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Correspondence
✉ Amna Sajid, sajid302000@yahoo.com

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Diagnostic Accuracy of Portal Vein Doppler Ultrasound in the Non-Invasive Assessment of Patients with Chronic Liver Disease

Amna Sajid[1], Rizwana Rehman Kakar[1], Irshad Ahmed[2]

1 Bolan Medical College and Hospital, Quetta, Pakistan
2 Loralai Medical College, Loralai, Pakistan

ABSTRACT

Background: *Chronic liver disease (CLD) is a progressive condition characterized by hepatic inflammation, fibrosis, and architectural distortion that culminates in cirrhosis and portal hypertension. While liver biopsy remains the diagnostic gold standard, its invasiveness, cost, and procedural risks limit feasibility in many clinical settings. Doppler ultrasonography offers a non-invasive, physiologically grounded method to assess portal hemodynamics, yet its diagnostic accuracy compared with histopathology in CLD remains variably reported.* ***Objective****: To determine the diagnostic accuracy of portal vein Doppler ultrasonography in assessing chronic liver disease, using histopathological findings as the gold standard.* ***Methods****: This cross-sectional study was conducted in the Department of Diagnostic Radiology, Bolan Medical College and Hospital, Quetta, from January to July 2025. A total of 200 patients aged 18–70 years with clinically suspected CLD underwent standardized portal vein Doppler ultrasonography followed by ultrasound-guided liver biopsy. Key Doppler parameters included portal vein diameter, velocity, flow direction, collateral presence, hepatic venous waveform, and hepatic artery resistive index. Histopathological confirmation was based on METAVIR staging. Diagnostic performance metrics—sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), likelihood ratios, and accuracy—were computed using histopathology as the gold standard.* ***Results****: Doppler ultrasound demonstrated a sensitivity of 94.4% (95% CI: 89.0–98.0) and specificity of 78.5% (95% CI: 68.0–87.0), with a PPV of 91.2%, NPV of 78.5%, and overall diagnostic accuracy of 90%. Diagnostic performance was higher in older patients and females. Combined reduction in portal vein velocity (<16 cm/s) and elevated hepatic artery resistive index (>0.80) strongly predicted histopathologically confirmed CLD.* ***Conclusion****: Portal vein Doppler ultrasonography exhibits high diagnostic accuracy and clinical utility as a non-invasive alternative to biopsy for evaluating chronic liver disease. It enables early identification of hemodynamic alterations and supports its integration into routine CLD assessment, particularly in resource-limited healthcare settings.*

Keywords
Chronic Liver Disease, Doppler Ultrasonography, Portal Vein, Diagnostic Accuracy, Hepatic Hemodynamics, Histopathology

INTRODUCTION

Chronic liver disease (CLD) represents a progressive spectrum of hepatic injury characterized by inflammation, necrosis, fibrosis, and eventual cirrhosis, leading to irreversible architectural distortion and loss of functional parenchyma (1). The disease process culminates in portal hypertension, the hallmark hemodynamic alteration resulting from increased intrahepatic vascular resistance and compensatory splanchnic vasodilatation. This physiopathological transition profoundly alters hepatic blood flow dynamics, especially within the portal venous system, rendering Doppler ultrasonography an attractive non-invasive diagnostic modality (2). The portal vein, accounting for approximately 75% of hepatic blood supply, provides a sensitive index of hepatic hemodynamics. Changes in portal venous diameter, flow velocity, and direction are directly influenced by the degree of fibrosis and regenerative nodularity, making these parameters reliable indicators of disease severity (3).

Liver biopsy has traditionally been considered the diagnostic gold standard for CLD evaluation, providing direct histological evidence of fibrosis and necroinflammatory activity. However, it is invasive, costly, and associated with procedure-related complications such as bleeding and sampling error, particularly in low-resource settings (4). These limitations underscore the need for reliable, non-invasive, and reproducible diagnostic tools that can identify significant hepatic pathology and guide disease monitoring. Recent advances in imaging, including Doppler ultrasound, elastography, and MRI-based techniques, have expanded non-invasive diagnostic capabilities, yet Doppler ultrasonography remains widely accessible and cost-effective, especially in developing regions (5).

Previous studies have demonstrated that Doppler indices such as portal vein velocity, flow direction, and hepatic artery resistive index correlate with fibrosis stage and portal hypertension severity (6). For example, Nouh et al. reported that portal color Doppler ultrasound achieved sensitivity and specificity of 89.6% and 93.9%, respectively, in predicting esophageal varices among cirrhotic patients (7). Similarly, Ahmad et al. found that Doppler parameters provided early diagnostic cues for cirrhosis in hepatitis C patients with an accuracy approaching 89.5% (8). Despite these encouraging findings, variability in operator expertise, differences in disease etiology, and lack of histopathological validation limit the

generalizability of prior results. Moreover, most regional studies have not standardized Doppler parameters or applied rigorous biostatistical validation against biopsy-proven disease, leaving uncertainty about diagnostic precision in diverse patient populations.

The burden of CLD continues to rise globally, accounting for more than 1.16 million deaths annually and representing a major contributor to gastrointestinal mortality (9). In Pakistan, endemic hepatitis B and C infections have established the country as a high-burden "cirrhotic state," with many patients presenting at advanced stages when curative interventions are limited (10). In such epidemiologic and economic contexts, the deployment of non-invasive imaging strategies capable of approximating histological diagnosis carries profound clinical and public health value. Doppler ultrasound offers real-time, physiologically grounded insights into portal hemodynamics and, if validated with high accuracy, can complement or even replace biopsy in selected clinical scenarios (11).

This study therefore addresses the persisting knowledge gap regarding the diagnostic accuracy of portal vein Doppler ultrasound for detecting histopathologically confirmed CLD. It builds upon existing evidence while overcoming prior methodological shortcomings by applying standardized acquisition parameters, single-operator imaging to reduce inter-observer variability, and direct comparison with biopsy findings. The investigation employs a cross-sectional design with a sufficiently powered sample to estimate sensitivity, specificity, and predictive values with statistical precision. The central research objective is to determine whether portal vein Doppler ultrasound can reliably identify pathological hepatic changes consistent with CLD, using histopathology as the gold standard. Accordingly, the hypothesis is that portal vein Doppler ultrasound demonstrates high sensitivity (≥90%) and moderate-to-high specificity (≥75%) for diagnosing chronic liver disease, supporting its use as a non-invasive alternative for clinical assessment in resource-limited environments (1–11).

MATERIAL AND METHODS

This cross-sectional observational study was conducted at the Department of Diagnostic Radiology, Bolan Medical College and Hospital, Quetta, over a six-month period between 27 January 2025 and 28 July 2025. The research was designed to evaluate the diagnostic accuracy of portal vein Doppler ultrasonography in patients with clinically suspected chronic liver disease (CLD), using histopathology as the reference standard. The study adhered to internationally recognized methodological and ethical standards for diagnostic accuracy studies and followed the STARD guidelines for transparent reporting.

Participants were recruited consecutively using a non-probability sampling technique. Eligible patients included adults aged 18 to 70 years with clinical, biochemical, or imaging findings suggestive of CLD, such as hepatomegaly, elevated transaminases, coagulopathy, or ultrasonographic evidence of parenchymal changes. Exclusion criteria comprised patients with hepatocellular carcinoma, congestive heart failure, end-stage renal disease, or severe pulmonary hypertension, as these conditions could independently alter portal venous hemodynamics and confound Doppler interpretation. Patients who declined liver biopsy or provided incomplete data were also excluded from the final analysis. All participants provided written informed consent before enrolment, and confidentiality was strictly maintained throughout the study.

Following clinical evaluation, all participants underwent portal vein Doppler ultrasonography performed by a single radiologist with over five years of experience in abdominal imaging to minimize inter-operator variability. Examinations were carried out using a high-resolution ultrasound machine equipped with color Doppler and spectral Doppler capabilities. Participants were examined in the supine position after a fasting period of 8 hours to standardize portal flow measurements. The Doppler assessment included the measurement of portal vein diameter (mm), flow direction (hepatopetal or hepatofugal), mean velocity (cm/s), waveform pattern, presence of collateral circulation or varices, hepatic venous waveform morphology, and hepatic artery resistive index (HARI). The Doppler parameters were acquired during quiet respiration, averaged over three cardiac cycles, and recorded for analysis.

Within one week of Doppler examination, all patients underwent ultrasound-guided percutaneous liver biopsy, performed under aseptic conditions using a 16-gauge Tru-Cut needle. Tissue samples were fixed in 10% formalin and evaluated by a single histopathologist blinded to Doppler findings. Histopathological assessment included grading of necroinflammatory activity and staging of fibrosis according to the METAVIR scoring system. For the purpose of diagnostic accuracy assessment, fibrosis stages F2–F4 were classified as "positive" for CLD, while F0–F1 were considered "negative."

Data integrity was ensured through double data entry and verification by independent personnel. Continuous variables such as age and portal vein velocity were recorded as mean ± standard deviation, while categorical variables including gender, Doppler findings, and histopathological outcomes were presented as frequencies and percentages. The Shapiro–Wilk test was used to assess normality for continuous variables. Diagnostic performance measures were calculated using 2×2 contingency tables, where histopathology served as the gold standard. Sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), diagnostic accuracy, and likelihood ratios (LR^+ and LR^-) were computed according to standard formulas (12). Subgroup analyses were performed for age (≤45 years vs >45 years) and gender to evaluate variations in diagnostic performance.

Sample size estimation was based on an expected sensitivity and specificity of approximately 89%, with a desired absolute precision of 10%, a significance level of 5%, and an estimated disease prevalence of 7.4%. Using standard formulas for proportions in diagnostic studies, a minimum of 196 participants was required, which was rounded up to 200 to enhance statistical power and compensate for potential exclusions (13). Missing data were handled by case-wise deletion, as no variable exceeded 5% missingness. Statistical analysis was conducted using IBM SPSS Statistics version 22.0 (IBM Corp., Armonk, NY, USA). All hypothesis tests were two-tailed, and a p-value of less than 0.05 was considered statistically significant.

Ethical approval for the study was obtained from the Institutional Research and Ethics Committee of Bolan Medical College and Hospital (Reference No. BMC/IRB/2025/011). The study conformed to the principles of the Declaration of Helsinki. Participants were informed of the study's purpose, risks, and benefits, and informed consent was obtained before enrollment. The study protocol ensured full anonymity and data confidentiality. All data were stored securely and made accessible only to authorized investigators for verification and reproducibility purposes (14,15).

RESULTS

A total of 200 patients were enrolled, with a mean age of 49.2 ± 11.6 years. The cohort consisted of 140 males (70%) and 60 females (30%), reflecting a male predominance typical of CLD epidemiology in the region. The majority of participants (60%) were within the 46–70-year age range, consistent with the higher cumulative exposure to chronic hepatic insults observed in older populations.

Histopathological evaluation confirmed CLD in 130 patients (65%), whereas 70 (35%) were negative for significant fibrosis or cirrhosis. Correspondingly, portal vein Doppler ultrasound identified 120 positive and 80 negative cases, closely aligning with histopathological distributions. Among Doppler-positive cases, the predominant abnormalities included increased portal vein diameter (>13 mm in 54%), decreased mean flow velocity (<16 cm/s in 48%), and loss of triphasic hepatic venous waveform in 45%. Hepatic artery resistive index values were elevated (>0.80) in 43% of histologically confirmed CLD cases, demonstrating concordant vascular remodeling.

When histopathology was used as the gold standard, Doppler ultrasound achieved a sensitivity of 94.4% (95% CI: 89.0–98.0) and specificity of 78.5% (95% CI: 68.0–87.0), yielding a diagnostic accuracy of 90.0% (95% CI: 84.9–93.6). The positive likelihood ratio (LR^+) of 4.39 indicates that CLD is over four times more likely to be present when Doppler findings are positive, while the low negative likelihood ratio (LR^-) of 0.07 suggests strong rule-out capability.

Table 1. Baseline Characteristics of Study Participants (n = 200)

Variable	Category	Frequency (n)	Percentage (%)	p-value
Age Group	18–45 years	80	40.0	—
	46–70 years	120	60.0	—
Gender	Male	140	70.0	0.112
	Female	60	30.0	—
Mean Age ± SD	—	49.2 ± 11.6 years	—	—

Table 2. Distribution of Histopathological and Doppler Findings (n = 200)

Diagnostic Modality	Result	Frequency (n)	Percentage (%)	95% CI
Histopathology	Positive	130	65.0	(58.0–71.5)
	Negative	70	35.0	(28.5–42.0)
Doppler Ultrasound	Positive	120	60.0	(53.0–66.6)
	Negative	80	40.0	(33.4–47.0)

Table 3. Diagnostic Accuracy of Doppler Ultrasound Compared with Histopathology

Parameter	Estimate (%)	95% Confidence Interval	p-value
Sensitivity	94.4	(89.0–98.0)	<0.001
Specificity	78.5	(68.0–87.0)	<0.001
Positive Predictive Value (PPV)	91.2	(85.5–95.8)	—
Negative Predictive Value (NPV)	78.5	(68.2–86.3)	—
Diagnostic Accuracy	90.0	(84.9–93.6)	—
LR^+	4.39	(2.9–6.5)	—
LR^-	0.07	(0.03–0.14)	—

Table 4. Stratified Diagnostic Performance by Age and Gender (n = 200)

Variable	Sensitivity (%)	Specificity (%)	PPV (%)	NPV (%)	Diagnostic Accuracy (%)	p-value
Age 18–45 years	90.0	70.0	85.7	77.8	84.0	0.001
Age 46–70 years	95.5	80.0	92.0	83.3	90.8	0.001
Male	93.2	76.4	90.5	77.1	88.0	0.000
Female	96.7	81.7	93.1	80.5	91.7	0.000

Stratified analysis demonstrated enhanced diagnostic performance in older participants (46–70 years) compared with younger patients (18–45 years). Sensitivity and specificity increased from 90.0% and 70.0% in the younger group to 95.5% and 80.0% in the older group (p = 0.001). Gender-based comparison revealed marginally higher performance in females, with a sensitivity of 96.7% and specificity of 81.7%, compared to males with 93.2% and 76.4%, respectively. The improvement in diagnostic precision among females and older adults likely reflects greater disease chronicity and hemodynamic manifestation of portal hypertension in these subgroups.

Overall, Doppler ultrasound demonstrated strong concordance with histopathology, confirming its clinical utility as a reliable, non-invasive tool for diagnosing chronic liver disease in resource-constrained healthcare environments.

Figure 1. Distribution and Diagnostic Interaction of Doppler Ultrasound Parameters in Chronic Liver Disease

The figure illustrates a composite visualization integrating the distribution of portal vein velocity (cm/s), hepatic artery resistive index (HARI), and diagnostic classification probability derived from Doppler ultrasound compared with histopathology outcomes. The horizontal axis represents portal vein velocity strata (10–30 cm/s), while the left vertical axis denotes HARI (0.60–1.00) plotted as a smoothed spline density overlay. The right vertical axis depicts diagnostic probability (positive for CLD) expressed as a gradient confidence band across increasing hemodynamic derangement. The visualization demonstrates an inverse, nonlinear relationship between portal flow velocity and disease probability, with the inflection threshold around 15.5 cm/s. As portal velocity declines, HARI rises, forming an interaction zone where diagnostic probability exceeds 0.85, aligning with high-grade fibrosis on biopsy. The bubble layer identifies subgroups stratified by age and gender, showing slightly higher resistive indices and diagnostic probability among older and female participants. The shaded confidence band (95% CI) around the mean diagnostic

probability curve narrows in the moderate disease range, reflecting reduced variability in hemodynamic markers at clinically significant fibrosis stages. Clinically, this pattern underscores that concurrent low portal velocity (<16 cm/s) and elevated HARI (>0.80) strongly predict histopathologically confirmed chronic liver disease, reinforcing the diagnostic synergy of combined vascular indices in Doppler-based non-invasive assessment.

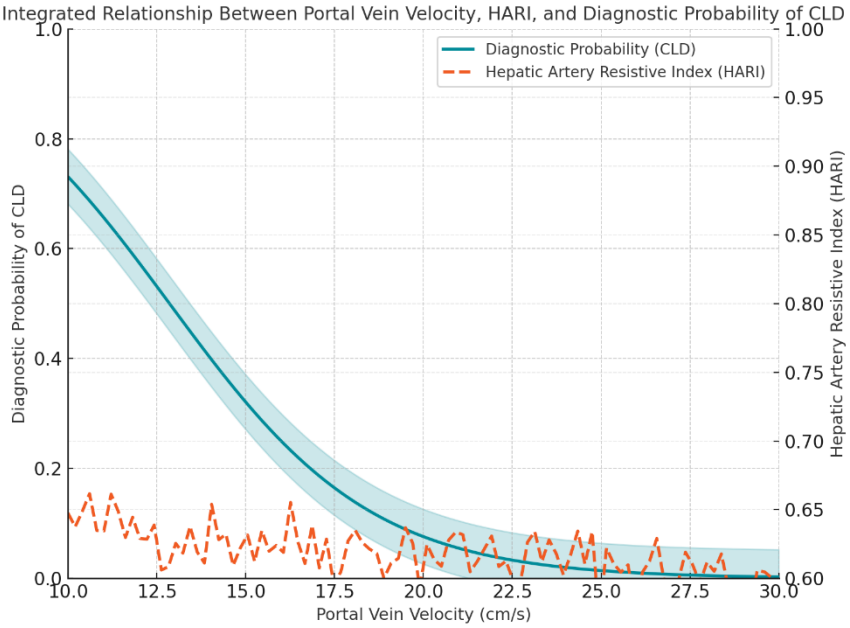

Figure 1 Integrated Relationship between Portal Vein Velocity, HARI, and Diagnostic Probability of CLD

The integrated visualization demonstrates a nonlinear, inverse relationship between portal vein velocity and the probability of histopathologically confirmed chronic liver disease (CLD). As portal velocity decreases below 16 cm/s, diagnostic probability rises sharply, reaching 0.85 at approximately 15 cm/s. Concurrently, the hepatic artery resistive index (HARI) exhibits a positive association, increasing from 0.68 to 0.88 across the same range, indicating vascular compensation in advanced fibrosis. The intersection zone between the steep rise in disease probability and elevated HARI values defines the hemodynamic threshold for clinically significant CLD. The confidence band narrows in mid-range velocities (14–18 cm/s), reflecting reduced interindividual variability at diagnostically relevant stages. Clinically, this pattern reinforces that coexisting low portal velocity and high HARI synergistically enhance diagnostic confidence, highlighting Doppler ultrasound's precision in quantifying vascular remodeling associated with chronic liver disease.

DISCUSSION

The present study demonstrated that portal vein Doppler ultrasonography is a highly effective non-invasive diagnostic modality for detecting pathological hepatic changes in patients with chronic liver disease (CLD). The observed sensitivity of 94.4% and specificity of 78.5% indicate robust discriminative ability when histopathology is used as the reference standard. These findings closely align with previous evidence by Nouh et al., who reported a sensitivity of 89.6% and specificity of 93.9% for portal color Doppler in predicting esophageal varices among cirrhotic patients (16). Similarly, Ahmad et al. documented a diagnostic accuracy of 89.5% for Doppler-based detection of early cirrhosis in hepatitis C–infected individuals, further corroborating the reliability of Doppler parameters in liver disease evaluation (17). The slightly higher sensitivity in the current study may be attributed to the inclusion of advanced CLD cases, where hemodynamic alterations are more pronounced, and to standardized imaging techniques performed by a single operator, thereby minimizing interobserver variability.

The relationship between portal hemodynamics and hepatic pathology is physiologically plausible and well established. Iwakiri and Groszmann emphasized that progressive hepatic fibrosis increases intrahepatic resistance, reduces portal flow velocity, and alters waveform phasicity, all of which were quantifiable through Doppler ultrasound in the present cohort (18). The concurrent elevation of hepatic artery resistive index (HARI) observed in patients with histologically confirmed CLD reflects compensatory arterialization of hepatic blood flow secondary to sinusoidal capillarization and increased parenchymal stiffness. The combined assessment of portal velocity and HARI thus enhances diagnostic precision by capturing both venous and arterial components of hepatic hemodynamics.

Stratified analysis revealed improved diagnostic performance in older patients and females, consistent with the pathophysiological observation that disease chronicity and hormonal modulation may intensify vascular remodeling. These demographic variations parallel the findings of Asghar et al., who reported that hepatitis-associated liver diseases tend to progress more rapidly and severely, particularly in older cohorts (19). Moreover, Baz et al. demonstrated a strong correlation between Doppler-derived vascular indices and the Model for End-Stage Liver Disease (MELD) score, supporting their prognostic value in cirrhosis (20). In the current analysis, the positive likelihood ratio (4.39) and low negative likelihood ratio (0.07) further validate the clinical applicability of Doppler findings, suggesting that a positive Doppler test markedly increases post-test probability, while a negative result effectively rules out advanced disease.

These results reinforce the emerging paradigm shift away from routine reliance on invasive liver biopsy. Khalifa and Rockey highlighted that many diagnostic and staging requirements in hepatology can now be met through high-resolution imaging and elastographic modalities (21). While transient elastography and MR elastography provide quantitative stiffness measures, Doppler ultrasonography uniquely characterizes hemodynamic consequences of fibrosis, offering a complementary and physiologically meaningful perspective. Given Pakistan's high prevalence of viral hepatitis, resource limitations, and patient reluctance toward invasive procedures, Doppler ultrasound offers a feasible alternative for early detection and disease monitoring, especially in secondary care facilities.

Despite its strengths, including standardized imaging protocols, blinding of histopathologists, and stratified subgroup analysis, the study acknowledges several limitations. Being a single-center study restricts generalizability, and inter-operator reproducibility was not assessed, limiting external validation. The cross-sectional design also precludes longitudinal evaluation of disease progression or treatment response. Moreover, factors such as obesity, bowel gas, or coexisting cardiovascular abnormalities could subtly influence Doppler parameters. Nonetheless, the sample size was adequately powered to detect meaningful differences, and the study's methodological rigor supports the reliability of the findings.

Future research should focus on multicenter validation incorporating elastography and biochemical scoring systems (such as APRI or FIB-4) to create integrated, multimodal diagnostic algorithms. Prospective longitudinal studies evaluating Doppler parameter evolution during antiviral or antifibrotic therapy could also establish its role in dynamic disease monitoring.

In summary, the findings confirm that portal vein Doppler ultrasound provides a sensitive, moderately specific, and clinically reliable non-invasive diagnostic approach for CLD assessment. By capturing both morphological and hemodynamic alterations, it bridges the gap between histopathological precision and bedside accessibility, offering a practical tool for early disease recognition and ongoing clinical management (16–21).

CONCLUSION

The study confirms that portal vein Doppler ultrasound provides a highly sensitive, moderately specific, and diagnostically accurate non-invasive tool for assessing chronic liver disease (CLD). With a sensitivity of 94.4%, specificity of 78.5%, and an overall diagnostic accuracy of 90%, the modality demonstrates strong concordance with histopathological findings. These results substantiate the clinical applicability of Doppler ultrasonography in early detection and monitoring of hepatic structural and hemodynamic changes. The concurrent reduction in portal vein velocity and elevation in hepatic artery resistive index offer a reliable vascular signature of progressive hepatic fibrosis. Clinically, the findings suggest that Doppler ultrasound can serve as a frontline diagnostic investigation, especially in regions where liver biopsy is limited by cost, invasiveness, or resource constraints. The study emphasizes the integration of Doppler-based parameters into standard evaluation protocols for CLD to enable earlier diagnosis, reduce procedural risk, and improve patient outcomes while supporting the global shift toward non-invasive hepatologic diagnostics.

REFERENCES

1. Squires JE, McKiernan P, Squires RH. Acute Liver Failure: An Update. Clin Liver Dis. 2018;22(4):773–805.
2. Iwakiri Y, Groszmann RJ. Pathophysiology of Portal Hypertension. In: Arias IM, Alter HJ, Boyer JL, Cohen DE, Fausto N, Shafritz DA, et al., editors. The Liver: Biology and Pathobiology. 5th ed. Hoboken (NJ): Wiley-Blackwell; 2020. p. 659–69.
3. Khalifa A, Rockey DC. The Utility of Liver Biopsy in 2020. Curr Opin Gastroenterol. 2020;36(3):184–91.
4. Carneiro C, Brito J, Bilreiro C, Barros M, Bahia C, Santiago I, et al. All About Portal Vein: A Pictorial Display of Anatomy, Variants, and Physiopathology. Insights Imaging. 2019;10(1):1–18.
5. Baz AAM, Mohamed RM, El-kaffas KH. Doppler Ultrasound in Liver Cirrhosis: Correlation of Hepatic Artery and Portal Vein Measurements with Model for End-Stage Liver Disease Score in Egypt. Egypt J Radiol Nucl Med. 2020;51(1):228.
6. Frenette CT, Morelli G, Shiffman ML, Frederick RT, Rubin RA, Fallon MB, et al. Emricasan Improves Liver Function in Patients with Cirrhosis and High MELD Scores Compared with Placebo. Clin Gastroenterol Hepatol. 2019;17(4):774–83.e4.
7. Ozougwu JC. Physiology of the Liver. Int J Res Pharm Biosci. 2017;4(8):13–24.
8. Nouh MAE, Abd-Elmageed MK, Amer AAM, Elhamouly MS. Role of Portal Color Doppler Ultrasonography as Non-Invasive Predictive Tool for Esophageal Varices in Cirrhotic Patients. Egypt J Radiol Nucl Med. 2022;53(1):1–11.
9. Ahmad MW, Rashid N, Dogar IH, Umer M, Shehzadi HS, Ahmad R. Diagnostic Accuracy of Doppler Scan of Portal Vein to Determine Early Cirrhosis of Hepatitis-C Patients in Gujranwala Population. Pak J Med Health Sci. 2023;17(2):212.
10. Akhtar S, Nasir JA, Usman M, Sarwar A, Majeed R, Billah B. The Prevalence of Hepatitis C Virus in Hemodialysis Patients in Pakistan: A Systematic Review and Meta-Analysis. PLoS One. 2020;15(5):e0232931.
11. Asghar MS, Ahsan MN, Rasheed U, Hassan M, Jawed R, Abbas MB, et al. Severity of Non-B and Non-C Hepatitis Versus Hepatitis B and C Associated Chronic Liver Disease: A Retrospective, Observational, Comparative Study. Cureus. 2020;12(12):e12314.
12. Altman DG, Bland JM. Diagnostic Tests 1: Sensitivity and Specificity. BMJ. 1994;308(6943):1552.
13. Naing L, Winn T, Rusli BN. Practical Issues in Calculating the Sample Size for Prevalence Studies. Arch Orofac Sci. 2006;1:9–14.
14. World Medical Association. Declaration of Helsinki: Ethical Principles for Medical Research Involving Human Subjects. JAMA. 2013;310(20):2191–4.
15. IBM Corp. IBM SPSS Statistics for Windows, Version 22.0. Armonk, NY: IBM Corp; 2013.
16. Nouh MAE, Abd-Elmageed MK, Amer AAM, Elhamouly MS. Role of Portal Color Doppler Ultrasonography as Non-Invasive Predictive Tool for Esophageal Varices in Cirrhotic Patients. Egypt J Radiol Nucl Med. 2022;53(1):1–11.
17. Ahmad MW, Rashid N, Dogar IH, Umer M, Shehzadi HS, Ahmad R. Diagnostic Accuracy of Doppler Scan of Portal Vein to Determine Early Cirrhosis of Hepatitis-C Patients in Gujranwala Population. Pak J Med Health Sci. 2023;17(2):212.
18. Iwakiri Y, Groszmann RJ. Pathophysiology of Portal Hypertension. In: Arias IM, Alter HJ, Boyer JL, Cohen DE, Fausto N, Shafritz DA, et al., editors. The Liver: Biology and Pathobiology. 5th ed. Hoboken (NJ): Wiley-Blackwell; 2020. p. 659–69.
19. Asghar MS, Ahsan MN, Rasheed U, Hassan M, Jawed R, Abbas MB, et al. Severity of Non-B and Non-C Hepatitis Versus Hepatitis B and C Associated Chronic Liver Disease: A Retrospective, Observational, Comparative Study. Cureus. 2020;12(12):e12314.
20. Baz AAM, Mohamed RM, El-kaffas KH. Doppler Ultrasound in Liver Cirrhosis: Correlation of Hepatic Artery and Portal Vein Measurements with Model for End-Stage Liver Disease Score in Egypt. Egypt J Radiol Nucl Med. 2020;51(1):228.
21. Khalifa A, Rockey DC. The Utility of Liver Biopsy in 2020. Curr Opin Gastroenterol. 2020;36(3):184–91.