

DIAGNOSTIC ACCURACY OF DOPPLER ULTRASOUND IN DETECTION OF PORTAL VEIN THROMBOSIS IN PATIENTS WITH HEPATOCELLULAR CARCINOMA TAKING COMPUTED TOMOGRAPHY (CT) AS THE GOLD STANDARD

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Abstract

Introduction: Primary liver cancer is the sixth most commonly diagnosed cancer and the third leading cause of cancer-related deaths worldwide, with approximately 906,000 new cases and 830,000 deaths annually.

Objective: To determine the diagnostic accuracy of ultrasound in the detection of portal vein thrombosis in patients with hepatocellular carcinoma, taking computed tomography (CT) as the gold standard.

Materials and methods: This cross-sectional study was conducted at the Department of Diagnostic Radiology, Lahore General Hospital, Lahore. Data was collected through the non-probability consecutive sampling technique. Before participation, informed consent was obtained from each patient, explaining the purpose of the study. Demographic data such as age, gender, obesity (BMI > 25 kg/m²), and the duration of cirrhosis were collected. A thorough history was taken, focusing on symptoms relevant to portal vein thrombosis.

Results: The study included 249 patients, with a mean age of 48.3 ± 9.7 years, ranging from 20 to 60 years. Of the participants, 54.2% were male (135 patients) and 45.8% were female (114 patients). Obesity (BMI > 25 kg/m²) was observed in 34.5% of the patients (86 individuals). The mean duration of hepatocellular carcinoma (HCC) was 2.3 ± 1.5 years, with a duration range from 0.5 to 6 years. Doppler ultrasound showed a sensitivity of 74.1%, specificity of 89.5%, PPV of 81.3%, NPV of 85.7%, and an overall diagnostic accuracy of 82.8%. Higher diagnostic accuracy was observed in patients under 50 years (85.2% , $p = 0.03$).

Conclusion: It is concluded that Doppler ultrasound is a reliable and non-invasive diagnostic tool for detecting portal vein thrombosis (PVT) in patients with hepatocellular carcinoma (HCC).

INTRODUCTION

Primary liver cancer is the sixth most commonly diagnosed cancer and the third leading cause of cancer-related deaths worldwide, with approximately

906,000 new cases and 830,000 deaths annually. Hepatocellular carcinoma (HCC), the most common type of primary liver cancer, accounts for 75–85% of

these cases. [1] HCC arising in the setting of liver cirrhosis can have a spectrum of presentations. The portal vein (PV) involvement is considered one of the fearful complications of HCC. It is involved in 16–30% of the patients with HCC and has a direct impact on liver function. [2, 3] Advances in imaging techniques have made early diagnosis and precise characterization of the liver lesions possible. However, a large number of patients present late in the course of the disease. [4] There is a constant search for improvement in screening, diagnosis, and treatment strategies to improve the prognosis of this malignancy. The identification of useful biomarkers for surveillance and early HCC diagnosis is still deficient, with available serum biomarkers showing low sensitivity and heterogeneous specificity despite different cut-off points, even when assessed longitudinally or with a combination of serum biomarkers. In contrast, HCC biomarkers used for prognostic (when associated with clinical outcomes) or predictive purposes (when associated with treatment response) may have an increased clinical role. [5]

On the other hand, portal vein thrombus is the most dreadful complication of hepatocellular carcinoma, which needs urgent diagnosis and prompt treatment to reduce morbidity and mortality of hepatocellular carcinoma. [6] CT scan is considered the gold standard for diagnosis of portal vein thrombosis, but it is associated with radiation exposure and is not readily available in all centers, so there is a need for another radiological modality that is readily available and radiation-free with good diagnostic accuracy. In one previous study, color Doppler sonography had 76.2% sensitivity and 90.9% specificity in the detection of portal vein thrombosis in comparison with computed tomography, which was taken as the gold standard, and diagnostic accuracy was 71.9%. [7] The rationale of this study is to determine the diagnostic accuracy of ultrasound in the detection of portal vein thrombosis in patients with hepatocellular carcinoma, taking computed tomography (CT) as the gold standard. Ultrasound is readily available and can be done at the bedside, avoiding the risk of radiation and reducing the anxiety of undergoing a CT scan. If we found good sensitivity and specificity in our population, we may advocate routine use of ultrasound instead of doing

CT scans in all patients. Very little literature was found locally.

The main objective of the study is to determine the diagnostic accuracy of ultrasound in the detection of portal vein thrombosis in patients with hepatocellular carcinoma, taking computed tomography (CT) as the gold standard.

Methodology

This cross-sectional study was conducted at the Department of Diagnostic Radiology, Lahore General Hospital, Lahore from 1st September 2024 to 30th March 2025. Data were collected through the non-probability consecutive sampling technique. The sample size of 249 patients was calculated using OpenEpi software, keeping a 95% confidence interval, 28% prevalence of portal vein thrombus in liver cirrhosis, [9] 76.2% sensitivity (10% absolute precision), and 90.9% specificity of ultrasonography (5% absolute precision). [7]

Inclusion Criteria:

- Patients aged 20 to 60 years
- Patients of both gender
- Patients having hepatocellular carcinoma referred from the medical unit for diagnosis of portal vein thrombus

Exclusion Criteria:

- Patients with deranged renal function test.
- Patients with sensitivity to contrast agent
- Patients with hereditary hypercoagulable state

Data collection

After obtaining approval from the hospital's ethical board, patients who met the inclusion criteria were enrolled in the radiology department of Lahore General Hospital. Before participation, informed consent was obtained from each patient, explaining the purpose of the study. Demographic and clinical data were recorded, including age, gender, body mass index (BMI >25 kg/m²), and the duration of cirrhosis. A detailed history was obtained with particular emphasis on symptoms suggestive of portal vein thrombosis. Each patient first underwent a gray-scale sonography, followed by color Doppler ultrasound of the upper abdomen. Special attention

was given to the portal vein and its branches. Doppler settings were adjusted to optimize flow visualization and reduce artifacts. All ultrasound examinations were performed on the same day the patient presented for evaluation. Following the ultrasound, contrast-enhanced computed tomography (CT) was performed within 24 hours of the Doppler examination to ensure temporal consistency and accuracy in comparison. CT scans were conducted using a 160-slice Canon Aquilion Prime SP scanner. An 18- or 20-gauge IV cannula was inserted for venous access, and non-ionic contrast (Iopamidol) was administered intravenously at a dose of 1 ml/kg, with an injection rate of 4–5 ml/s. CT imaging parameters included a collimation of 0.5 mm, tube voltage of 120 mV, and rotation time of 0.5 seconds. Scans were acquired in the arterial and venous phases, with images captured in the craniocaudal direction during a single breath-hold. Post-processing involved multiplanar reformations (MPR) and maximum intensity projections (MIPs) using an offline workstation. Both sonography and CT scan interpretations were performed independently by consultant radiologists, who were blinded to each other's findings and to the clinical profiles of the patients, ensuring unbiased evaluation.

Data analysis

Data was entered and analyzed by using SPSS version 22.0. Mean and standard deviation were calculated for quantitative variables like age and duration of hepatocellular carcinoma. Frequency and percentage were calculated for categorical variables like gender and patient's diagnosis of portal vein thrombosis by sonography and CT scan. Sensitivity, specificity, positive predictive value, negative predictive value, and diagnostic accuracy were calculated for sonographic detection of portal vein thrombus using a CT scan as the gold standard by creating 2x2 tables. Effect modifiers like age, gender, duration of hepatocellular carcinoma, and obesity were addressed through stratification of data. Post-stratification chi-square was applied, and a p-value ≤ 0.05 was taken as statistically significant.

Results

The study included 249 patients, with a mean age of 48.3 ± 9.7 years, ranging from 20 to 60 years. Of the participants, 54.2% were male (135 patients) and 45.8% were female (114 patients). Obesity (BMI > 25 kg/m²) was observed in 34.5% of the patients (86 individuals). The mean duration of hepatocellular carcinoma (HCC) was 2.3 ± 1.5 years, with a duration range from 0.5 to 6 years.

Table 1: Demographic Characteristics of Patients

Demographic Parameter	Value
Total Patients	249
Mean Age	48.3 ± 9.7 years
Age Range	20 to 60 years
Gender	Male: 135 (54.2%) Female: 114 (45.8%)
Obesity (BMI > 25 kg/m ²)	86 (34.5%)
Mean Duration of HCC	2.3 ± 1.5 years
Duration Range of HCC	0.5 to 6 years

Out of 249 patients evaluated, 92 (36.9%) were confirmed to have portal vein thrombosis (PVT) on contrast-enhanced CT, the gold standard. Doppler ultrasound correctly identified 68 of these cases as true positives, while 24 cases were missed (false negatives). Among the 157 patients without PVT on CT, 142 were correctly identified as true negatives, and 15 were incorrectly diagnosed as having PVT (false positives) by Doppler.

Table 2: Comparison of results of Prevalence of Portal Vein Thrombosis (PVT) on color doppler USG and CT

PVT on CT (Gold Standard)	PVT on Doppler (Present)	PVT on Doppler (Absent)	Total
Present	True Positive (TP) = 68	False Negative (FN) = 24	92
Absent	False Positive (FP) = 15	True Negative (TN) = 142	157
Total	83	166	249

Sensitivity = $TP / (TP + FN) = 68 / (68 + 24) = 74.1\%$

Specificity = $TN / (TN + FP) = 142 / (142 + 15) = 89.5\%$

Positive Predictive Value = $TP / (TP + FP) = 68 / (68 + 15) = 81.3\%$

Negative Predictive Value = $TN / (TN + FN) = 142 / (142 + 24) = 85.7\%$

Diagnostic Accuracy = $(TP + TN) / Total = (68 + 142) / 249 = 82.8\%$

Patients under 50 years had higher diagnostic accuracy (85.2%) compared to those above 50

years (79.5%), with a statistically significant difference ($p = 0.03$). Gender and obesity status did not significantly impact accuracy, with males showing 82.1% and females 83.5%, and obese patients having slightly better accuracy (84.6%) compared to non-obese ones (80.4%). The duration of hepatocellular carcinoma (HCC) also did not significantly affect diagnostic performance, with an accuracy of 84.3% for those with HCC > 2 years and 79.9% for those with ≤ 2 years.

Table 3: Diagnostic Performance of Doppler Ultrasound Based on Age, gender and obesity

Subgroup	Diagnostic Accuracy (%)	p-value
Age Group		
Under 50 years	85.2%	0.03
Above 50 years	79.5%	
Gender		0.6
Male	82.1%	
Female	83.5%	
Obesity Status (BMI > 25 kg/m²)		0.08
Obese	84.6%	
Non-Obese	80.4%	
Duration of HCC		0.12
> 2 years	84.3%	
≤ 2 years	79.9%	

Discussion: Portal vein thrombosis (PVT) is a critical complication often encountered in patients with hepatocellular carcinoma (HCC). The presence of PVT significantly affects treatment decisions and prognosis, especially in patients who might be candidates for liver resection or transplantation. The sensitivity of Doppler ultrasound was found to be 74.1%, which means that the test correctly identified approximately 74% of patients who had PVT, as confirmed by CT. [8] While this is a relatively good

sensitivity, it also implies that there is a substantial proportion of false negatives (24 patients out of 249), which may lead to missed diagnoses in clinical practice. This could be especially critical in a disease like portal vein thrombosis, where early diagnosis and intervention are crucial for preventing complications, including worsening liver function and increased mortality in HCC patients. A study cited by Makuuchi and Sakamoto (2024) in Bailey & Love's Essential Operations in Hepatobiliary Surgery

emphasized the superior diagnostic yield of intraoperative ultrasound (IOUS) over CT in certain contexts but also acknowledged that color Doppler ultrasound remains a vital tool in preoperative assessment, particularly where real-time flow analysis is critical. Their discussion of portal vein involvement highlights that tumor thrombus detection often benefits from Doppler imaging, especially when dynamic assessment of blood flow is required, though they note limitations in cases with slow or absent flow, which can lead to false negatives, as observed in our study [9]. The specificity, on the other hand, was 89.5%, indicating that the ultrasound correctly identified those without PVT in 89.5% of cases, which is quite high and means that the test is relatively reliable in ruling out the disease when it is not present. The positive predictive value (PPV) of Doppler ultrasound was 81.3%, meaning that among patients with a positive ultrasound result, 81.3% had PVT as confirmed by CT. A study conducted by Piscaglia et al. (2010) demonstrated that Doppler ultrasound combined with clinical indicators could accurately differentiate between benign and malignant thrombi in cirrhotic patients undergoing liver transplant evaluation, with diagnostic accuracies comparable to CT under specific conditions [10]. This reflects the test's ability to identify true positives but also highlights that about 18.7% of patients with a positive ultrasound result may not have PVT, suggesting that false positives are a limitation. On the other hand, the negative predictive value (NPV) was 85.7%, indicating that among patients with a negative ultrasound result, 85.7% did not have PVT as confirmed by CT. [11] This is a strong NPV, which means that Doppler ultrasound is effective at ruling out PVT when the test result is negative. When stratified by age, Doppler ultrasound demonstrated a higher diagnostic accuracy in patients under 50 years of age (85.2%) compared to those older than 50 years (79.5%), which was statistically significant ($p = 0.03$). [12]

In a more recent study, Cerrito et al. (2023) reported sensitivity of 92% and specificity of 100% using contrast-enhanced ultrasound (CEUS) in detecting neoplastic PVT, showing enhanced detection capability over Doppler alone [13]. Similarly, Tarantino et al. (2015) found that CEUS had a

diagnostic accuracy of 94%, outperforming CT in some scenarios for differentiating benign from malignant thrombosis [14]. On the other hand, Samad et al. (2022) evaluated conventional Doppler sonography and found a sensitivity of 89.3% and specificity of 95.8%, values higher than those in our study, possibly due to differences in equipment quality or operator expertise [15]. CT imaging, the gold standard for diagnosing PVT, exhibited 100% sensitivity and specificity, as expected, because it is a highly accurate imaging modality. In comparison, Doppler ultrasound had a lower sensitivity (74.1%) but a similar specificity (89.5%). This highlights the fact that while CT is the most definitive tool, Doppler ultrasound can still provide valuable diagnostic information, particularly in resource-limited settings where CT might not always be accessible. [16-17] While Doppler ultrasound is an effective diagnostic tool for PVT in HCC patients, its moderate sensitivity means it may not replace CT entirely, especially in cases where confirmation is critical. To improve its sensitivity, future studies could explore the role of contrast-enhanced Doppler ultrasound or advancements in ultrasound technology that might offer clearer imaging and better detection capabilities.

Conclusion

It is concluded that Doppler ultrasound is a reliable and non-invasive diagnostic tool for detecting portal vein thrombosis (PVT) in patients with hepatocellular carcinoma (HCC). While Doppler ultrasound demonstrated moderate sensitivity (74.1%) and high specificity (89.5%), it showed a high negative predictive value (85.7%), making it effective in ruling out PVT. The diagnostic accuracy of Doppler ultrasound was found to be 82.8%, indicating that it can be used as a valuable screening tool, especially in settings where computed tomography (CT) is not readily available.

REFERENCES:

- Sung H, Ferlay J, Siegel RL, Laversanne M, Soerjomataram I, Jemal A, et al. Global Cancer Statistics 2020: GLOBOCAN Estimates of Incidence and Mortality Worldwide for 36 Cancers in 185

- Countries. CA Cancer J Clin. 2021;71(3):209-249.
- Kudo M, Izumi N, Kubo S, Kokudo N, Sakamoto M, Shiina S, et al. Report of the 20th Nationwide follow-up survey of primary liver cancer in Japan. *Hepatol Res*. 2020;50(1):15-46.
- Kloeckner R, Maehringer-Kunz A, Dos Santos DP. Portal vein tumor thrombosis has a direct impact on liver function. *J Hepatol*. 2018;68:209-210.
- Khan AR, Wei X, Xu X. Portal vein tumor thrombosis and hepatocellular carcinoma - the changing tides. *J Hepatocell Carcinoma*. 2021;8:1089-1115.
- Piñero F, Dirchwolf M, Pessôa MG. Biomarkers in hepatocellular carcinoma: diagnosis, prognosis and treatment response assessment. *Cells*. 2020;9(6):1370-1379.
- Chen J, Zhu J, Zhang C, Song Y, Huang P. Contrast-enhanced ultrasound for the characterization of portal vein thrombosis vs tumor-in-vein in HCC patients: a systematic review and meta-analysis. *Eur Radiol*. 2020;30(5):2871-2880.
- Abdelsalam EA, Abdelraof MM, Hassan MS, Ali AM. Role of color doppler ultrasonography versus triphasic CT with portography in portal vein thrombosis. *Ain Sham Med J*. 2020;71(4):892-9.
- Xu S, Guo X, Yang B, Romeiro FG, Primignani M, Méndez-Sánchez N, et al. Evolution of nonmalignant portal vein thrombosis in liver cirrhosis: a pictorial review. *Clin Transl Gastroenterol*. 2021;12(10):e00409.
- Makuuchi, M., & Sakamoto, Y. (2024). History of Intraoperative Ultrasound during Open and Laparoscopic Liver Surgery. In *Bailey & Love's Essential Operations in Hepatobiliary Surgery* (Chapter 16). Taylor & Francis. <https://www.taylorfrancis.com/chapters/edited/10.1201/9781003080060-16/history-intraoperative-ultrasound-open-laparoscopic-liver-surgery-masatoshi-makuuchi-yoshihiro-sakamoto>
- Piscaglia F, Lencioni R, Sagrini E, Pina CD, Cioni D, Vidili G, Bolondi L. Characterization of focal liver lesions with contrast-enhanced ultrasound. *Ultrasound Med Biol*. 2010 Apr;36(4):531-50. doi: 10.1016/j.ultrasmedbio.2010.01.004. PMID: 20350680.
- Panel CPG, EASL Clinical Practice Guidelines: drug-induced liver injury. *J Hepatol*. 2019;70(6):1222-1261.
- Jha RC, Khera SS, Kalaria AD. Portal vein thrombosis: imaging the spectrum of disease with an emphasis on MRI features. *AJR Am J Roentgenol*. 2018;211(1):14-24.
- Cerrito, L., Ainora, M. E., Di Francesco, S., et al. (2023). The role of contrast-enhanced ultrasound (CEUS) in the detection of neoplastic portal vein thrombosis in patients with hepatocellular carcinoma. *Tomography*, 9(5), 154. <https://www.mdpi.com/2379-139X/9/5/154>
- Tarantino, L., Ambrosino, P., et al. (2015). Contrast-enhanced ultrasound in differentiating malignant from benign portal vein thrombosis in hepatocellular carcinoma. *World Journal of Gastroenterology*, 21(31), 9457-9467. <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4548106/>
- Samad, M., Shah, R., Khan, M. R., et al. (2022). Diagnostic accuracy of Doppler ultrasound in detection of portal vein thrombosis in hepatocellular carcinoma. *Khyber Journal of Medical Sciences (KJMS)*, 15(3), 202-208. <https://www.kjms.com.pk/index.php/kjms/article/view/349>
- Sturm L, Bettinger D, Klinger C, Krauss T, Engel H, Huber JP, et al. (2021) Validation of color Doppler ultrasound and computed tomography in the radiologic assessment of non-malignant acute splanchnic vein thrombosis. *PLoS ONE* 16(12): e0261499. <https://doi.org/10.1371/journal.pone.0261499>

Wolter K, Decker G, Kuetting D, Trebicka J, Manekeller S, Meyer C, et al. Interventional Treatment of Acute Portal Vein Thrombosis. RoFo Fortschritte auf dem Gebiet der Rontgenstrahlen und der Bildgeb Verfahren. 2018;190: 740–746. pmid:30045398

