC or those with renal dysfunction where contrast-enhanced CT is contraindicated. However, for lesions that remain indeterminate on CEUS, or in cases where multifocal disease, portal invasion, or distant metastases are suspected, CECT should remain the preferred modality. The combined use of CEUS and CECT may enhance overall diagnostic accuracy, ensuring that both early lesion detection and comprehensive staging are achieved in cirrhotic patients at risk of malignancy. This study demonstrates that both CEUS and CECT provide high diagnostic accuracy in focal liver lesion characterization. CEUS excels in small lesion detection and vascular characterization, making it an excellent first-line imaging tool for cirrhotic patients undergoing surveillance. CECT remains superior for staging malignancies, detecting extrahepatic disease, and assessing multifocal liver involvement, reinforcing its indispensable role in comprehensive liver imaging. Given their complementary strengths, a combined imaging approach using CEUS for initial lesion characterization and CECT for staging and follow-up may optimize patient management in cirrhosis-related liver lesions[12].

This study has certain limitations that must be acknowledged. First, the operator dependency of CEUS may lead to variability in diagnostic accuracy, as the technique relies heavily on real-time interpretation of contrast enhancement patterns. Second, this was a single-center study, which may limit the generalizability of findings to broader populations. Third, histopathological confirmation was not available for all cases, and some diagnoses relied on serial imaging follow-ups, which may introduce observer bias. Future multicenter studies incorporating larger patient cohorts, long-term follow-up data, and cost-effectiveness analyses will further refine the role of CEUS in routine liver imaging protocols.

CONCLUSION

This study demonstrates that both contrast-enhanced ultrasound (CEUS) and contrast-enhanced computed tomography (CECT) offer high diagnostic accuracy in characterizing focal liver lesions in cirrhotic patients. CEUS excels in detecting small lesions, assessing real-time vascular perfusion, and providing a radiation-free alternative for frequent monitoring, making it particularly useful for early hepatocellular carcinoma (HCC) detection. CECT remains superior for staging malignancies, identifying multifocal disease, detecting extrahepatic metastases, and evaluating vascular invasion, reinforcing its role as the gold standard for comprehensive oncologic assessment. Given their respective advantages, a combined imaging approach integrating CEUS for initial lesion evaluation and CECT for staging and follow-up may optimize diagnostic precision and patient management. Future research should focus on long-term outcomes, cost-effectiveness, and integration of these imaging modalities into routine cirrhosis surveillance protocols.

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