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Imaging Assessment of Focal Liver Lesions: Comparative Evaluation of Ultrasonography and Triple-Phase Computed Tomography in a Tertiary Care Centre

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ABSTRACT

Background: Focal liver lesions (FLLs) span a wide benign-to-malignant spectrum, from simple cysts and hemangiomas to hepatocellular carcinoma (HCC) and metastases. Ultrasonography (USG) is the first-line detection modality, whereas triple-phase contrast-enhanced computed tomography (CT) enables definitive characterization through dynamic enhancement kinetics.
Aim: To evaluate FLLs on USG and correlate the findings with triple-phase CT for accurate benign–malignant differentiation.
Methods: This prospective observational study enrolled 100 patients with FLLs detected on grayscale and Doppler USG, each subsequently evaluated with a non-contrast, late-arterial, portal-venous, and delayed CT protocol. Imaging features were correlated with the CT-based reference diagnosis. Categorical associations were tested with the chi-square and Fisher exact tests; $p < 0.05$ was significant.
Results: Benign lesions constituted 53% and malignant 47%. HCC was commonest (25%), followed by hemangioma (23%) and metastasis (19%). USG identified focal liver lesions in all enrolled patients but agreed with the final CT diagnosis in only 78% of cases; triple-phase CT refined or altered the diagnosis in 22% of cases; triple-phase CT upgraded or altered the diagnosis in 22%. Arterial enhancement, washout, capsule appearance, and vascular invasion were strongly associated with malignancy ($p < 0.001$); washout and vascular invasion occurred exclusively in malignant lesions, and vascular invasion carried a 100% positive predictive value for malignancy.
Conclusion: USG is an effective screening tool for detecting FLLs, but triple-phase CT is indispensable for definitive characterization, staging, and management planning. A combined, stepwise imaging strategy maximizes diagnostic accuracy.

Keywords: Focal liver lesions; Ultrasonography; Triple-phase CT; Hepatocellular carcinoma; Liver metastasis; Imaging correlation.

INTRODUCTION

Focal liver lesions encompass a broad spectrum of benign and malignant pathologies, ranging from simple cysts, hemangiomas, and inflammatory abscesses to hepatocellular carcinoma, cholangiocarcinoma, and metastatic deposits [1,2]. With the expanding use of cross-sectional imaging, such lesions are increasingly detected, often incidentally, and their accurate characterization is pivotal because management pathways diverge sharply between benign and malignant disease [3,4].

Ultrasonography is widely available, inexpensive, and free of ionizing radiation, making it the customary first-line modality for hepatic evaluation. However, the considerable overlap in sonographic appearances across different pathologies limits its specificity for definitive characterization [5,7]. Triple-phase contrast-enhanced CT addresses this limitation by capturing dynamic enhancement across late-arterial, portal-venous, and delayed phases, allowing lesions to be classified according to their vascular behavior—the basis of modern systems such as LI-RADS and the AASLD and EASL guidance for HCC [14,15,19].

The benign category typically includes hemangiomas, simple cysts, and inflammatory abscesses, whereas the malignant category comprises hepatocellular carcinoma, cholangiocarcinoma, and metastatic deposits, each with characteristic enhancement signatures—peripheral nodular fill-in in hemangiomas, arterial hyperenhancement with washout in HCC, and rim or target patterns in abscesses and metastases [3,8,13]. Because these entities can mimic one another on grayscale imaging, a structured multiphasic approach is essential for confident differentiation [4,18].

Despite well-established imaging criteria, prospective data directly comparing USG impressions with triple-phase CT in routine practice—and quantifying the incremental value of CT—remain limited in this population. The present study was undertaken to evaluate FLLs on USG, correlate them with triple-phase CT, and define the imaging features that most reliably discriminate benign from malignant lesions.

MATERIALS AND METHODS

Study design and population. This prospective observational study was conducted in the Department of Radiodiagnosis of a tertiary-care teaching hospital. Consecutive patients presenting with acute or chronic right hypochondrial or abdominal pain, referred from outpatient, inpatient, or emergency services, in whom a focal liver lesion was detected on ultrasonography, were eligible. Adult patients providing written informed consent were included; those with contraindications to contrast-enhanced CT, and pregnant patients, were excluded.

Sample size. Using an expected USG-based FLL prevalence of 15.1%, 95% confidence, and 3% precision, the minimum sample size was 91; a total of 100 patients with confirmed lesions were enrolled.

Imaging protocol. All patients first underwent grayscale and color-Doppler USG (GE Voluson P8, Versana, and Logiq systems) for lesion detection, echogenicity, number, and location. Triple-phase CT was then performed on a 16-/128-slice scanner, comprising a non-contrast acquisition followed by late-arterial (~20–35 s), portal-venous (~60–70 s), and delayed (~3–5 min) phases after intravenous iodinated contrast. Lesions were assessed for arterial enhancement, washout, delayed enhancement, capsule appearance, vascular invasion, and extrahepatic spread.

Reference standard and statistics. The final diagnosis established by triple-phase CT, together with available clinical and laboratory findings, served as the imaging reference standard for lesion characterization. Data were analyzed in SPSS v29. Continuous variables were summarized as mean ± SD and categorical variables as frequencies and percentages. The chi-square test was used for categorical associations, with the Fisher exact test where expected cell counts were below five or contained zeros; the independent-samples t-test compared mean lesion size between groups. A two-tailed $p < 0.05$ was considered significant and $p < 0.001$ highly significant.

RESULTS

Demographics, presentation, and risk factors

The cohort comprised 100 patients with a mean age of 45.6 years; the largest group was 41–50 years (30%), and there was a slight female predominance (54%). Right upper-quadrant pain was universal (100%), with abdominal distension in 75%, jaundice in 27%, and fever in 15%. Diabetes mellitus (48%) and alcohol use (24%) were the principal documented risk factors (Table 1).

Table 1. Baseline demographics, clinical presentation, and risk factors (n = 100)

Parameter	Distribution — n (%)
Age (years)	21–30: 14 (14); 31–40: 24 (24); 41–50: 30 (30); 51–60: 20 (20); >60: 12 (12). Mean 45.6 yr
Sex	Female: 54 (54); Male: 46 (46)
Presenting symptoms	RUQ pain: 100 (100); Abdominal distension: 75 (75); Jaundice: 27 (27); Fever: 15 (15)
Risk factors	Diabetes mellitus: 48 (48); Alcohol use: 24 (24)

Lesion spectrum and morphology

Benign lesions constituted 53% and malignant 47% of the cohort. Hepatocellular carcinoma was the single commonest diagnosis (25%), followed by hemangioma (23%), metastasis (19%), abscess (15%), simple cyst (15%), and cholangiocarcinoma (3%) (Table 2, Figure 1). On morphology, the mean lesion size was 6.58 cm (range 1.7–12 cm), with

most lesions 5–8 cm (33%) or >8 cm (25%); 62% were solitary and 32% were bilobar. Mixed echogenicity was the commonest sonographic pattern (41%) (Table 3).

Table 2. Final diagnosis spectrum with corresponding USG provisional diagnosis (n = 100)

Final diagnosis	n (%)	Nature	USG dx (n)
Hepatocellular carcinoma	25 (25)	Malignant	23
Hemangioma	23 (23)	Benign	20
Metastasis	19 (19)	Malignant	18
Abscess	15 (15)	Benign	16
Simple cyst	15 (15)	Benign	15
Cholangiocarcinoma	3 (3)	Malignant	—
Indeterminate (USG only)	—	—	8
Benign vs malignant	**53 vs 47**		

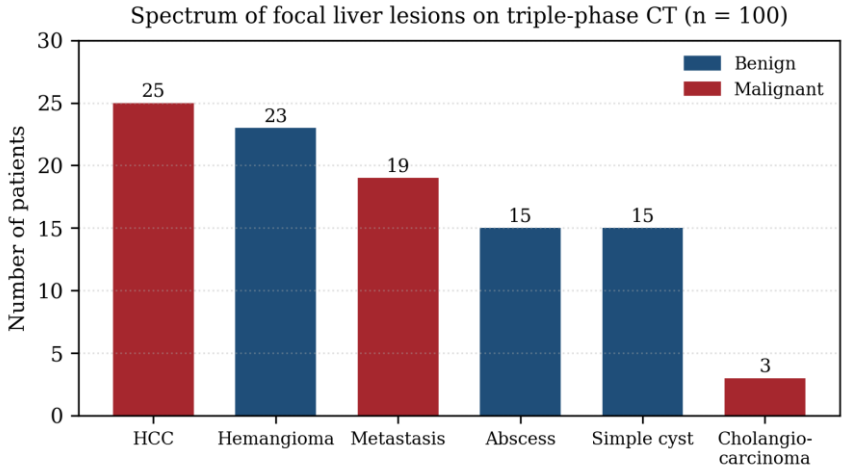


Figure 1. Distribution of the six focal liver lesion diagnoses confirmed on triple-phase CT (n = 100), colour-coded by biological nature. Hepatocellular carcinoma was the commonest lesion (25%), followed by hemangioma (23%) and metastasis (19%); malignant diagnoses (red) collectively accounted for 47% of the cohort and benign diagnoses (blue) for 53%.

Table 3. Lesion morphology: size, multiplicity, location, and USG echogenicity (n = 100)

Feature	Category	n (%)
Lesion size (mean 6.58 cm)	<3 cm	16 (16)
	3–5 cm	26 (26)
	5–8 cm	33 (33)
	>8 cm	25 (25)
Multiplicity	Single	62 (62)
	Multiple	38 (38)
Lobar location	Left	35 (35)
	Right	33 (33)
	Bilobar	32 (32)
USG echogenicity	Mixed	41 (41)
	Hyperechoic	32 (32)
	Hypoechoic	27 (27)

Table 4. Age-specific distribution of focal liver lesions by diagnosis (n = 100)

Age (yr)	Abscess	Cholangio	HCC	Heman-gioma	Meta- stasis	Cyst
21–30	4	0	0	6	0	4
31–40	5	0	3	9	3	4
41–50	3	1	8	5	8	5
51–60	2	2	8	2	4	2
>60	1	0	6	1	4	0

Diagnoses showed clear age-related clustering: hemangiomas peaked in younger adults (21–40 years), whereas HCC and metastatic disease concentrated in patients older than 40 years, in keeping with the latency of chronic liver injury and the rising incidence of extrahepatic primaries with age (Table 4).

CT enhancement features and benign–malignant correlation

On triple-phase CT, arterial phase enhancement was seen in 66% of lesions, washout in 36%, delayed enhancement in 34%, and a capsule in 54% (Table 5). When correlated with lesion nature, arterial enhancement, washout, capsule appearance, and vascular invasion were all strongly associated with malignancy ($p < 0.001$), whereas delayed enhancement was significantly more frequent in benign lesions ($p = 0.019$). Notably, washout and vascular invasion occurred exclusively in malignant lesions, with no benign lesion exhibiting either feature; vascular invasion therefore carried a 100% positive predictive value for malignancy (Table 6, Figure 2).

Table 5. Triple-phase CT imaging features across the cohort (n = 100)

Triple-phase CT feature	Present (%)	Absent (%)
Arterial phase enhancement	66	34
Washout phenomenon	36	64
Delayed phase enhancement	34	66
Capsule appearance	54	46
Vascular invasion	47	53
Extrahepatic disease extension	34	66

Table 6. Association of CT features with lesion nature

CT feature	Benign (n=53)	Malignant (n=47)	p-value
Arterial enhancement present	23	43	<0.001
Washout present	0	37	<0.001
Delayed enhancement present	24	10	0.019
Capsule present	15	40	<0.001
Vascular invasion present	0	47	<0.001
Bilobar involvement	12	20	—

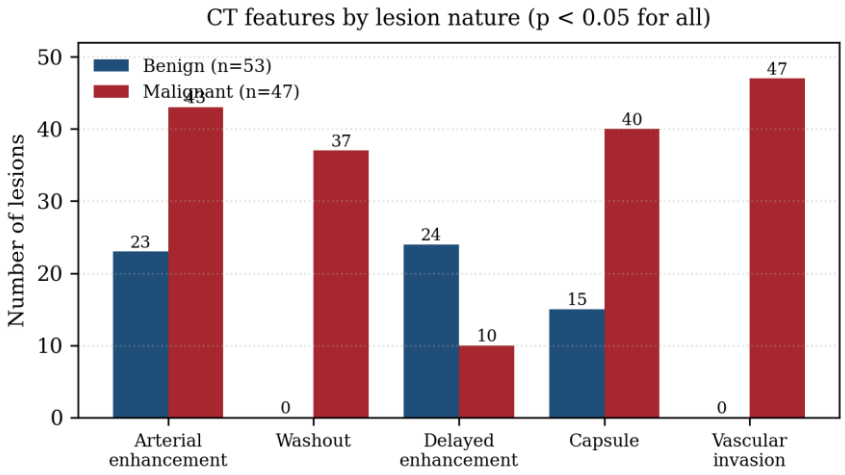


Figure 2. Frequency of the five key triple-phase CT features in benign (blue) versus malignant (red) lesions. Arterial enhancement, capsule appearance, washout, and vascular invasion were all significantly more frequent in malignant lesions ($p < 0.001$), whereas delayed enhancement predominated in benign lesions ($p = 0.019$). Washout and vascular invasion were seen in no benign lesion, the latter yielding a 100% positive predictive value for malignancy.

Lesion size also tracked with biology: small lesions (<3 cm) were predominantly benign (12 of 16), while the malignant share rose with size (15 of 25 lesions >8 cm were malignant). However, the mean size difference between benign and malignant lesions was not statistically significant ($p = 0.229$), indicating that enhancement kinetics outperform size as a discriminator (Figure 3).

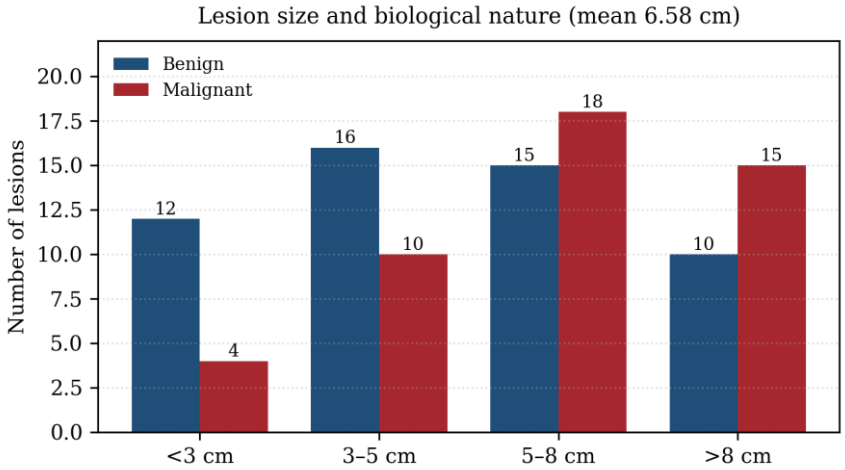


Figure 3. Distribution of benign and malignant lesions across four size categories. Small lesions (<3 cm) were predominantly benign (12 of 16), while the malignant proportion rose with increasing size (15 of 25 lesions >8 cm were malignant). Despite this trend, the mean size difference between benign and malignant lesions was not statistically significant ($p = 0.229$), indicating that size is a supportive rather than a definitive discriminator.

USG versus triple-phase CT performance

USG identified focal liver lesions in all enrolled patients, as lesion detection on ultrasonography was an inclusion criterion. However, USG agreed with the final CT diagnosis in only 78% of cases, while triple-phase CT refined or altered the diagnosis in 22% of patients—chiefly by resolving indeterminate impressions, distinguishing echogenic metastases from hemangiomas, and revealing staging features such as vascular invasion and bilobar disease (Table 7).

Table 7. Diagnostic performance of the USG-to-CT imaging pathway

Diagnostic metric	Value	Interpretation
USG identification of enrolled lesions	100%	All enrolled patients had lesions detected on initial USG
USG–CT diagnostic concordance	78%	Agreement on final diagnosis
Diagnostic upgrade by CT	22%	CT changed/refined USG diagnosis

Diagnostic metric	Value	Interpretation
PPV of vascular invasion for malignancy	100%	Absolute malignancy marker

DISCUSSION

In this prospective cohort, a focal liver lesion detected on screening USG carried a substantial (47%) probability of malignancy, underscoring that such lesions warrant structured cross-sectional characterization rather than presumptive reassurance—an approach consistent with the ACR white paper on incidental liver lesions [14]. The mean age of 45.6 years and the diagnostic mix reflect the cumulative burden of chronic liver disease and the liver's role as a frequent metastatic target [11,20].

The lesion distribution observed in the present study was comparable to previous reports, with hepatocellular carcinoma representing the most common malignant lesion and hemangioma the most frequent benign lesion. Similar studies evaluating focal liver lesions have likewise demonstrated the superiority of multiphasic CT over ultrasonography for lesion characterization, particularly in differentiating hypervascular tumors from benign vascular lesions and in assessing vascular invasion. These findings reinforce the established role of triple-phase CT as the preferred cross-sectional imaging modality for comprehensive evaluation of focal liver lesions.

The dynamic-enhancement findings reproduce the established biological signatures of hepatic tumors. Arterial hyperenhancement followed by washout—the radiological backbone of non-invasive HCC diagnosis in the AASLD, EASL, and LI-RADS frameworks—was strongly linked to malignancy, with washout seen in no benign lesion [15,16,19]. Delayed enhancement, conversely, favored benign disease, in keeping with the progressive centripetal fill-in characteristic of hemangiomas [3,18]. Capsule appearance, a major LI-RADS feature, was significantly more frequent in malignant lesions, and vascular invasion behaved as an absolute malignancy marker [16].

Size and distribution provided supportive rather than definitive discrimination: larger and bilobar lesions skewed malignant, yet the mean-size difference between groups was not significant, reinforcing that enhancement kinetics and morphologic signs outweigh size alone [20]. Most importantly, although USG detected all lesions, triple-phase CT changed management-relevant diagnosis in 22% of cases and reached only 78% concordance with USG impressions, echoing foundational work showing that triphasic protocols substantially improve lesion characterization [21]. These data support a stepwise pathway—USG for detection and triage, triple-phase CT for definitive characterization and staging.

Viewed by lesion type, the dynamic patterns translated directly into specific diagnoses. Hepatocellular carcinomas dominated the arterial-enhancing, washout-positive, capsulated group; hemangiomas combined arterial enhancement with progressive delayed fill-in and never showed washout; metastases frequently presented as multiple lesions with variable, often rim-like enhancement; pyogenic and amoebic abscesses showed peripheral rim enhancement with non-enhancing necrotic cores and clustered with febrile presentations; and simple cysts remained uniformly non-enhancing. This concordance between enhancement signature and final diagnosis explains why triple-phase CT achieved near-complete agreement with the reference standard while USG alone left 8% of lesions indeterminate [13,17].

The study has limitations. It was single-centre with a modest sample of 100 patients and an inherent selection bias toward referred, lesion-positive patients. Final characterization rested on imaging rather than universal histopathology, very small (<1–2 cm) lesions are difficult to characterize, and the radiation burden of triple-phase CT restricts its screening use. Long-term follow-up for lesion progression and outcomes was not performed.

CONCLUSION

Ultrasonography is a sensitive, accessible first-line tool that reliably detects focal liver lesions, but it lacks the specificity for definitive characterization. Triple-phase contrast-enhanced CT, by resolving lesion vascularity across arterial, portal-venous, and delayed phases, provides decisive benign–malignant differentiation and critical staging information, altering the diagnosis in nearly one-quarter of cases. A combined, stepwise USG-to-CT imaging strategy therefore offers the most accurate and clinically actionable evaluation of focal liver lesions.

DECLARATIONS

Ethics: Institutional ethics approval and written informed consent were obtained. Conflict of interest: None declared. Funding: None.

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