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To Study Hepatic Venous Waveforms and Spleno-Portal Index on Ultrasound in Cases of Liver Cirrhosis and Their Correlation with Disease Severity.

Dr. Vivek Yonati[1], Dr. Prachi Shukla[2], Dr. Alka Agrawal[3], Dr. Soham Roy Chowdhury[4*], Dr. Shrikant Shukla[5], Dr. Jatin Rawat[6].

[1]*Associate professor, Department of Radiodiagnosis, MGMMC MYH Indore (M.P).*
[2]*Assistant Professor, Department of Radiodiagnosis, MGMMC MYH indore (M.P).*
[3]*Professor and Head of Department, Department of Radiodiagnosis, MGMMC MYH Indore (M.P).*
[4]*Junior Resident, Department of Radiodiagnosis, MGMMC MYH Indore (M.P).*
[5]*Junior Resident, Department of Radiodiagnosis, MGMMC MYH Indore (M.P).*
[6]*Junior Resident, Department of Radiodiagnosis, MGMMC MYH Indore (M.P).*

Correspondence:
Dr. Soham Roy Chowdhury.
Junior Resident, Department of Radiodiagnosis, MGMMC MYH indore (M.P).

Email: sohamr97@gmail.com

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Abstract

Background: Doppler ultrasonography provides a non-invasive assessment of haemodynamic changes in liver cirrhosis. This study evaluated hepatic venous waveforms, damping index, and spleno-portal index and examined their association with disease severity. ***Methods:*** This hospital-based cross-sectional study included 100 adults with clinically diagnosed liver cirrhosis. B-mode and Doppler ultrasonography were performed to assess hepatic venous waveform, damping index, portal venous flow, and spleno-portal index. Disease severity was graded using the Child–Pugh classification. Associations were tested using the chi-square test or Fisher's exact test. Diagnostic performance for identifying Child–Pugh class C cirrhosis was assessed using receiver operating characteristic analysis. ***Results:*** The mean age was 46.3 ± 13.7 years, and 82% of participants were male. Child–Pugh classes A, B, and C accounted for 8%, 35%, and 57% of patients, respectively. Hepatic venous waveforms were biphasic in 54%, monophasic in 34%, and triphasic/tetraphasic in 12%. Hepatic venous waveform was significantly associated with Child–Pugh class (p=0.001); 82.4% of patients with a monophasic waveform belonged to class C. A damping index above 0.6 was also associated with disease severity (p=0.004), whereas the spleno-portal index was not (p=0.089). The damping index showed the highest overall discrimination for class C cirrhosis (AUC=0.66). ***Conclusion:*** Hepatic venous waveform and damping index may complement clinical assessment of cirrhosis severity. The spleno-portal index showed limited sensitivity and should not be used alone for severity grading.

Keywords: Child–Pugh class; cirrhosis; damping index; Doppler ultrasonography; hepatic venous waveform; spleno-portal index.

INTRODUCTION

Liver cirrhosis is a chronic and irreversible condition characterized by diffuse fibrosis, distortion of normal hepatic architecture, and the formation of regenerative nodules. It may be classified morphologically as micronodular or macronodular, with alcohol-related liver disease and chronic viral hepatitis being important underlying causes [1]. Chronic liver disease affects approximately 1.5 billion people worldwide, while cirrhosis and its complications account for substantial morbidity and mortality. In India, the burden is particularly high. Alcohol-related liver disease, chronic hepatitis B and C, and non-alcoholic fatty liver disease are among the leading causes [2].

Progressive fibrosis increases resistance to hepatic blood flow and leads to portal hypertension, which is a major cause of complications such as ascites, splenomegaly, variceal bleeding, and hepatic encephalopathy [3]. Although liver biopsy has traditionally been considered the reference standard for assessing hepatic fibrosis, it is invasive and is limited by sampling errors, subjective interpretation, and procedure-related complications [4]. Clinical scoring systems, including the Child–Pugh and Model for End-Stage Liver Disease scores, are widely used to assess disease severity and prognosis. Serum-based fibrosis markers have also been proposed, but their accuracy may be influenced by extrahepatic factors [5]. Computed

tomography and magnetic resonance imaging can demonstrate structural changes; however, they are relatively expensive and provide limited dynamic assessment of hepatic blood flow [6].

Doppler ultrasonography offers a safe, accessible, and non-invasive method for evaluating hepatic haemodynamics. With progressive cirrhosis, the normal triphasic hepatic venous waveform may become biphasic or monophasic. The damping index provides a quantitative measure of this loss of phasicity, with higher values indicating greater waveform flattening. The spleno-portal index incorporates splenic and portal venous parameters and may serve as an indirect indicator of portal hypertension [7]. Therefore, this study evaluates hepatic venous waveforms, damping index, and spleno-portal index in patients with liver cirrhosis and examines their correlation with disease severity assessed using the Child–Pugh score.

MATERIALS AND METHODS

This hospital-based cross-sectional study was conducted in the Department of Radiodiagnosis, M.G.M. Medical College, M.Y. Hospital, and Super Speciality Hospital, Indore, Madhya Pradesh, India. The study was carried out over one year after obtaining approval from the Institutional Scientific and Ethics Committee. Written informed consent was obtained from all participants before enrolment.

A total of 100 adult patients referred by the Department of Medicine and associated departments for hepatic and portal venous Doppler ultrasonography were included. Patients aged over 18 years with a clinical diagnosis of liver cirrhosis or its sequelae and who provided informed consent were eligible. Patients with a history of hepatic surgery, liver tumour, abdominal trauma, obesity, veno-occlusive disease, or renal disease were excluded.

A detailed clinical history was obtained, and relevant clinical findings and complications of liver cirrhosis were recorded. Disease severity was assessed using the Child–Pugh classification based on the available clinical and laboratory parameters. Before ultrasonography, patients were instructed to fast for 4–6 hours to reduce interference from bowel gas. All examinations were performed using a 3–5 MHz curvilinear transducer, with the patient in the supine or slight left lateral decubitus position.

B-mode ultrasonography was initially performed to assess liver size, margins, echotexture, portal vein diameter, and splenic dimensions. The craniocaudal length of the right hepatic lobe was measured in the midclavicular line. The right hepatic vein was examined through a subcostal or intercostal approach. The Doppler cursor was aligned with the direction of blood flow, and a sample volume of 5–10 mm was used. Recordings were obtained during suspended respiration at the end of expiration to minimize respiratory variation. Hepatic venous waveforms were classified as triphasic, biphasic, or monophasic. The damping index was determined from the minimum and maximum velocities of the hepatic venous waveform (Figure 1).

For portal venous assessment, the main portal vein was examined at the porta hepatis before its division into the right and left branches. The Doppler sample volume was placed within the longitudinal axis of the vessel, and the insonation angle was maintained below 60°. Patients were asked to briefly suspend respiration during image acquisition. The direction of portal venous flow was categorized as hepatopetal or hepatofugal. The main portal vein diameter and mean blood-flow velocity were also recorded. The spleen was examined in the right lateral decubitus position. Its craniocaudal and transverse dimensions and echotexture were documented. The splenic index was obtained from the maximum craniocaudal and transverse diameters. The spleno-portal index was determined using the splenic index and mean portal vein velocity.

Data were entered into Microsoft Excel and analysed using jamovi software. Continuous variables were summarized as mean and standard deviation, while categorical variables were presented as frequencies and percentages. Associations of hepatic venous waveform, damping index, and spleno-portal index with Child–Pugh class were examined using the chi-square test or Fisher's exact test, as appropriate. Receiver operating characteristic curve analysis was performed to evaluate their ability to identify Child–Pugh class C cirrhosis. Diagnostic performance was expressed as sensitivity, specificity, positive predictive value, negative predictive value, and area under the curve. All tests were two-sided, and $p<0.05$ was considered statistically significant.

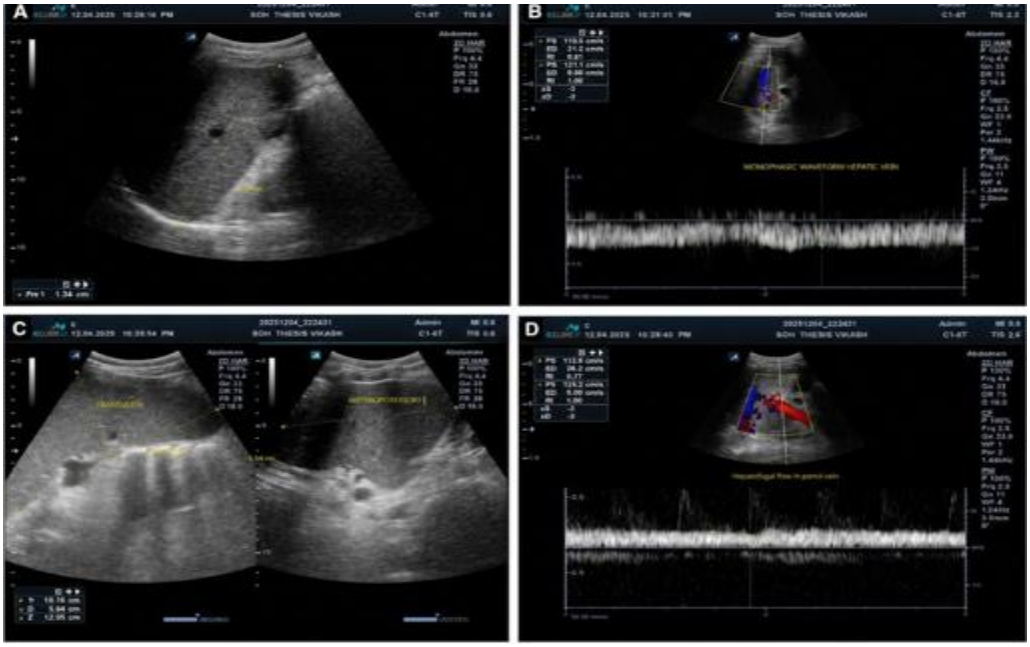

Figure 1. B-mode and Doppler ultrasonographic findings in a patient with Child–Pugh class C liver cirrhosis. (A) Liver showing a regular surface and heterogeneous echotexture. (B) Monophasic hepatic venous waveform. (C) Splenomegaly. (D) Hepatofugal flow in the portal vein

RESULTS

Among the 100 participants, the mean age was 46.3 ± 13.7 years, with the largest proportion aged 41–50 years (31%), followed by 31–40 years (24%). Most participants were male (82%). Abdominal pain and distension were the most frequent symptoms (79%), whereas ascites was the most common clinical sign (91%). Alcohol-related cirrhosis was the predominant aetiology (89%) (Table 1).

Table 1. Demographic and clinical characteristics of the study population (N = 100)

Variable	Category	Number (n)	Percentage (%)
Age group (years)	18–20	1	1.0
	21–30	11	11.0
	31–40	24	24.0
	41–50	31	31.0
	51–60	15	15.0
	61–70	12	12.0
	>70	6	6.0
Sex	Male	82	82.0
	Female	18	18.0
Clinical symptoms	Abdominal pain and distension	79	79.0
	Pedal oedema	66	66.0
	Shortness of breath	43	43.0
	Haematemesis/melena	18	18.0
	Altered sensorium	15	15.0
Clinical signs	Ascites	91	91.0
	Pedal oedema	70	70.0
	Jaundice	59	59.0
	Splenomegaly	37	37.0
	Hepatomegaly	14	14.0
Aetiology	Alcohol-related cirrhosis	89	89.0
	Alcohol with hepatitis B	4	4.0
	Hepatitis B	2	2.0
	Cryptogenic cirrhosis	5	5.0

More than half of the participants were classified as Child–Pugh class C (57%), while 35% and 8% belonged to classes B and A, respectively. Gross ascites was present in 32%. Serum albumin below 2.8 g/dL was observed in 67%, bilirubin above 3 mg/dL in 46%, and PT prolongation exceeding six seconds in 66% of patients with available data. On B-mode ultrasonography, ascites, splenomegaly, and irregular liver surface were observed in 91%, 54%, and 51%, respectively (Table 2).

Table 2. Clinical severity, laboratory parameters, and B-mode ultrasonographic findings

Parameter	Category	n (%)
Child–Pugh class	A	8 (8.0)
	B	35 (35.0)
	C	57 (57.0)
Ascites grade	None	9 (9.0)
	Minimal	17 (17.0)
	Mild	25 (25.0)
	Moderate	17 (17.0)
	Gross	32 (32.0)
Serum albumin, g/dL	<2.8	67 (67.0)
	2.8–3.5	17 (17.0)
	>3.5	16 (16.0)
Serum bilirubin, mg/dL	<1.2	16 (16.0)
	1.2–2.0	16 (16.0)
	2.1–3.0	22 (22.0)
	>3.0	46 (46.0)
PT prolongation	<4 seconds	13 (13.4)
	4–6 seconds	20 (20.6)
	>6 seconds	64 (66.0)
B-mode findings	Ascites	91 (91.0)
	Splenomegaly	54 (54.0)
	Irregular liver surface	51 (51.0)
	Pleural effusion	48 (48.0)
	Periportal/perisplenic collaterals	39 (39.0)
	Hepatomegaly	20 (20.0)
	Dilated portal vein	16 (16.0)
	Portal vein thrombosis	4 (4.0)

The most frequent hepatic venous waveform was biphasic (54%), followed by monophasic (34%) and triphasic/tetraphasic (12%). A damping index above 0.6 was recorded in 48%. Among 96 patients with a measurable spleno-portal index, 41.7% had values between 4 and 8, while 39.6% had values below 4 (Table 3).

Table 3. Hepatic and portal venous Doppler findings

Doppler parameter	Category	n (%)
Hepatic venous waveform	Monophasic	34 (34.0)
	Biphasic	54 (54.0)
	Triphasic/tetraphasic	12 (12.0)
Damping index	>0.6	48 (48.0)
	≤0.6	52 (52.0)
Spleno-portal index	<4	38 (39.6)
	4–8	40 (41.7)
	8.1–12	17 (17.7)
	>12	1 (1.0)

Hepatic venous waveform was significantly associated with Child–Pugh class (p=0.001), with 82.4% of monophasic waveforms occurring in class C. A damping index above 0.6 was also significantly associated with disease severity

(p=0.004). Although increasing spleno-portal index values were more frequent in class C, the association was not statistically significant (p=0.089) (Table 4).

Table 4. Association of Doppler parameters with Child–Pugh class

Doppler parameter	Category	Class A	Class B	Class C	p-value
Hepatic venous waveform	Monophasic	2 (5.9)	4 (11.8)	28 (82.4)	0.001
	Biphasic	3 (5.6)	26 (48.1)	25 (46.3)	
	Triphasic/tetraphasic	3 (25.0)	5 (41.7)	4 (33.3)	
Damping index	>0.6	4 (8.3)	9 (18.8)	35 (72.9)	0.004
	≤0.6	4 (7.7)	26 (50.0)	22 (42.3)	
Spleno-portal index	<4	4 (10.5)	20 (52.6)	14 (36.8)	0.089
	4–8	2 (5.0)	13 (32.5)	25 (62.5)	
	8.1–12	2 (11.8)	1 (5.9)	14 (82.4)	
	>12	0	0	1 (100.0)	

Abnormal hepatic venous waveform demonstrated high sensitivity (93.0%) but low specificity (18.6%) for identifying Child–Pugh class C. The damping index provided the highest overall discrimination (AUC=0.66), while an elevated spleno-portal index showed high specificity (93.0%) but low sensitivity (26.3%) (Table 5).

Table 5. Diagnostic performance of Doppler parameters for identifying Child–Pugh class C cirrhosis

Parameter	Sensitivity (%)	Specificity (%)	PPV (%)	NPV (%)	AUC
Abnormal hepatic venous waveform	93.0	18.6	60.2	66.7	0.56
Damping index >0.6	61.4	69.8	72.9	57.7	0.66
Elevated spleno-portal index	26.3	93.0	83.3	48.8	0.63

DISCUSSION

This study evaluated hepatic venous waveforms, damping index, and spleno-portal index as non-invasive indicators of disease severity in 100 patients with liver cirrhosis. The mean age was 46.3 ± 13.7 years, and 82% of participants were male. This profile was comparable to that reported by Bhutto et al., who observed a mean age of 48.2 years and a predominance of men among patients with chronic liver disease [8]. The marked male predominance in our cohort may be explained by the high frequency of alcohol-related cirrhosis, which accounted for 89% of cases.

Most patients presented with features of advanced disease. Abdominal pain and distension were reported by 79%, while ascites was detected clinically in 91%. Low serum albumin, elevated bilirubin, and prolonged prothrombin time were also common. Similar clinical findings were described by Mahapatra et al., while Runyon et al. identified ascites as an important marker of hepatic decompensation [9], [10]. Furthermore, 57% of our patients belonged to Child–Pugh class C. This proportion was higher than that reported by Mittal et al., possibly because the present study was conducted at a tertiary referral centre receiving patients with more advanced disease [11].

On B-mode ultrasonography, ascites was the most frequent finding, followed by splenomegaly, irregular liver surface, pleural effusion, and portosystemic collaterals. These findings reflect portal hypertension, reduced hepatic synthetic function, and progressive architectural distortion. Similar observations were reported by Berzigotti et al., who emphasized the value of ultrasonography in identifying morphological and haemodynamic changes associated with chronic liver disease [12].

The biphasic hepatic venous waveform was the most common pattern, observed in 54% of patients, followed by the monophasic pattern in 34%. Only 12% retained a triphasic or tetraphasic waveform. Hepatic venous waveform was significantly associated with Child–Pugh class (p=0.001), with 82.4% of patients showing a monophasic waveform belonging to class C. This progressive loss of phasicity may result from hepatic fibrosis and reduced venous compliance. A similar association between waveform abnormalities and cirrhosis severity was reported by Yasmin et al [13]. Kawanaka et al. also observed progressive waveform flattening with worsening liver disease [14]. Likewise, Bolondi et al. found that loss of the normal triphasic pattern was more frequent in advanced cirrhosis [15].

A damping index above 0.6 was found in 48% of patients and was significantly associated with Child–Pugh class (p=0.004). Nearly 73% of patients with an elevated damping index belonged to class C. These findings support the observations of Kim et al., who found that increased damping reflected worsening hepatic dysfunction and reduced venous phasicity [16]. The spleno-portal index was not significantly associated with Child–Pugh class (p=0.089). Piscaglia et al. similarly reported that portal Doppler indices may not consistently parallel clinical severity because they are affected by collateral circulation, respiration, hydration, and compensatory haemodynamic changes [17].

Abnormal hepatic venous waveforms showed high sensitivity but poor specificity for class C cirrhosis. The damping index provided the best overall discrimination, whereas an elevated spleno-portal index had high specificity but low sensitivity. Thus, hepatic venous waveform and damping index may complement clinical assessment, but none of these Doppler parameters should be used alone to grade cirrhosis severity.

This study has certain limitations. Its cross-sectional, single-centre design and relatively small sample may limit the generalizability of the findings. Most participants had alcohol-related and advanced cirrhosis, resulting in an uneven distribution across Child–Pugh classes. Doppler measurements were not compared with hepatic venous pressure gradient or histopathological findings. In addition, interobserver variability and the effects of physiological factors on Doppler parameters were not assessed. Larger prospective studies with longitudinal follow-up are required to validate their prognostic value.

CONCLUSION

Doppler ultrasonography provides a safe, accessible, and non-invasive approach to assessing haemodynamic alterations in liver cirrhosis. Abnormal hepatic venous waveforms, particularly monophasic patterns, and a damping index above 0.6 were significantly associated with higher Child–Pugh class, supporting their value in severity assessment. The spleno-portal index showed high specificity but limited sensitivity. Incorporating hepatic venous waveform and damping index assessment into routine ultrasonography may improve risk stratification and follow-up. Further prospective studies using hepatic venous pressure measurements are required for validation.

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