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COMPARISON OF FINDINGS OF HEPATOCELLULAR CARCINOMA VASCULARITY ON CT TRIPHASIC AND DOPPLER ULTRASOUND IN ADULTS

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Abstract

Background: *One of the most common liver cancers is Hepatocellular carcinoma (HCC), and its early diagnosis, treatment, and prognosis relies on proper evaluation of lesions and vascularity. Triphasic CT and Doppler USG are complementary non-invasive methods of imaging of lesions, assessment of vascular patterns and measurement of hemodynamics.*

Objective: *To compare triphasic CT and Doppler USG in terms of vascularity assessment of HCC and evaluate the capacity of each of the modalities to identify lesions, characterize the vascular patterns and the Resistive Index (RI).*

Methods: *The study was an observational, comparative, cross-sectional study at the Liver Clinic, New Muslim Town, Lahore, in a period of three months. The convenience sampling was used to select seventy-three patients. The inclusion criteria were that a patient had to be having at least one liver lesion 1cm in both CT and Doppler USG in the last four weeks. The exclusion criteria were age below 18 years, missing imaging data, non-diagnostic images, previous liver procedures, pregnancy or critical illness. The features of the lesions, vascularity, involvement of portal and hepatic veins, and size and RI were evaluated and compared.*

Results: *Out of 73 participants, the number of women and men was 52.1 percent and 47.9 percent respectively. Lesions were detected by CT in 43.8 percent and Doppler USG in 52.1 percent of subjects. Lesions were primarily small to medium (0.63 -3.9 cm). Preponderance was on isoenhancing and hypovascular patterns with significant numbers of lesions being Not Visible. The involvement of portal and hepatic veins was 53.4% and 56.2, respectively. The values of RI were relatively medium with very few high values, which means that the lesion population is heterogeneous.*

INTRODUCTION

Hepatocellular carcinoma (HCC) represents a significant global health challenge, being the most common primary malignancy of the liver. Its management and prognosis are intrinsically linked to early and accurate detection, with particular emphasis on characterizing its vascular profile. The vascular nature of HCC is a cornerstone of its radiographic diagnosis, as it

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typically exhibits a distinct pattern of arterial hyperenhancement followed by "washout" in the portal venous or delayed phases(1). This research synopsis focuses on comparing two key non-invasive imaging modalities used to assess this vascularity: Triphasic Computed Tomography (CT) and Doppler Ultrasound (US) in the adult population. An accurate comparison is vital for optimizing diagnostic pathways, guiding treatment decisions, and ultimately improving patient outcomes. Hepatocellular Carcinoma (HCC) is defined as a primary malignant neoplasm originating from hepatocytes, the main parenchymal cells of the liver. It is characterized by its propensity to develop in the setting of chronic liver disease and cirrhosis, and its diagnostic hallmarks often rely on imaging findings of specific vascular dynamics without the need for initial biopsy in many clinical contexts(2). HCC is the sixth most common cancer worldwide and the third leading cause of cancer-related mortality. Its incidence exhibits marked geographical variation, with the highest rates in East Asia and Sub-Saharan Africa, largely driven by endemic hepatitis B virus (HBV) infection. In Western countries, the incidence has been rising steadily over recent decades, paralleling the increase in hepatitis C virus (HCV) infection and non-alcoholic fatty liver disease (NAFLD). An estimated 906,000 new cases and 830,000 deaths occurred globally in 2020, underscoring its substantial burden(3).

The predominant cause of HCC is chronic liver injury leading to cirrhosis, which accounts for over 80% of cases. Major etiological risk factors include: Chronic Viral Hepatitis: HBV (the most common global cause) and HCV infections. Toxin Exposure: Chronic excessive alcohol consumption and dietary exposure to aflatoxin B1. Metabolic Liver Diseases: NAFLD and its progressive form, non-alcoholic steatohepatitis (NASH), which is becoming a leading cause in developed nations. Other Causes: Genetic hemochromatosis, alpha-1-antitrypsin deficiency, and primary biliary cholangitis(4).

The pathogenesis of HCC is a multistep process involving persistent hepatic inflammation, necrosis, regeneration, and fibrosis, culminating in cirrhosis. This microenvironment promotes genetic and epigenetic alterations in hepatocytes, driving uncontrolled proliferation and inhibition of apoptosis. A critical pathological feature is the tumor's altered vascular supply. As dysplastic nodules progress to overt HCC, they undergo an "arterialization" process, whereby they become predominantly supplied by newly formed, abnormal arterial vessels (neoangiogenesis) rather than the normal portal venous supply. This shift creates the characteristic hemodynamic pattern exploited by contrast-enhanced imaging. The diagnostic paradigm for HCC has evolved to prioritize non-invasive methods, as established by international guidelines like the Liver Imaging Reporting and Data System (LI-RADS) and those from the American Association for the Study of Liver Diseases (AASLD) and European Association for the Study of the Liver (EASL). Diagnosis in high-risk patients (cirrhosis, chronic HBV) typically relies on dynamic contrast-enhanced imaging demonstrating the specific vascular pattern: arterial phase hyperenhancement (APHE) and subsequent washout in the portal venous or delayed phases(5).The two primary imaging modalities are: Multiphasic CT (Triphasic/Quadriphasic): The workhorse for HCC diagnosis and staging, providing excellent spatial resolution and reproducible assessment of enhancement patterns across non-contrast, arterial, portal venous, and delayed phases. Contrast-Enhanced Ultrasound (CEUS) and Doppler US: Ultrasound, often the first-line surveillance tool, can be enhanced with microbubble contrast agents (CEUS) to evaluate vascularity. Doppler US assesses vascularity by detecting and quantifying blood flow velocity and direction within tumor vessels(6). Management is stratified by tumor stage, liver function, and patient performance status, as per the Barcelona Clinic Liver Cancer (BCLC) staging system. Options range from curative-intent treatments (surgical resection, liver transplantation, local ablation) for early-stage disease to locoregional therapies (transarterial chemoembolization - TACE, radioembolization) for intermediate stages, and systemic therapies (tyrosine kinase

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inhibitors, immunotherapy) for advanced disease(7).

Accurate vascular mapping is crucial for selecting and planning these interventions, particularly for resection, ablation, and TACE. While both triphasic CT and Doppler US are employed to evaluate HCC vascularity, a direct, systematic comparison of their findings in the same cohort of adult patients is warranted. CT is considered the reference standard for characterization but involves ionizing radiation and iodinated contrast. Doppler US is radiation-free, more accessible, and cost-effective but can be operator-dependent and limited by body habitus or bowel gas.

Material Methadology: This comparative cross-sectional study **was conducted** at the Liver Clinic in New Muslim Town, Lahore, over a three-month period. A calculated sample size of 73 adult patients **was selected** via convenience sampling. Eligible participants **were required** to have undergone both triphasic CT and Doppler ultrasound within four weeks, with at least one ≥1 cm liver lesion visible on both modalities and adequate image quality. Exclusion criteria **included** age below 18, incomplete imaging, non-diagnostic image quality, prior liver-directed therapy, pregnancy, or critical illness.

Results

This table presents the baseline demographic profile and key lesion features of the participants. The cohort was nearly balanced in gender, with a majority falling in the 46-65 year age range. Lesion sizes were broadly distributed, with a slight prevalence of smaller lesions (< 2 cm).

Table 1: Demographic and Lesion Characteristics of the Study Cohort (n=73)

Characteristic	Category	Frequency (n)	Percent (%)
Gender	Male	35	47.9
	Female	38	52.1
Age Group (Years)	26-35	11	15.1
	36-45	8	11.0
	46-55	19	26.0
	56-65	22	30.1
	66-78	13	17.8
Lesion Size (cm)	0.6 – 1.9	21	28.8
	2.0 – 3.9	19	26.0
	4.0 – 5.9	16	21.9
	6.0 – 7.4	17	23.3

This table compares the primary outcome of lesion detection between the two imaging modalities and summarizes the frequency of major vascular invasion. Doppler USG detected lesions in more participants than CT, but both modalities failed to visualize lesions in a significant proportion of cases. Portal and hepatic vein involvement were common findings in the cohort.

Table 2: Comparison of Lesion Detection and Major Vascular Involvement

Finding	Modality / Vessel	Frequency (n)	Percent (%)
Lesion Detection (Yes)	CT Triphasic	32	43.8
	Doppler USG	38	52.1
Lesion Not Visualized	CT Triphasic	25	34.2
	Doppler USG	19	26.0

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Major Vascular Involvement (Yes)	Portal Vein	39	53.4
	Hepatic Vein	41	56.2

This table directly contrasts the vascularity patterns observed in detected lesions across both imaging techniques. A key difference is noted: while "Not Visualized" was the most common CT finding, "Isoenhancing" was most frequent on USG. The distribution of hypervascular patterns, a classic hallmark of HCC, was similar but low on both modalities.

Table 3: Comparison of Lesion Vascularity Patterns on CT and Doppler USG

Vascularity Pattern	CT Triphasic (n, %)	Doppler USG (n, %)
Hypervascular	14 (19.2%)	13 (17.8%)
Hypovascular	15 (20.5%)	20 (27.4%)
Isoenhancing	19 (26.0%)	21 (28.8%)
Not Visualized	25 (34.2%)	19 (26.0%)

This table details the quantitative Doppler parameter (Resistive Index) measured within detected lesions. The majority of participants (78.1%) had an RI value below 0.75, indicating a prevalence of lesions with low to moderate vascular resistance. Only one case showed a very high RI (>0.85).

Table 4: Distribution of Doppler Ultrasound Resistive Index (RI) Values

Resistive Index (RI) Range	**Frequency (n)**	**Percent (%)**
0.45 – 0.54	23	31.5
0.55 – 0.64	17	23.3
0.65 – 0.74	17	23.3
0.75 – 0.84	15	20.5
0.85	1	1.4

DISCUSSION

The primary objective of this study was to compare the findings of hepatocellular carcinoma vascularity using two fundamental imaging modalities—Triphasic CT and Doppler Ultrasound—in an adult cohort. The results reveal significant insights into their diagnostic performance, concordance, and distinct roles, particularly in a setting where lesions exhibited a wide spectrum of sizes and vascular patterns.

Our findings indicate that Doppler USG demonstrated a higher detection rate for focal liver lesions (52.1%) compared to Triphasic CT (43.8%). This appears counterintuitive, given CT's established role as a comprehensive staging tool and its high sensitivity as reported in literature (Marrero et al., 2018). However, this discrepancy can be explained by the study's design and the nature of Doppler ultrasound. USG is highly operator-dependent and excels at detecting soft-tissue interfaces and blood flow in real-time, potentially allowing it to identify subtle perfusion changes or smaller lesions that may not meet the strict enhancement criteria for detection on CT. This finding aligns partially with studies by Strobel et al. (2019), which emphasize the high sensitivity of Contrast-Enhanced Ultrasound (CEUS) for detecting lesion vascularity, especially in lesions <2 cm where CT arterial phase timing is critical. Conversely, the higher proportion of "Not Visualized" lesions on CT (34.2% vs. 26.0% on USG) suggests that in a cohort not exclusively

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comprised of typical HCCs, CT may fail to characterize lesions that lack the classic hypervascular profile, a known limitation in early or well-differentiated HCC and in certain non-HCC malignancies (Forner et al., 2018).

The comparative analysis of vascularity patterns uncovers a critical diagnostic divergence. On CT, the most frequent finding was a "Not Visualized" pattern, followed by isoenhancement. The hallmark "Hypervascular" pattern was present in only 19.2% of cases. In stark contrast, on Doppler USG, "Isoenhancing" was the most common pattern (28.8%), with a notable prevalence of "Hypovascular" lesions (27.4%). This disparity underscores a fundamental difference in imaging technology and contrast dynamics. CT relies on the extracellular distribution of iodinated contrast, highlighting the architectural arterial supply. The lower hypervascular yield may reflect a study population with advanced liver disease and complex backgrounds where classic HCC features are diluted by dysplastic nodules or other pathologies, a phenomenon documented in cirrhotic livers (Chernyak et al., 2018). Doppler US, especially when utilizing microbubble contrast, assesses blood pool agents within vessels, which can be more sensitive to low-velocity flow and may categorize lesions differently based on intravascular kinetics rather than interstitial enhancement, potentially explaining the higher rate of isoenhancing lesions (Strobel et al., 2019). Our results contrast with the LI-RADS criteria, where arterial hyperenhancement is the pivotal feature, suggesting our cohort may have included many non-HCC lesions or HCCs with atypical imaging. Furthermore, the high prevalence of major vascular involvement—Portal Vein (53.4%) and Hepatic Vein (56.2%)—paints a picture of a cohort with advanced disease. This high rate likely influenced the vascularity findings, as large or invasive tumors often exhibit heterogeneous or atypical enhancement due to necrosis, shunting, or thrombosis. The Doppler Resistive Index (RI) distribution, with the majority (78.1%) of values below 0.75, supports this. While malignant lesions often exhibit high resistance (RI > 0.75) due to increased vascular stiffness, the prevalence of lower RI values in this study may indicate a mix of highly vascularized tumors with arteriovenous shunting (lowering RI) or the inclusion of non-malignant hypervascular lesions common in cirrhosis, such as regenerative or dysplastic nodules (Gorg et al., 2017). This finding partially contrasts with previous studies that associate higher RI (>0.75) with malignancy, highlighting the complexity of hemodynamics in a heterogeneous liver parenchyma.

In conclusion, this study demonstrates that Triphasic CT and Doppler USG offer complementary, not interchangeable, assessments of liver lesion vascularity. The higher detection rate of Doppler USG, coupled with its different categorization of vascular patterns, suggests it holds significant value as an initial, accessible tool for lesion detection and hemodynamic assessment, particularly in resource-limited settings. However, its operator dependence and the atypical findings in this cohort relative to classic HCC literature call for careful interpretation. Conversely, while CT identified fewer lesions as hypervascular, its standardized protocol and ability to stage extrahepatic disease remain irreplaceable (Kloeckner et al., 2020). The high rate of vascular invasion and the spectrum of non-hypervascular lesions highlight the diagnostic challenge in cirrhotic livers. Therefore, an integrated imaging approach, considering patient-specific risk factors and clinical context, is paramount. Future studies with histopathological correlation are essential to determine which modality's vascular pattern classification more accurately predicts final HCC diagnosis in such diverse populations.

Conclusion

This study concludes that while Doppler Ultrasound demonstrated a higher lesion detection rate, both it and Triphasic CT identified the classic hypervascular HCC pattern in a minority of cases within this cohort, indicating a high prevalence of atypical lesions. The significant discrepancy in characterized vascularity patterns underscores that the two modalities provide complementary, non-

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interchangeable hemodynamic information. Their integrated use, rather than reliance on a single test, is essential for accurate assessment, especially in patients with advanced liver disease where diagnostic features are often non-classical.

LIMITATIONS

- The use of a single-center, convenience sampling method limits the generalizability of the findings to broader populations.
- The study lacked histopathological confirmation, preventing definitive correlation between imaging findings and final HCC diagnosis.
- The absence of Contrast-Enhanced Ultrasound (CEUS) for the Doppler assessment restricted a direct comparison with the contrast-enhanced CT protocol.

RECOMMENDATIONS

- Future multi-center studies with larger, randomly selected cohorts are recommended to validate these comparative findings.
- Further research should incorporate biopsy correlation to determine which modality's vascular pattern most accurately predicts histopathology.
- A direct comparative study between Triphasic CT and standardized Contrast-Enhanced Ultrasound (CEUS) should be conducted for a more definitive assessment of vascularity.

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