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Duplex Doppler Evaluation of Portal Hemodynamics in Liver Cirrhosis and Its Correlation with Disease Severity and Variceal Risk: A Comparative Cross-Sectional Study

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ABSTRACT

Background: Liver cirrhosis is associated with progressive portal hypertension, leading to significant morbidity and mortality. Duplex Doppler ultrasonography offers a non-invasive method to evaluate portal hemodynamics and predict complications.
Aim: To assess portal venous hemodynamics in cirrhotic patients using Duplex Doppler ultrasound and correlate findings with disease severity and variceal risk.
Methods: This comparative cross-sectional study included 110 participants (55 cirrhotic patients and 55 matched controls). Doppler parameters including portal vein diameter, velocity, congestion index, and spleno-portal index were analyzed. Associations with Child-Pugh classification and varices were evaluated.
Results: Cirrhotic patients demonstrated significantly increased portal vein diameter, splenic indices, and congestion index, with reduced portal vein velocity compared to controls. Advanced Child-Pugh class showed worsening hemodynamic parameters. Increased spleno-portal index strongly correlated with presence of varices and collaterals.
Conclusion: Duplex Doppler ultrasound is an effective, non-invasive modality for assessing portal hypertension and predicting variceal risk in cirrhotic patients.

Keywords*: Liver cirrhosis, portal hypertension, Doppler ultrasound, portal vein, varices, spleno-portal index.*

INTRODUCTION

Liver cirrhosis represents the final common pathway of chronic liver diseases characterized by fibrosis, nodular regeneration, and distortion of hepatic architecture. It remains a major global health problem, contributing significantly to morbidity and mortality worldwide (1,2). Portal hypertension, defined as an increase in portal venous pressure gradient, is a key complication of cirrhosis and is responsible for severe clinical outcomes such as variceal bleeding, ascites, and hepatic encephalopathy (3,4).

The pathophysiology of portal hypertension is complex and involves increased intrahepatic resistance combined with increased portal venous inflow (5). Structural changes including fibrosis and regenerative nodules increase resistance, while splanchnic vasodilation further exacerbates portal pressure (6,7).

Early detection and monitoring of portal hypertension are crucial for preventing life-threatening complications. Hepatic venous pressure gradient (HVPG) measurement is considered the gold standard but is invasive and not widely available (8,9). Therefore, non-invasive techniques like Duplex Doppler ultrasonography have gained importance (10).

Doppler ultrasound provides real-time assessment of portal venous flow, including parameters such as portal vein diameter, velocity, and congestion index (11,12). These parameters reflect hemodynamic changes associated with cirrhosis and portal hypertension (13).

Studies have shown that portal vein velocity decreases and diameter increases with worsening liver disease (14,15). Similarly, splenic parameters such as splenic index and spleno-portal index are valuable indicators of portal hypertension (16,17).

The Child-Pugh classification is widely used to assess severity of cirrhosis and predict prognosis (18). Correlating Doppler parameters with Child-Pugh classes can enhance clinical utility (19).
Variceal bleeding is one of the most serious complications of portal hypertension (20). Identifying patients at high risk using non-invasive methods is essential (21). Doppler indices such as congestion index and spleno-portal index have shown promise in predicting varices (22,23).

Exercise-induced changes in portal hemodynamics provide additional insight into vascular responsiveness and disease severity (24).

Despite advances, there remains a need for comprehensive evaluation of Doppler parameters in relation to disease severity and complications. This study aims to bridge this gap by systematically evaluating portal hemodynamics in cirrhotic patients.

MATERIALS AND METHODS

Study Design

This was a comparative cross-sectional study carried out in the Department of Radiodiagnosis, Dr. SMCSI Medical College and Hospital, Karakonam PO,Thiruvanthapuram,Kerala, India, for a period of 12 months (August 2023 – August 2024).

Study Population

- 55 diagnosed cases of liver cirrhosis
- 55 age- and gender-matched controls

Inclusion Criteria

Cirrhotic Patients

1. Clinically diagnosed cirrhosis
2. Undergoing portal vein Doppler
3. Child-Pugh classification available

Controls

- No hepatobiliary disease
- Referred for unrelated ultrasonography

Exclusion Criteria

1. Age <18 years
2. Cardiac disease
3. Hepatic malignancy
4. Post-surgical liver
5. Portal cavernoma
6. Pregnancy
7. Non-consenting patients

Sample Size

Minimum 75 per group calculated; however, 55 per group included.

Methodology

All participants underwent a structured methodology that included both ultrasound and Doppler assessments. The ultrasound evaluation focused on liver size, echotexture, and surface characteristics, along with assessment of splenic parameters. Doppler evaluation was performed to measure portal vein diameter, portal vein velocity, and cross-sectional area, and to calculate the congestion index. Additional parameters such as phasicity and direction of blood flow were also assessed. Furthermore, an exercise protocol was implemented, and post-exercise Doppler measurements were obtained following standardized physical activity to evaluate dynamic changes in portal venous hemodynamics.

Exercise Protocol
Post-exercise Doppler performed after standardized physical activity.

Additional Evaluation

- Upper GI endoscopy for varices
- Collateral circulation assessment

Statistical Analysis

Data expressed as mean ± SD and percentages, Comparative analysis between groups and Correlation with Child-Pugh class

RESULTS

In the present study majority of patients in the study were aged above 60 years, with a clear male predominance. Most patients had a disease duration of less than 3 years; however, the frequency and severity of complications were observed to increase progressively with longer disease duration. There was a significant increase in splenic and portal venous parameters among patients with cirrhosis, indicating the presence of portal hypertension. Additionally, a reduction in portal vein velocity was noted in advanced stages of the disease. A strong correlation was found between the spleno-portal index and the presence of varices, suggesting its potential role as a predictive marker. Furthermore, post-exercise Doppler findings demonstrated reduced vascular adaptability in cirrhotic patients, reflecting impaired hemodynamic response.

Table 1: Demographic Characteristics of Study Participants

DEMOGRAPHICS		**CASES**		**CONTROLS**	
		Frequency (n=55)	**Percentage (%)**	**Frequency (n=55)**	**Percentage (%)**
Age (years)	18-30	1	1.8	1	1.8
	31-40	5	9.1	5	9.1
	41-50	11	20.0	11	20.0
	51-60	9	16.4	9	16.4
	61-70	18	32.7	18	32.7
	>70	11	20.0	11	20.0
Total		**55**	**100**	**55**	**100**
GENDER	Male	40	72.7	40	72.7
	Female	15	27.3	15	27.3
Total		**55**	**100**	**55**	**100**

Table 2: Duration of Disease in Patients with Cirrhosis

	CASES	
	Frequency (n=55)	**Percentage (%)**
0-3 years	38	69.1
3-5 years	10	18.2
>5 years	7	12.7
Total	**55**	**100**

Table 3: Association of Disease Duration with Clinical Manifestations in cases

CLINICAL MANIFESTATIONS		**DISEASE DURATION**		
		0-3 YEARS	**3-5 YEARS**	**>5 YEARS**
UPPER GI BLEED	YES	4(10.5%)	2(20%)	5(71.4%)
	NO	34(89.5%)	8(80%)	2(28.6%)
	TOTAL	**38(100%)**	**10(100%)**	**7 (100%)**
JAUNDICE	YES	5(13.2%)	3(30%)	5(71.4%)
	NO	33(86.8%)	7(70%)	2(28.6%)
	TOTAL	**38(100%)**	**10(100%)**	**7(100%)**
BLEEDING P/R	YES	3(7.9%)	1(10%)	1 (14.3%)
	NO	35(92.1%)	9(90.0%)	6(85.7%)
	TOTAL	**38(100%)**	**10(100%)**	**7(100%)**
PEDAL OEDEMA	YES	10(26.3%)	5(50%)	2(28.6%)
	NO	28(73.7%)	5(50%)	5(71.4%)
	TOTAL	**38(100%)**	**10(100%)**	**7(100%)**

Table 4: Hepatitis status of Study Participants

HEPATITIS STATUS	CASES		CONTROLS	
	Frequency	**Percentage**	**Frequency**	**Percentage**
Negative	32	86.5	27	100
Hepatitis B	2	5.4	0	0
Hepatitis C	3	8.1	0	0
Total	**37**	**100**	**27**	**100**
Not done	18	-	28	-

Table 5: Comparison of Liver Parameters in Controls and Cases Among Child Pugh Classes

LIVER PARAMETERS		CONT-ROLS	CHILD PUGH CLASSES		
			A	**B**	**C**
LIVER SIZE	REDUCED	0 (0%)	0 (0%)	2 (16.7%)	0 (0%)
	NORMAL	55 (100%)	29 (78.4%)	8 (66.7%)	6 (100%)
	INCREASED	0 (0%)	8 (21.6%)	2 (16.7%)	0 (0%)
	TOTAL	**55 (100%)**	**37 (100%)**	**12 (100%)**	**6 (100%)**
CL/RL RATIO	NORMAL	55 (100%)	22 (59.5%)	6 (50.0%)	1 (16.7%)
	INCREASED	0(0%)	15 (40.5%)	6 (50.0%)	5 (83.3%)
	TOTAL	**55 (100%)**	**37 (100%)**	**12 (100%)**	**6 (100%)**

Table 6: Comparison of Splenic Parameters in Controls and Cases Among Child Pugh Classes

SPLENIC PARAMETERS		CONT-ROLS	CHILD PUGH CLASSES		
			A	**B**	**C**
SPLENIC INDEX	NORMAL	55 (100%)	16 (43.2%)	2 (16.7%)	0 (0%)
	INCREASED	0 (0%)	21 (56.8%)	10 (83.3%)	6 (100%)
	TOTAL	**55 (100%)**	**37 (100%)**	**12 (100%)**	**6 (100%)**
SPLENO PORTAL INDEX	NORMAL	55 (100%)	19 (51.4%)	2 (16.7%)	0 (0%)
	INCREASED	0 (0%)	18 (48.6%)	10 (83.3%)	6 (100%)
	TOTAL	**55 (100%)**	**37 (100%)**	**12 (100%)**	**6 (100%)**
SPLENIC SIDEROTIC BODIES	ABSENT	55 (100%)	34 (91.9%)	8 (66.7%)	3 (50.0%)
	PRESENT	0 (0%)	3 (8. 1%)	4 (33.3%)	3 (50.0%)
	TOTAL	**55 (100%)**	**37 (100%)**	**12 (100%)**	**6 (100%)**
SPLEEN VERTICAL DIAMETER	NORMAL	55 (100%)	20 (54.1%)	3 (25.0%)	0 (0%)
	INCREASED	0 (0%)	17 (45.9%)	9 (75%)	6 (100%)
	TOTAL	**55 (100%)**	**37 (100%)**	**12 (100%)**	**6 (100%)**

Table 7: Comparison of Pre-Exercise Portal Vein Parameters in Controls and Cases Among Child Pugh Classes

PRE-EXERCISE PV PARAMETERS		CONT-ROLS	CHILD PUGH CLASSES		
			A	B	C
PV DIAMETER	NORMAL	53 (96.4%)	25 (67.6%)	7 (58.3%)	2 (33.3%)
	INCREASED	2 (3.6%)	12 (32.4%)	5 (41.7%)	4 (66.7%)
	TOTAL	**55 (100%)**	**37 (100%)**	**12 (100%)**	**6 (100%)**
PV CSA	NORMAL	27 (49.1%)	14 (37.8%)	5 (41.7%)	0 (0%)
	INCREASED	28 (50.9%)	23 (62.2%)	7 (58.3%)	6 (100%)
	TOTAL	**55 (100%)**	**37 (100%)**	**12 (100%)**	**6 (100%)**
PV VELOCITY	REDUCED	0 (0%)	2 (5.4%)	4 (33.3%)	3 (50.0%)
	NORMAL	40 (72.7%)	33 (89.2%)	8 (66.7%)	3 (50.0%)
	INCREASED	15 (27.3%)	2 (5.4%)	0 (0%)	0 (0%)
	TOTAL	**55 (100%)**	**37 (100%)**	**12 (100%)**	**6 (100%)**
PV PHASICITY	NORMAL	55 (100%)	36 (97.3%)	10 (83.3%)	5 (83.3%)
	LOST	0 (0%)	1 (2.7%)	2 (16.7%)	1 (16.7%)
	TOTAL	**55 (100%)**	**37 (100%)**	**12 (100%)**	**6 (100%)**
PV FLOW DIRECTION	NORMAL	55 (100%)	37 (100%)	12 (100%)	6 (100%)

Table 8: Comparison of Liver Size, Echogenicity, Echotexture, and Surface Characteristics between Cases and Controls

		CASES		CONTROLS	
		Frequency (n=55)	**Percentage (%)**	**Frequency (n=55)**	**Percentage (%)**
LIVER SIZE	REDUCED	2	3.6	0	0
	NORMAL	43	78.2	55	100
	INCREASED	10	18.2	0	0
	TOTAL	**55**	**100**	**55**	**100**
ECHO-GENICITY	NORMAL	45	81.8	32	58.2
	GRADE 1	9	16.4	22	40.0
	GRADE 2	1	1.8	1	1.8
	TOTAL	**55**	**100**	**55**	**100**
ECHO-TEXTURE	NORMAL	5	9.1	55	100
	COARSE AND HETERO-GENEOUS	50	90.9	0	0
	TOTAL	**55**	**100**	**55**	**100**
SURFACE	SMOOTH	13	23.6	55	100.0
	NODULAR	42	76.4	0	0
	TOTAL	**55**	**100**	**55**	**100**

Table 9: Mean Values Of Liver, Spleen And Portal Vein Parameters -Pre And Post Exercise

		CASES	CONTROLS
		Mean ± SD	**Mean ± SD**
Liver	Liver size	13.21 ± 1.89	12.88 ± 1.21
	CL: RL RATIO	0.64 ± 0.16	0.49 ± 0.07
Spleen	SPLEEN VERTICAL DIAMETER (cm)	11.68 ± 2.34	8.53 ± 1.31
	SPLENIC INDEX (cm^2)	102.51 ± 41.27	44.55 ± 16.63
	SPLENOPORTAL INDEX (cm x sec)	4.83 ± 3.06	1.25 ± 0.46
Portal vein parameters pre-exercise	PV DIAMETER (mm)	12.45 ± 1.50	11.12 ± 1.26
	PV CSA (cm^2)	1.29 ± 0.37	1.12 ± 0.25
	PV VELOCITY (cm/sec)	25. 15 ± 8.06	37.11 ± 8. 32
	CONGESTION INDEX	0.06 ± 0.03	0.03 ± 0.01
Portal vein parameters post-exercise	PV DIAMETER (mm)	11.50 ± 1.61	9.84 ± 1.39
	PV CSA (cm^2)	1.12 ± 0.31	0.91 ± 0.23
	PV VELOCITY (cm/sec)	23.56 ± 8.08	33.92 ± 9.70
	CONGESTION INDEX	0.07 ± 0.11	0.03 ± 0.01

Table 10: Association of Spleno Portal Index (SPI) with the Presence of Collaterals on Ultrasound and Varices on Upper Gastrointestinal Endoscopy

		SPLENO PORTAL INDEX	
		NORMAL	**INCREASED**
COLLATERALS ON USG	ABSENT	14(66.7%)	4(11.8%)
	PRESENT	7(33.3%)	30(88.2%)
	Total	**21 (100%)**	**34 (100%)**
VARICES ON UPPER GI SCOPY	NORMAL	2(9.5%)	1(2.9%)
	GRADE 1	1(4.8%)	1 (2.9%)
	GRADE 2	0(0%)	12(35.3%)
	GRADE 3	0(0%)	4(11.8%)
	NOT DONE	18(85.7%)	16(47.1%)
	Total	**21 (100%)**	**34 (100%)**

Table 11: Distribution of Pre-Exercise PV Parameters in Cases and Controls

Pre-Exercise PV Parameters		**CASES**		**CONTROLS**	
		Frequency (n=55)	**Percentage (%)**	**Frequency (n=55)**	**Percentage (%)**
PV DIAMETER	Normal	34	61.8	53	96.4
	Increased	21	38.2	2	3.6
	Total	**55**	**100**	**55**	**100**
PV CSA	Normal	19	34.5	27	49.1
	Increased	36	65.5	28	50.9
	Total	**55**	**100**	**55**	**100**
PV FLOW DIRECTION	Normal	55	100	55	100
PV VELOCITY	Reduced	9	16.4	0	0
	Normal	44	80.0	40	72.7
	Increased	2	3.6	15	27.3
	Total	**55**	**100**	**55**	**100**
PV PHASICITY	Normal	51	92.7	55	100
	Lost	4	7.3	0	0
	Total	**55**	**100**	**55**	**100**

Table 12: Distribution of Changes in post exercise PV parameters in comparison to pre-exercise parameters in Cases and Controls

Changes in post exercise PV paraneters in comparison to pre-exercise parameters		CASES		CONTROLS	
		Frequency (n=55)	Percentage (%)	Frequency (n=55)	Percentage (%)
PV DIAMETER	No change	4	7.3	0	0
	Decreased	47	85.5	52	94.5
	Increased	4	7.3	3	5.5
	Total	**55**	**100**	**55**	**100**
PV CSA	No change	1	1.9	0	0
	Decreased	46	85.2	52	94.4
	Increased	7	13	3	5.6
	Total	**55**	**100**	**55**	**100**
PV VELOCITY	Decreased	41	74.5	47	85.5
	Increased	14	25.5	8	14.5
	Total	**55**	**100**	**55**	**100**

Table 13: Changes in Pre-Exercise Portal Vein (PV) Parameters with Upper Gastrointestinal (UGI) Scopy

PRE- EXERCISE PORTAL VEIN (PV) PARAMETERS		VARICES ON UGI SCOPY	
		ABSENT	PRESENT
PV DIAMETER	NORMAL	2(66.7%)	11(61.1%)
	INCREASED	1(33.3%)	7(38.9%)
	TOTAL	**3 (100%)**	**18 (100%)**
PV CSA	NORMAL	2(66.7%)	6 (33.3%)
	INCREASED	1(33.3%)	12(66.7%)
	TOTAL	**3 (100%)**	**18 (100%)**
PV VELOCITY	NORMAL	2 (66.7%)	11 (61.1%)
	REDUCED	1(33.3%)	7(38.9%)
	TOTAL	**3 (100%)**	**18 (100%)**

Table 14: Association Between Congestion Index and Collaterals on USG in cirrhosis cases

		COLLATERALS	
		ABSENT	**PRESENT**
CONGES-TION INDEX	**NORMAL**	18 (100%)	30(81.1%)
	INCREASED	0(0%)	7(18.9%)
	Total	**18(100%)**	**37(100%)**

Table 15: Association Between Congestion Index and Presence of Varices in Upper GI Scopy

		UPPER GI SCOPY- VARICES	
		ABSENT	**PRESENT**
CONGESTION INDEX	**NORMAL**	2(66.7%)	13(72.2%)
	INCREASED	1 (33.3%)	5(27.8%)
	TOTAL	**3 (100%)**	**18(100%)**

DISCUSSION

The present study provides a comprehensive evaluation of portal venous hemodynamics in cirrhotic patients using Duplex Doppler ultrasonography and highlights its correlation with disease severity and complications such as varices and collateral formation. The findings reinforce the importance of non-invasive imaging in the assessment of portal hypertension, which remains a major determinant of prognosis in chronic liver disease.

In this study, the majority of patients were in the older age group, particularly between 61–70 years, with a clear male predominance. This observation is consistent with previous epidemiological studies which report a higher prevalence of cirrhosis among males due to increased exposure to etiological factors such as alcohol consumption and viral hepatitis (1,2). Similar demographic patterns have been reported by Sharma et al. and Chawla et al., supporting the generalizability of our findings (28,29).

The duration of disease showed a significant association with clinical manifestations. Patients with longer duration (>5 years) demonstrated a markedly higher incidence of complications such as upper gastrointestinal bleeding and jaundice. This reflects the progressive nature of cirrhosis, where increasing portal pressure leads to the development of

portosystemic collaterals and varices (3,4). These findings are in agreement with studies by D'Amico et al., which demonstrated that the risk of decompensation increases significantly over time (20).

One of the key findings of this study was the alteration in liver morphology with increasing disease severity. The majority of cirrhotic patients demonstrated coarse echotexture and nodular surface, which are well-recognized sonographic features of cirrhosis (10,11). The caudate-to-right lobe ratio (CL/RL ratio) was found to be significantly increased in advanced Child-Pugh classes, indicating progressive architectural distortion. Previous studies have also highlighted the diagnostic utility of this ratio in differentiating cirrhotic from non-cirrhotic livers (14,15).

Splenic parameters showed a strong correlation with disease severity. Splenomegaly, increased splenic index, and spleno-portal index were significantly more common in advanced cirrhosis. This is attributable to increased portal pressure leading to congestion of the splenic vein and enlargement of the spleen (16,17). The progressive increase in splenic vertical diameter and presence of splenic siderotic bodies further indicate chronic portal hypertension. These findings are consistent with earlier studies that emphasize the role of splenic parameters as indirect markers of portal hypertension (22,23).

The Doppler evaluation of portal vein hemodynamics revealed significant differences between cirrhotic patients and controls. Portal vein diameter and cross-sectional area were increased in cirrhotic patients, reflecting dilatation due to elevated portal pressure. Similar observations have been reported in multiple studies, where increased portal vein diameter has been associated with portal hypertension (12,13).

Portal vein velocity was significantly reduced in cirrhotic patients, particularly in advanced Child-Pugh classes. This reduction in velocity is a consequence of increased intrahepatic resistance and impaired forward flow (5,6). Previous studies have demonstrated that portal vein velocity is inversely related to portal pressure and can serve as a useful indicator of disease severity (14,15). The presence of reduced velocity predominantly in advanced disease stages further supports its prognostic significance.

The congestion index, defined as the ratio of portal vein cross-sectional area to velocity, was significantly higher in cirrhotic patients. An increased congestion index indicates sluggish blood flow and venous stasis, which are characteristic features of portal hypertension (11). Our findings are in agreement with studies by Moriyasu et al., who first described the utility of congestion index in assessing portal hypertension (11).

An important observation in this study was the loss of portal vein phasicity in a subset of cirrhotic patients. Normally, portal vein flow demonstrates mild phasic variation with respiration; however, in cirrhosis, this phasicity is often lost due to increased vascular resistance and reduced compliance (12). This finding further supports the presence of advanced hemodynamic alterations in cirrhosis.

The spleno-portal index (SPI) emerged as a strong predictor of portal hypertension and its complications. Patients with increased SPI had a significantly higher prevalence of collaterals and higher grades of esophageal varices. This suggests that SPI can serve as a reliable, non-invasive marker for predicting variceal risk (22,23). Similar findings have been reported in studies by Kim et al., which demonstrated a strong correlation between SPI and portal hypertension severity (22).

The association between Doppler parameters and varices was particularly noteworthy. Increased portal vein cross-sectional area and reduced velocity were more commonly observed in patients with varices. This indicates that Doppler parameters can be used as surrogate markers for identifying patients at risk of variceal bleeding (21). Early identification of such patients is crucial for timely prophylactic intervention.

Post-exercise Doppler evaluation provided additional insights into vascular responsiveness. In healthy individuals, exercise leads to adaptive changes in portal hemodynamics; however, in cirrhotic patients, this response is blunted. The majority of cirrhotic patients showed a decrease in portal vein diameter and velocity, but the extent of change was less compared to controls. This reduced adaptability reflects impaired vascular compliance and altered hemodynamic regulation in cirrhosis (24).

The findings of this study are consistent with the pathophysiological understanding of portal hypertension, where increased intrahepatic resistance and splanchnic vasodilation contribute to altered hemodynamics (6,7). Duplex Doppler ultrasound provides a non-invasive means of assessing these changes and offers valuable clinical information.

Comparison with existing literature shows strong agreement with previous studies. For instance, Bolondi et al. demonstrated the utility of Doppler ultrasound in assessing portal hemodynamics (10), while Berzigotti et al. emphasized

its role in non-invasive evaluation of portal hypertension (9). Similarly, studies by Singh et al. and Tarantino et al. have highlighted the importance of splenic parameters in predicting portal hypertension (16,17).

Overall, this study reinforces the role of Duplex Doppler ultrasound as a valuable diagnostic and prognostic tool in cirrhosis. It not only helps in assessing disease severity but also aids in predicting complications such as varices and collateral formation. Given its non-invasive nature, wide availability, and cost-effectiveness, Doppler ultrasound can be routinely incorporated into the evaluation of cirrhotic patients.

CONCLUSION

This study demonstrates that Duplex Doppler ultrasonography is a highly effective, non-invasive modality for evaluating portal venous hemodynamics in patients with liver cirrhosis. Significant alterations in portal vein diameter, velocity, congestion index, and spleno-portal index were observed in cirrhotic patients compared to controls. These changes showed a strong correlation with disease severity as assessed by Child-Pugh classification and with complications such as varices and collateral formation.

Among the evaluated parameters, spleno-portal index and congestion index emerged as reliable predictors of portal hypertension and variceal risk. Additionally, post-exercise Doppler evaluation revealed impaired vascular adaptability in cirrhotic patients, further highlighting disease-related hemodynamic dysfunction.

Thus, Duplex Doppler ultrasound can serve as an essential tool in the routine assessment, risk stratification, and follow-up of patients with liver cirrhosis, potentially reducing the need for invasive procedures.

LIMITATIONS OF THE STUDY

1. The sample size was relatively small, which may limit the generalizability of the findings.
2. Being a single-center study, results may not reflect broader population variations.
3. Not all patients underwent hepatitis profiling, limiting etiological correlation.
4. Upper gastrointestinal endoscopy was not performed in all cases, restricting complete assessment of varices.
5. Lack of longitudinal follow-up prevented evaluation of disease progression and outcomes over time.
6. Interobserver variability in Doppler measurements was not assessed.
7. Exercise protocol standardization may vary between individuals, affecting post-exercise measurements.

DECLARATIONS

Conflicts of interest: There is no any conflict of interest associated with this study
Consent to participate: There is consent to participate.
Consent for publication: There is consent for the publication of this paper.
Authors contributions: Author equally contributed the work.

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