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DUPLEX DOPPLER EVALUATION OF PORTAL HYPERTENSION IN CIRRHOTIC PATIENTS AND ITS CORRELATION WITH CHILD-PUGH SCORE

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ABSTRACT

Background: Portal hypertension is a major consequence of cirrhosis and is associated with progressive changes in portal and hepatic venous hemodynamics. Although hepatic venous pressure gradient measurement is the reference standard, its invasive nature limits routine use. Duplex Doppler ultrasonography offers a non-invasive method for assessing portal flow, hepatic venous waveform characteristics and derived vascular indices.

Objective: To evaluate portal hypertension on duplex Doppler in cirrhotic patients and assess its correlation with Child-Pugh class, with additional evaluation of Doppler indices for prediction of esophageal varices.

Materials and methods: This cross-sectional study included 93 adults with cirrhosis evaluated over 18 months at Teerthanker Mahaveer Medical College and Research Centre. Ultrasonography and Doppler examinations were performed on a Siemens ACUSON S2000/S3000 system using a 6C1 HD convex transducer. Portal vein velocity and flow direction, hepatic venous waveform and hepatic venous damping index (HVDI), splenic index, splenoportal index (SPI), portal congestion index (PCI), ascites and portosystemic collaterals were assessed and correlated with Child-Pugh class. Statistical analysis included correlation, one-way ANOVA, group comparison, ROC analysis and logistic regression.

Results: Mean age was 52.34 ± 15.16 years and 78.5% of patients were male. Child-Pugh class A, B and C accounted for 51.6%, 30.1% and 18.3% of the cohort, respectively. Portal vein velocity correlated negatively with Child-Pugh class ($r = -0.254$, $p = 0.014$), whereas HVD and PCI correlated positively (all $p < 0.001$). Esophageal varices were identified in 17 patients. On multivariate analysis, HVDI (adjusted OR 49.16) and SPI (adjusted OR 1.375) remained independent predictors of varices.

Conclusion: Duplex Doppler parameters demonstrate progressive hemodynamic deterioration with increasing Child-Pugh severity. HVDI, SPI and PCI are useful non-invasive markers, while HVDI and SPI may help identify cirrhotic patients at increased risk of esophageal varices.

KEYWORDS: Portal hypertension; cirrhosis; duplex Doppler ultrasonography; Child-Pugh score; hepatic venous damping index; splenoportal index; portal congestion index; esophageal varices

1. INTRODUCTION

Chronic liver disease may progress to cirrhosis, characterized by fibrosis, nodular regeneration and distortion of the hepatic vascular architecture. The resulting increase in intrahepatic resistance is a principal mechanism of portal hypertension, which contributes to ascites, portosystemic collateral formation and gastroesophageal varices. Variceal bleeding remains one of the most clinically important complications because it is associated with substantial morbidity and mortality.1-6

Portal hypertension can be assessed directly or indirectly. Hepatic venous pressure gradient measurement is widely used as a reference method for clinically significant portal hypertension, but it is invasive and not routinely available in all settings. This has encouraged the use of non-invasive imaging methods, particularly ultrasonography and Doppler techniques, for serial assessment of portal and hepatic venous hemodynamics.7-9

Duplex Doppler ultrasonography allows simultaneous evaluation of liver morphology, portal vein caliber, direction and velocity of portal flow, hepatic venous waveform, splenic dimensions and collateral circulation. With worsening portal

hypertension, portal venous velocity may decrease, hepatofugal flow may appear and the normal triphasic hepatic venous waveform may become dampened or monophasic. These changes reflect altered vascular resistance and reduced transmission of right atrial pulsatility through a stiff cirrhotic liver.10,11

Several derived indices have been proposed to improve the objectivity of Doppler assessment. The hepatic venous damping index (HVDI) expresses the ratio of minimum to maximum hepatic venous velocity; the splenoportal index (SPI) relates splenic size to mean portal venous velocity; and the portal congestion index (PCI) relates portal vein cross-sectional area to mean portal venous velocity. These indices may capture the combined effects of venous congestion, splenic enlargement and reduced portal flow and have been investigated in relation to Child-Pugh severity and esophageal varices.10,12-14

The Child-Pugh classification remains a practical clinical method for grading hepatic dysfunction. Demonstrating a reproducible relationship between Child-Pugh class and non-invasive Doppler parameters could strengthen the role of ultrasonography in disease stratification and in selecting patients who warrant closer endoscopic surveillance. The present study therefore evaluated morphologic and hemodynamic Doppler findings in cirrhotic patients, correlated these findings with Child-Pugh class and examined their association with esophageal varices.10,15-17

MATERIALS AND METHODS

A cross-sectional study was conducted in the Department of Radiodiagnosis, Teerthanker Mahaveer Medical College and Research Centre, Moradabad, in collaboration with the Department of General Medicine. The study duration was 18 months after approval from the institutional ethics committee. The calculated minimum sample size was 93, based on an assumed cirrhosis prevalence of 42%, a 10% margin of error and a 95% confidence level. The final analysis included 93 adult patients with clinical and laboratory evidence of liver cirrhosis classified using the Child-Pugh system.

Adults aged 18 years or older referred for abdominal ultrasonography with cirrhosis and written informed consent were eligible. Patients with portal hypertension secondary to causes other than chronic liver disease, pregnant women, patients with recent abdominal surgery and those with hepatocellular carcinoma were excluded. Examinations were performed after fasting with patients in the supine position using a Siemens ACUSON S2000/S3000 ultrasound scanner and a 6C1 HD convex transducer.

B-mode ultrasonography included assessment of portal vein diameter during quiet and deep respiration, portal vein cross-sectional area, splenic dimensions, ascites and portosystemic collaterals. Color and spectral Doppler were used to determine portal flow direction and mean portal vein velocity. Hepatic venous waveforms were recorded from the right or middle hepatic vein; at least three recordings were obtained and mean values were used. HVDI was calculated as minimum hepatic venous velocity divided by maximum velocity. SPI was calculated as splenic index divided by mean portal vein velocity, and PCI as portal vein cross-sectional area divided by mean portal vein velocity.10,11,13,14

Doppler findings were correlated with Child-Pugh class. Where endoscopic information was available, the presence and grade of esophageal varices were recorded. Statistical analysis included descriptive statistics, Spearman correlation for relationships with Child-Pugh class, one-way ANOVA for comparison of continuous Doppler indices across Child-Pugh classes, analysis of categorical waveform and flow-direction patterns, comparison of Doppler indices according to variceal status, receiver-operating-characteristic analysis, and univariate and multivariate logistic regression for predictors of esophageal varices. A p value <0.05 was considered statistically significant.

RESULTS

Demographic and clinical profile

The cohort comprised 93 patients with a mean age of 52.34 ± 15.16 years. Males constituted 78.5% of the study population. Ascites was present in 60 patients and portosystemic collaterals in 31. Child-Pugh class A was the most frequent category, followed by class B and class C. Esophageal varices were identified in 17 patients; among these, Grade I varices predominated.

Table 1. Demographic and clinical profile of the study population.

Variable	Finding
Sample size	93
Age, years (mean ± SD)	52.34 ± 15.16
Male / Female	73 (78.5%) / 20 (21.5%)
Ascites, present / absent	60 (64.5%) / 33 (35.5%)
Portosystemic collaterals, present / absent	31 (33.3%) / 62 (66.7%)
Child-Pugh class A / B / C	48 (51.6%) / 28 (30.1%) / 17 (18.3%)
Esophageal varices, present / absent	17 / 76

Variceal grade I / II / III (among varices)	11 (64.7%) / 4 (23.5%) / 2 (11.8%)

Doppler hemodynamic parameters and Child-Pugh severity

Overall mean portal vein velocity was 14.34 ± 2.81 cm/s, while mean HVDI, SPI and PCI were 0.51 ± 0.18, 3.93 ± 2.65 and 0.066 ± 0.026, respectively. Portal vein velocity showed a significant negative correlation with Child-Pugh class ($r = -0.254$, $p = 0.014$). In contrast, HVDI ($r = 0.500$), SPI ($r = 0.414$) and PCI ($r = 0.495$) increased significantly with worsening Child-Pugh class (all $p < 0.001$).

Table 2. Comparison of principal Doppler parameters across Child-Pugh classes.

Parameter	Overall	Class A	Class B	Class C	p value
Portal vein velocity (cm/s)	14.34 ± 2.81	14.54 ± 2.66	15.48 ± 2.68	11.91 ± 1.97	<0.001
HVDI	0.51 ± 0.18	0.44 ± 0.14	0.54 ± 0.19	0.68 ± 0.13	<0.001
SPI	3.93 ± 2.65	3.25 ± 1.61	3.46 ± 1.99	6.61 ± 4.09	<0.001
PCI	0.066 ± 0.026	0.059 ± 0.019	0.060 ± 0.018	0.098 ± 0.029	<0.001

Hepatopetal portal flow was seen in 75 patients and hepatofugal flow in 18. Triphasic hepatic venous waveform was present in 70 patients and monophasic waveform in 23. Both flow direction and hepatic venous waveform demonstrated significant associations with Child-Pugh class. Monophasic waveform and hepatofugal flow were concentrated in the most advanced class.

Table 3. Distribution of hepatic venous waveform and portal flow direction across Child-Pugh classes.

Finding	Class A (n=48)	Class B (n=28)	Class C (n=17)	Association
Hepatic venous waveform: Triphasic	45	21	4	<0.001
Hepatic venous waveform: Monophasic	3	7	13	<0.001
Portal flow: Hepatopetal	44	26	5	<0.001
Portal flow: Hepatofugal	4	2	12	<0.001

Doppler parameters and esophageal varices

Patients with esophageal varices had higher HVDI (0.65 ± 0.16 versus 0.48 ± 0.16) and SPI (6.10 ± 4.07 versus 3.33 ± 1.71), with both differences reported as statistically significant ($p < 0.001$). PCI was also higher in the variceal group (0.084 ± 0.032 versus 0.062 ± 0.021). ROC analysis demonstrated the highest discrimination for HVDI, followed by SPI and PCI. On univariate regression, higher HVDI, SPI and PCI and lower portal vein velocity were associated with varices. On multivariate analysis, HVDI and SPI remained independent predictors.

Table 4. Doppler indices for prediction of esophageal varices.

Parameter	Varices present	Varices absent	ROC cutoff	AUC	Sensitivity	Specificity
HVDI	0.65 ± 0.16	0.48 ± 0.16	0.50	0.778	80%	56%
SPI	6.10 ± 4.07	3.33 ± 1.71	3.50	0.763	80%	58%
PCI	0.084 ± 0.032	0.062 ± 0.021	0.07	0.723	70%	62%

In multivariate logistic regression, HVDI remained an independent predictor of esophageal varices with an adjusted odds ratio of 49.16 (95% CI 1.86-1297.25; $p = 0.020$). SPI also remained independently associated with varices (adjusted OR 1.375, 95% CI 1.05-1.80; $p = 0.020$).

Representative image examples

Representative ultrasound images from the thesis demonstrate the Doppler patterns used for hemodynamic assessment. Image headers were cropped to minimize identifying information while retaining the relevant diagnostic waveform and flow features.

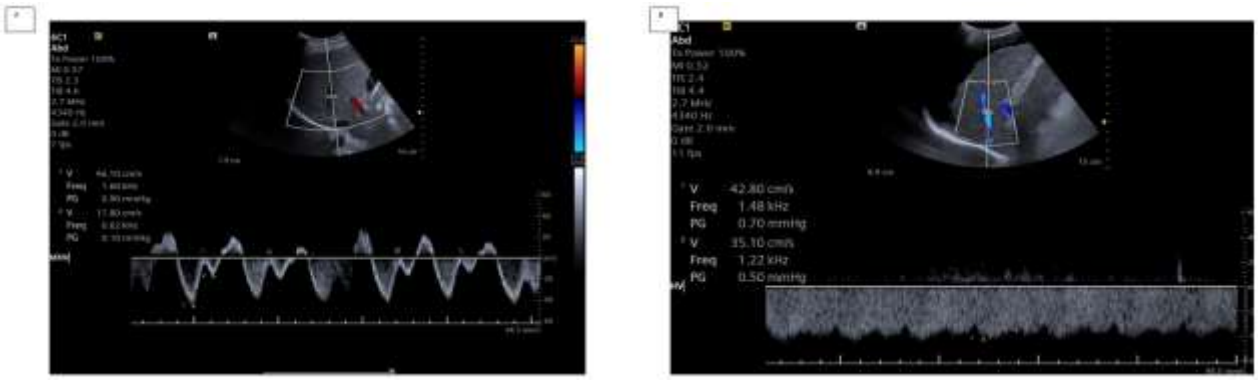

Figure 1. Representative hepatic venous waveform assessment. (A) Triphasic hepatic venous waveform with HVDI 0.36 in a normal example. (B) Dampened monophasic hepatic venous waveform with HVDI 0.82 in a Child-Pugh class C cirrhotic patient.

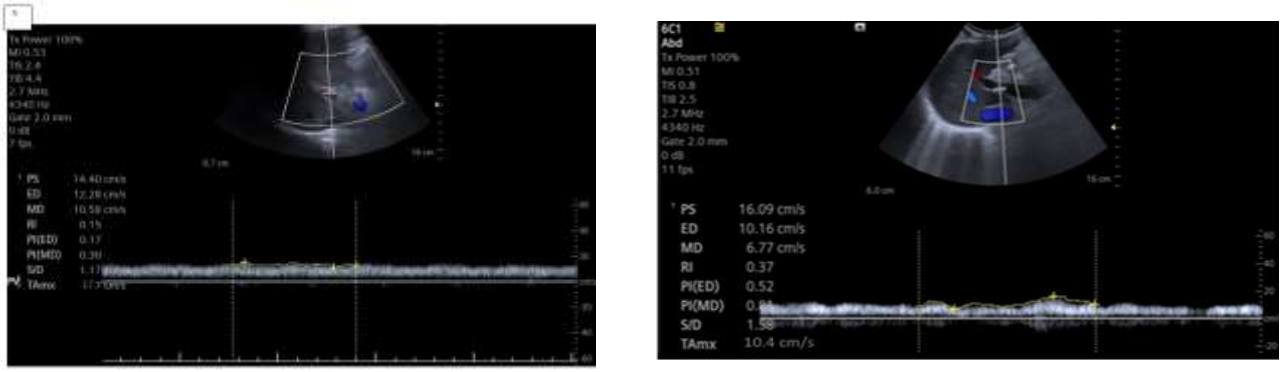

Figure 2. Representative portal venous spectral Doppler assessment. (A) Preserved portal venous spectral signal in the normal example. (B) Reduced mean portal vein velocity of approximately 11.4 cm/s in a cirrhotic patient.

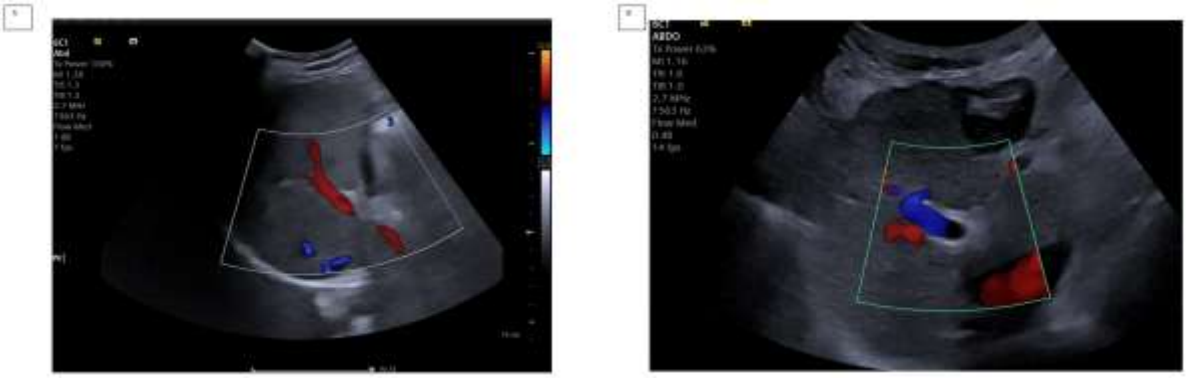

Figure 3. Representative color Doppler assessment of portal flow direction. (A) Hepatopetal portal flow in the normal example. (B) Hepatofugal portal flow in a cirrhotic patient.

DISCUSSION

The present study demonstrates that duplex Doppler ultrasonography provides clinically relevant information on portal and hepatic venous hemodynamics in cirrhosis. The principal finding was a progressive deterioration in Doppler parameters with worsening Child-Pugh class: portal vein velocity decreased, while HVDI, SPI and PCI increased. In addition, hepatic venous waveform flattening and hepatofugal portal flow were significantly associated with more advanced liver dysfunction. These results support the use of a multiparametric Doppler approach rather than reliance on a single measurement.10,15-20

The study population showed a marked male predominance and a mean age in the early fifties. Ascites was common and one-third of patients had portosystemic collaterals, reflecting the clinical burden of portal hypertension. Although the distribution of Child-Pugh classes was weighted toward class A, the class C subgroup demonstrated the clearest hemodynamic abnormalities. Similar studies from India and other settings have also reported substantial alterations in portal and hepatic venous Doppler profiles among patients with cirrhosis and portal hypertension.15,18-20

Portal vein velocity was inversely related to Child-Pugh severity and was lowest in class C. This pattern is physiologically plausible because increasing intrahepatic resistance and collateralization reduce effective hepatopetal portal flow as cirrhosis progresses. Mittal et al. described associations between portal vein Doppler findings and disease severity, while Zhang et al. reported lower portal vein velocity in patients with more abnormal hepatic venous waveforms and higher portal pressure. Ali et al. likewise found a progressive decline in portal vein velocity across Child-Pugh classes.15,16,18

HVDI demonstrated one of the strongest relationships with Child-Pugh class in the present study. The index increased from 0.44 in class A to 0.68 in class C, and monophasic waveforms became much more frequent with advanced disease. These findings are consistent with the concept that cirrhotic architectural distortion reduces hepatic venous compliance and damps transmitted cardiac pulsatility. Antil et al. and Kim et al. previously emphasized the value of damping behavior of hepatic venous waveforms in relation to portal pressure and liver dysfunction.10,13

SPI and PCI also rose substantially in class C. SPI incorporates splenic enlargement and reduced portal flow, whereas PCI combines portal vein cross-sectional area with flow velocity. Their increase with worsening Child-Pugh class therefore reflects complementary components of portal venous congestion. Prior work has described SPI as a potential non-invasive marker of esophageal varices and has shown that congestion index increases as cirrhosis becomes more severe.12,14,18

The categorical Doppler findings were equally informative. Triphasic hepatic venous waveforms predominated in class A, while monophasic waveforms were most frequent in class C. Hepatofugal portal flow was also concentrated in class C. These observations indicate that both waveform morphology and direction of portal flow change with advancing portal hypertension and may provide rapid qualitative clues before quantitative indices are calculated.11,16,19,20

Esophageal varices were identified in 17 patients. HVDI and SPI were significantly higher in patients with varices, and PCI was also increased. HVDI provided the highest ROC discrimination (AUC 0.778), while SPI showed a similar AUC of 0.763. Importantly, multivariate logistic regression retained HVDI and SPI as independent predictors. Antil et al. also reported higher damping and splenoportal indices in patients with varices, although their group differences were not statistically significant, illustrating that diagnostic performance may vary with case mix and disease stage.10,12,14

From a practical perspective, the evaluated measurements can be obtained during routine abdominal ultrasound without ionizing radiation or invasive pressure measurement. The combination of portal vein velocity, HVDI, SPI, PCI, hepatic venous waveform and portal flow direction may therefore help stratify hemodynamic severity and identify patients who warrant closer surveillance for varices. However, the study was limited by its sample size, lack of direct comparison with invasive portal pressure measurements, absence of interobserver variability analysis and unequal distribution of patients across Child-Pugh classes. These limitations should be considered when generalizing the reported cutoffs and odds ratios.7-10,17

CONCLUSION

Duplex Doppler ultrasonography is a useful non-invasive modality for assessment of portal hypertension in cirrhotic patients. Portal vein velocity decreased with increasing Child-Pugh severity, whereas HVDI, SPI and PCI increased. Monophasic hepatic venous waveform and hepatofugal portal flow were more frequent in advanced disease. Patients with esophageal varices had higher Doppler indices, and HVDI and SPI remained independent predictors on multivariate analysis. Incorporating these parameters into routine Doppler examination may improve non-invasive severity assessment and help identify patients at greater risk of esophageal varices.

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