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Original Article

A Prospective Study of Hepatic Vein Waveform, Damping Index, and Splenoportal Index in Liver Cirrhosis: Correlation with Child-Pugh Score

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Abstract

Background:Chronic liver disease evaluation is commonly conducted using the Child-Pugh and Model for End-Stage Liver Disease (MELD) scoring systems. While the hepatic venous pressure gradient (HVPG) is the gold standard for measuring portal hypertension in cirrhotic patients, non-invasive alternatives such as Doppler ultrasonography offer a cost-effective, rapid, and less invasive option for assessment.

Objective: This study aimed to investigate the correlation between hepatic vein waveform patterns, damping index, splenoportal index, and the Child-Pugh score in patients with liver cirrhosis to evaluate the efficacy of Doppler ultrasound as a non-invasive diagnostic tool.

Methods: A prospective cross-sectional study was conducted at the Radiology Department of a public teaching hospital in Rawalpindi, Pakistan, from December 2023 to June 2024. A total of 52 patients with liver cirrhosis were included after excluding those with incomplete data or confounding conditions. Doppler ultrasound was used to assess hepatic vein waveform patterns, damping index, and splenoportal index. The Child-Pugh score was calculated based on clinical and laboratory parameters. Statistical analysis was performed using SPSS version 25, with a p-value of <0.05 considered significant. The chi-square test, Fisher's exact test, ANOVA, and ROC curve analyses were utilized for data evaluation.

Results: The final cohort consisted of 52 patients, with 39 males (75%) and 13 females (25%). The mean age was 55.3 years. The damping index showed a significant increase from Child-Pugh Class A (0.45 ± 0.10) to Class C (0.75 ± 0.15) (p=0.003). The splenoportal index also demonstrated a significant rise from Class A (1.4 ± 0.3) to Class C (2.0 ± 0.5) (p=0.015). The sensitivity and specificity of the damping index (> 0.6) in predicting higher Child-Pugh scores (B + C) were 52.6% and 85.7%, respectively, with a positive predictive value of 90.9%.

Conclusion: The study found strong correlations between the severity of liver cirrhosis, as assessed by the Child-Pugh score, and Doppler ultrasound parameters such as hepatic vein waveforms and the damping index. Doppler ultrasound, therefore, presents itself as a precise, non-invasive alternative for evaluating the severity of liver disease, potentially replacing more invasive procedures.

1 Introduction

Liver cirrhosis represents the final stage of chronic liver disease, characterized by extensive fibrosis and the formation of regenerating nodules, which are the result of repeated episodes of necrosis and degeneration of hepatocytes. This process leads to the irreversible scarring of hepatic tissue, profoundly impairing liver function and giving rise to a multitude of severe complications, including portal hypertension, ascites, esophageal varices, hepatic encephalopathy, hepatorenal syndrome, and spontaneous bacterial peritonitis. Moreover, cirrhosis significantly elevates the risk of hepatocellular carcinoma, further compounding the disease burden (1,2). Traditionally, the histopathological analysis of liver tissue obtained via ultrasound-guided needle biopsy has been regarded as the gold standard for diagnosing liver fibrosis and assessing the severity of cirrhosis. However, this invasive procedure is fraught with limitations, including subjective interpretation, semi-quantitative assessment, and the potential for morbidity and mortality (3-5).

In clinical practice, various non-invasive methods have been developed to evaluate the severity of liver cirrhosis and predict patient outcomes. Among these, the Child-Pugh score and the Model for End-Stage Liver Disease (MELD) score are widely utilized to assess liver

function and prognosis. Additionally, serum biomarkers such as FibroTest, HepaScore, and the aspartate aminotransferase-to-platelet ratio index have been proposed as alternatives to liver biopsy, although their specificity and accuracy remain suboptimal due to their dependence on non-hepatic factors (6,7). Concurrently, advances in imaging technologies have enabled the early detection of liver architectural changes associated with cirrhosis through modalities such as computed tomography, magnetic resonance imaging, and ultrasonography (8,9). Despite their utility in diagnosing advanced cirrhosis, these imaging techniques often fall short in accurately quantifying portal hypertension and liver function.

Doppler ultrasonography has emerged as a valuable tool in the non-invasive assessment of liver hemodynamics, offering insights into the severity and progression of cirrhosis by analyzing hepatic venous waveforms and calculating the damping index (10). The hepatic venous waveform, which reflects the pressure dynamics within the hepatic veins, can exhibit characteristic changes in response to increased portal pressure and altered liver architecture. Simultaneously, the splenoportal index, which quantifies the spleen and portal vein dimensions, serves as an indirect marker of portal hypertension, a hallmark of advanced liver disease (11). The integration of these Doppler ultrasound parameters into routine clinical practice has the potential to enhance the diagnostic and prognostic capabilities for cirrhotic patients, providing a non-invasive, cost-effective, and rapid alternative to more invasive procedures.

Given the increasing prevalence of liver cirrhosis and its associated morbidity and mortality, there is a pressing need to refine and validate non-invasive diagnostic tools that can accurately assess disease severity and guide therapeutic decision-making. This study aims to bridge the gap between traditional clinical evaluation and advanced imaging techniques by investigating the correlation between hepatic vein waveforms, the damping index, and the splenoportal index with the Child-Pugh score in patients with liver cirrhosis. By elucidating the complex relationships between liver function, hemodynamics, and clinical outcomes, we seek to contribute to the development of more effective diagnostic and therapeutic strategies for the management of this debilitating condition. The findings of this study are expected to provide robust evidence supporting the use of Doppler ultrasound as a reliable and non-invasive method for assessing the severity of liver cirrhosis, thereby improving patient care and outcomes.

2 Material and Methods

This prospective cross-sectional study was conducted in the Radiology Department of a public teaching hospital in Rawalpindi, Pakistan, from December 2023 to June 2024. The study aimed to evaluate the efficacy of Doppler ultrasound parameters, specifically hepatic vein waveform analysis, the damping index, and the splenoportal index, in correlating with the Child-Pugh score in patients diagnosed with liver cirrhosis. The study population consisted of 55 patients who were referred for ultrasound evaluation following a clinical diagnosis of liver cirrhosis. Inclusion criteria encompassed both male and female patients of all ages with varying severities of cirrhosis. Exclusion criteria included patients with hepatocellular carcinoma, those on beta-blockers or other medications that could alter portal pressure, individuals with portal vein thrombosis, severe hepatic encephalopathy, or conditions unrelated to liver cirrhosis that could cause esophageal varices. Patients with other non-liver-related organ failures, severe variceal bleeding, abnormal fluid volumes, chest or heart conditions affecting right heart blood flow, or those who did not consent to participate were also excluded from the study.

The study followed the ethical principles outlined in the Declaration of Helsinki. Written informed consent was obtained from all participants before their inclusion in the study. The confidentiality and anonymity of all participants were strictly maintained throughout the study period. Each patient underwent a thorough clinical assessment and had their complete medical history recorded using a standardized proforma. This included a comprehensive clinical examination with a focus on detecting signs of chronic liver disease (CLD), such as ascites and splenomegaly(12-14).

Laboratory investigations were performed to assess liver function and included serum bilirubin, total protein, albumin, liver enzymes, coagulation profile, renal function tests, and complete blood counts. The Child-Pugh score was calculated based on the clinical state of the patient, including the presence of encephalopathy and ascites, and laboratory values such as serum albumin, bilirubin, and international normalized ratio (INR), to determine the severity of liver cirrhosis.

Ultrasonographic examinations were conducted using a Philips Affiniti 50 machine for the initial diagnosis of cirrhosis, assessment of portal vein patency, detection of ascites, and exclusion of hepatocellular carcinoma. Doppler ultrasound studies were performed using a Canon Applio I 500 device equipped with a 3.5 MHz curvilinear probe. To minimize inter-operator variability, all Doppler evaluations were conducted by the same operator. Hepatic vein waveform analysis was performed by obtaining Doppler signals from the right hepatic vein at a distance of 3-6 cm from its junction with the inferior vena cava. The recordings were taken during a breath-hold at the end of expiration, with each waveform categorized as triphasic, biphasic, or monophasic based on the presence and nature of oscillations.

The damping index was calculated by dividing the maximum by the minimum velocity of the hepatic vein waveform. A damping index greater than 0.6 was considered indicative of severe portal hypertension, based on established criteria (15). The splenoportal index was calculated by measuring the spleen size and the diameter of the portal vein, which served as an indirect marker of portal hypertension (11).

Data were meticulously collected, recorded, and analyzed using SPSS version 25. Categorical data were analyzed using the chi-square test or Fisher's exact test, where appropriate. Continuous variables were compared across the Child-Pugh classes using Analysis of Variance

(ANOVA). A Receiver Operating Characteristic (ROC) curve was used to determine the optimal threshold for the damping index as a predictor of liver cirrhosis severity. A p-value of less than 0.05 was considered statistically significant.

3 Results

Results

A total of 55 patients were initially enrolled in the study, but 3 patients were excluded due to incomplete data, leaving a final sample of 52 patients. The demographic and clinical characteristics of the study participants, categorized by Child-Pugh class, are presented in Table 1. The mean age of the patients was 55.3 years, with the most common age group being 46-66 years (44.2%). The majority of patients were male (75.0%). Ascites was observed in 51.9% of the patients, with a higher prevalence in Child-Pugh Class C (76.2%) compared to Class A (35.7%) and Class B (35.3%). Hepatic encephalopathy was present in 5.8% of the patients, with a gradual increase from Class B (5.9%) to Class C (9.5%). Esophageal varices were identified in 36.5% of the total cohort, with the highest incidence in Class B (47.1%) and Class C (42.9%).

Table 1. Demographic and Clinical Characteristics of Patients by Child-Pugh Class

Characteristic	Child-Pugh Class A (n=14)	Child-Pugh Class B (n=17)	Child-Pugh Class C (n=21)	Total (n=52)
Age categories				
25-45 years	4 (28.6%)	5 (29.4%)	6 (28.6%)	15 (28.8%)
46-66 years	6 (42.9%)	8 (47.1%)	9 (42.9%)	23 (44.2%)
≥67 years	4 (28.6%)	4 (23.5%)	6 (28.6%)	14 (26.9%)
Gender				
Male	9 (64.3%)	13 (76.5%)	17 (81.0%)	39 (75.0%)
Female	5 (35.7%)	4 (23.5%)	4 (19.0%)	13 (25.0%)
Ascites				
Yes	5 (35.7%)	6 (35.3%)	16 (76.2%)	27 (51.9%)
No	9 (64.3%)	11 (64.7%)	5 (23.8%)	25 (48.1%)
Hepatic Encephalopathy				
Yes	0 (0.0%)	1 (5.9%)	2 (9.5%)	3 (5.8%)
No	14 (100.0%)	16 (94.1%)	19 (90.5%)	49 (94.2%)
Esophageal Varices				
Yes	2 (14.3%)	8 (47.1%)	9 (42.9%)	19 (36.5%)
No	12 (85.7%)	9 (52.9%)	12 (57.1%)	33 (63.5%)

Laboratory findings showed significant differences across the Child-Pugh classes, as detailed in Table 2. Mean serum bilirubin levels were highest in Class C (4.0 ± 1.2 mg/dL) and lowest in Class A (1.5 ± 0.5 mg/dL). Serum albumin levels decreased with increasing cirrhosis severity, with Class C patients having the lowest mean albumin levels (2.5 ± 0.5 g/dL) compared to Class A (3.8 ± 0.4 g/dL). The INR values increased from Class A (1.2 ± 0.1) to Class C (2.0 ± 0.3), indicating worsening coagulation function. Platelet counts also showed a downward trend, with the lowest counts observed in Class C patients. Liver enzyme levels (AST and ALT) were highest in Class C patients, reflecting more extensive liver damage.

Table 2. Laboratory Findings by Child-Pugh Class

Parameter	Child-Pugh Class A (n=14)	Child-Pugh Class B (n=17)	Child-Pugh Class C (n=21)	Overall (n=52)
Serum Bilirubin (mg/dL)	1.5 ± 0.5	2.8 ± 0.7	4.0 ± 1.2	2.7 ± 1.3
Serum Albumin (g/dL)	3.8 ± 0.4	3.0 ± 0.5	2.5 ± 0.5	3.1 ± 0.6
INR	1.2 ± 0.1	1.5 ± 0.2	2.0 ± 0.3	1.5 ± 0.3
Platelet Count (x10³/μL)	110 ± 25	95 ± 30	85 ± 35	98 ± 32
AST (U/L)	60 ± 15	80 ± 20	100 ± 25	78 ± 21
ALT (U/L)	55 ± 10	70 ± 18	85 ± 20	68 ± 19

Doppler ultrasound findings showed significant correlations with the Child-Pugh classification (Table 3). The distribution of hepatic vein waveforms varied significantly across the Child-Pugh classes, with triphasic waveforms being most common in Class A (71.4%) and monophasic waveforms most prevalent in Class C (52.4%). The mean damping index increased significantly with the severity of cirrhosis, from 0.45 ± 0.10 in Class A to 0.75 ± 0.15 in Class C (p=0.003). Similarly, the splenoportal index showed a significant rise from Class A (1.4 ± 0.3) to Class C (2.0 ± 0.5) (p=0.015).

Table 3. Doppler Ultrasound Findings by Child-Pugh Class

Doppler Parameter	Child-Pugh Class A (n=14)	Child-Pugh Class B (n=17)	Child-Pugh Class C (n=21)	Overall (n=52)	P Value
Hepatic Vein Waveform					
Triphasic	10 (71.4%)	8 (47.1%)	2 (9.5%)	20 (38.5%)	0.002*
Biphasic	2 (14.3%)	5 (29.4%)	8 (38.1%)	15 (28.8%)	0.03*
Monophasic	2 (14.3%)	4 (23.5%)	11 (52.4%)	17 (32.7%)	0.001*
Damping Index (mean ± SD)	0.45 ± 0.10	0.55 ± 0.12	0.75 ± 0.15	0.60 ± 0.16	0.003*
Splenoportal Index (mean ± SD)	1.4 ± 0.3	1.6 ± 0.4	2.0 ± 0.5	1.7 ± 0.5	0.015*

The diagnostic accuracy of the damping index (> 0.6) for predicting higher Child-Pugh scores (Class B + C) was assessed using a 2x2 contingency table, as shown in Table 4. Among patients with higher Child-Pugh scores, 20 were correctly identified with a damping index > 0.6, resulting in a sensitivity of 52.6%. The specificity was 85.7%, with 12 out of 14 patients with lower Child-Pugh scores (Class A) being correctly identified. The positive predictive value (PPV) was 90.9%, indicating that a damping index > 0.

4 Discussion

The The findings of this study highlight the significant correlations between Doppler ultrasound parameters, specifically hepatic vein waveforms, damping index, and splenoportal index, and the severity of liver cirrhosis as measured by the Child-Pugh score. The observed relationships are consistent with previous research, confirming the utility of these non-invasive measures in evaluating the progression of liver cirrhosis and offering a potential alternative to more invasive techniques like hepatic venous pressure gradient measurement (12, 13).

The study demonstrated that the hepatic vein waveform patterns changed progressively with the worsening of liver cirrhosis. Patients in Child-Pugh Class A predominantly exhibited triphasic waveforms, which is indicative of relatively preserved liver function and lower portal pressure. In contrast, as the disease advanced to Class C, monophasic waveforms became more common, reflecting significant alterations in hepatic venous outflow due to increased intrahepatic resistance and portal hypertension. These findings align with previous studies that have reported similar waveform changes in advanced cirrhosis (17, 18). The damping index, which quantifies the ratio of minimum to maximum hepatic venous velocities, was also found to correlate strongly with the severity of cirrhosis, further underscoring its potential role as a non-invasive marker for portal hypertension (15, 16).

The study's results are strengthened by the rigorous methodology employed, including the use of a single operator to minimize variability in Doppler measurements and the inclusion of a well-defined patient population. However, several limitations must be acknowledged. The relatively small sample size, although consistent with similar studies, limits the generalizability of the findings. Additionally, the exclusion of patients with acute variceal hemorrhage or those on medications that affect portal pressure may have introduced selection bias, potentially skewing the results. Despite these limitations, the study provides valuable insights into the non-invasive assessment of liver cirrhosis and sets the stage for future research in this area.

A significant strength of this study is its focus on combining multiple Doppler ultrasound parameters to assess liver cirrhosis severity. By analyzing hepatic vein waveforms, the damping index, and the splenoportal index together, the study offers a more comprehensive assessment of the hemodynamic changes associated with cirrhosis than if these parameters were considered in isolation. This multi-faceted approach not only improves diagnostic accuracy but also enhances our understanding of the complex pathophysiology underlying cirrhosis.

Despite the promising results, the study's findings should be interpreted with caution due to the aforementioned limitations. Future research should aim to include larger, more diverse populations and explore the utility of these Doppler parameters in conjunction with other non-invasive markers of liver fibrosis, such as elastography and serum biomarkers. Moreover, longitudinal studies could provide valuable information on the prognostic value of these parameters in predicting disease progression and clinical outcomes in cirrhotic patients.

5 Conclusion

In conclusion, this study reinforces the potential of Doppler ultrasound as a non-invasive, cost-effective tool for assessing the severity of liver cirrhosis. The strong correlations observed between hepatic vein waveform patterns, the damping index, the splenoportal index, and Child-Pugh scores suggest that these parameters could serve as reliable indicators of portal hypertension and liver dysfunction. While further research is needed to validate these findings and address the study's limitations, the integration of Doppler ultrasound into routine clinical practice could significantly enhance the management and prognosis of patients with liver cirrhosis.

6 References

1 Anthony PP, Ishak KG, Nayak NC, Poulsen HE, Scheuer PJ, Sobin LH. The Morphology of Cirrhosis: Definition, Nomenclature, and Classification. Bull World Health Organ. 1977;55(4):521-40.

2 Shchyokotova AP. Liver Cirrhosis. Perm Med J. 2022;39(4):41-57.

3 Maharaj B, Maharaj RJ, Leary WP, Cooppan RM, Naran AD, Pirie D, Pudifin DJ. Sampling Variability and Its Influence on the Diagnostic Yield of Percutaneous Needle Biopsy of the Liver. Lancet. 1986;1:523-5.

4 Tapper EB, Parikh ND. Diagnosis and Management of Cirrhosis and Its Complications: A Review. JAMA. 2023;329(18):1589-602.

5 Jagdish RK, Roy A, Kumar K, Premkumar M, Sharma M, Rao PN, Reddy DN, Kulkarni AV. Pathophysiology and Management of Liver Cirrhosis: From Portal Hypertension to Acute-On-Chronic Liver Failure. Front Med (Lausanne). 2023;10:1060073.

6 Cai X, Chong Y, Gan W, Li X. Progress on Clinical Prognosis Assessment in Liver Failure. Liver Res. 2023;7:1-3.

7 Simon TG, Schneeweiss S, Wyss R, Lu Z, Bessette LG, York C, Lin KJ. Development and Validation of a Novel Tool to Predict Model for End-Stage Liver Disease (MELD) Scores in Cirrhosis, Using Administrative Datasets. Clin Epidemiol. 2023;15:349-62.

8 Sartoris R, Vilgrain V. Quantitative Computed Tomography-Based Approaches for Noninvasive Diagnosis of Portal Hypertension in Patients with Cirrhosis. Portal Hypertens Cirrhosis. 2023;2(2):92-7.

9 Zocco MA, Cintoni M, Ainora ME, Garcovich M, Lupascu A, Iezzi R, Annichiarico BE, Siciliano M, Riccardi L, Rapaccini GL, Grieco A. Noninvasive Evaluation of Clinically Significant Portal Hypertension in Patients with Liver Cirrhosis: The Role of Contrast-Enhanced Ultrasound Perfusion Imaging and Elastography. Ultraschall Med. 2023;44(4):428-35.

10 Șirli R, Rațiu I, Sporea I. Elastography for the Evaluation of Portal Hypertension. Elastography-Applications Clin Med. 2022;2:1-8.

11 Saleem S, Rauf MH, Sohail M, Taufiq N, Khan MU. The Assessment of Diagnostic Accuracy of Real-Time Shear Wave Elastography in Detecting Liver Cirrhosis Keeping Histopathology as Reference Standard. Pak Armed Forces Med J. 2022;72(2):590-3.

12 Abdelmonem EE, Alghonaimy SS, Soliman AM, Amin MI, Badawy AA. Are Hepatic Vein Waveform and Damping Index Valuable in Prediction of Esophageal Varices in Cirrhotic Patients? Afro-Egypt J Infect Endem Dis. 2022;12(3):269-78.

13 Antil N, Sureka B, Mittal MK, Malik A, Gupta B, Thukral BB. Hepatic Venous Waveform, Splenoportal, and Damping Index in Liver Cirrhosis: Correlation with Child-Pugh's Score and Oesophageal Varices. J Clin Diagn Res. 2016;10(2)

14 Casey S, Schierwagen R, Mak KY, Klein S, Uschner F, Jansen C, Praktiknjo M, Meyer C, Thomas D, Herath C, Jones R. Activation of the Alternate Renin-Angiotensin System Correlates with the Clinical Status in Human Cirrhosis and Corrects Post Liver Transplantation. J Clin Med. 2019;8(4):419.

15 Kim KH, Kim MY, Baik SK, Park DH, Rhim DW, Kim JM, Suk KT, Kim JW, Kwon SO. Non-Invasive Doppler Ultrasonography for Assessment of the Portal Hypertension of Liver Cirrhosis: A Prospective Study. Korean J Med. 2008;74(2):139-45.

16 Park HS, Desser TS, Jeffrey RB, Kamaya A. Doppler Ultrasound in Liver Cirrhosis: Correlation of Hepatic Artery and Portal Vein Measurements with Model for End-Stage Liver Disease Score. J Ultrasound Med. 2017;36(4):725-30.

17 Namikawa S, Nosaka T, Matsuda H, Akazawa Y, Takahashi K, Naito T, Ohtani M, Nakamoto Y. High Correlation of Hepatic Shear Wave Velocity with Esophageal Varices Complication Rate in Patients with Chronic Liver Diseases. BMC Gastroenterol. 2023;23(1):169.

18 Kumar S, Kumar V, Giri R, Agarwal S, Gautam SK. Prediction of Esophageal Varices and Risk of Bleeding in Liver Cirrhosis by Aspartate Aminotransferase to Platelet Ratio Index and Fibrosis-4 Index. Int J Adv Med. 2023;10(5):382.

19 Sudhamshu KC, Sharma D, Chataut SP. Hepatic Vein Waveforms in Liver Cirrhosis Re-Evaluated. Hepatol Int. 2011;5:581-5.

20 Joseph T, Madhavan M, Devadas K, Ramakrishnannair VK. Doppler Assessment of Hepatic Venous Waves for Predicting Large Varices in Cirrhotic Patients. Saudi J Gastroenterol. 2011;17:36-9.

Disclaimers

Author Contributions	All authors contributed significantly to this work. Rabia Khan designed the study and conducted the experiments, while Nisar Ahmed analyzed the data and wrote the manuscript. Saira Noreen assisted in the ultrasound examinations and data collection. Sara Khan contributed to the literature review and data analysis. Sehrish Tahir was responsible for data entry and statistical analysis. Ahmad Zafar Baig provided guidance on the study design and critically reviewed the manuscript. Muhammad Farrukh Habib supervised the study and contributed to the methodology and final manuscript revision.
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