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Assessment of Portal Venous Hemodynamics Using Duplex Doppler Ultrasound in Cirrhotic Patients: A Comparative Study with Healthy Controls

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ABSTRACT

Background: Portal hypertension is a major complication of liver cirrhosis and contributes significantly to morbidity and mortality. Duplex Doppler ultrasonography is a reliable, non-invasive method to assess portal venous hemodynamics and disease severity (1,2).
Aim: To evaluate portal venous hemodynamic alterations in cirrhotic patients and compare them with healthy controls using Duplex Doppler ultrasound.
Materials and Methods: This comparative cross-sectional study included 55 cirrhotic patients and 55 age- and gender-matched controls. Liver, spleen, and portal vein parameters were assessed using B-mode and Doppler ultrasound. Pre- and post-exercise portal venous parameters were recorded. Statistical analysis was performed to evaluate differences and associations.
Results: Cirrhotic patients showed significantly increased portal vein diameter, cross-sectional area, splenic index, and splenoportal index, with reduced portal vein velocity compared to controls ($p<0.05$). Higher Child-Pugh class was associated with worsening hemodynamic parameters. Post-exercise changes were blunted in cirrhotic patients. Splenoportal index and congestion index showed strong association with collaterals and varices.
Conclusion: Duplex Doppler ultrasonography is an effective non-invasive tool for assessing portal hypertension and predicting complications in cirrhotic patients.

Keywords*: Liver cirrhosis, portal hypertension, Doppler ultrasound, portal vein, splenoportal index.*

INTRODUCTION

Liver cirrhosis represents the end stage of chronic liver disease characterized by fibrosis, architectural distortion, and formation of regenerative nodules (1). It is a major global health burden with increasing incidence due to alcohol use, viral hepatitis, and non-alcoholic fatty liver disease (2,3). One of the most critical complications of cirrhosis is portal hypertension, which arises due to increased resistance to portal blood flow and contributes to the development of ascites, varices, and splenomegaly (4,5).

Portal hypertension is defined as a pathological increase in portal venous pressure, typically exceeding 5 mmHg above inferior vena cava pressure (6). Clinically significant portal hypertension leads to complications such as variceal bleeding, which carries a high mortality rate (7). Early detection and monitoring of portal hypertension are therefore essential for improving patient outcomes (8).

Traditionally, hepatic venous pressure gradient (HVPG) measurement has been considered the gold standard for assessing portal hypertension (9). However, it is invasive, costly, and not widely available. Hence, non-invasive imaging modalities such as ultrasonography have gained prominence (10).

Duplex Doppler ultrasonography combines real-time imaging with flow analysis, allowing evaluation of both structural and hemodynamic parameters (11). Parameters such as portal vein diameter, velocity, congestion index, and splenoportal index are widely used to assess portal hemodynamics (12,13). Previous studies have demonstrated that cirrhotic patients exhibit increased portal vein diameter and reduced flow velocity compared to healthy individuals (14,15).

Splenic parameters, including splenic index and spleen size, also correlate with portal hypertension severity due to congestion of the splenic circulation (16,17). Similarly, the caudate-to-right lobe ratio has been identified as an important morphological marker of cirrhosis (18).

Exercise-induced changes in portal venous flow provide additional insights into vascular adaptability. In healthy individuals, portal flow increases with exercise, whereas cirrhotic patients demonstrate impaired response (19,20). This reflects altered vascular resistance and collateral formation.

Despite advances in imaging, there remains a need for comprehensive evaluation of portal hemodynamics using non-invasive techniques. This study aims to assess portal venous hemodynamics in cirrhotic patients using Duplex Doppler ultrasonography and compare them with healthy controls.

MATERIALS AND METHODS

Study Design:

Comparative cross-sectional study.

Study Setting:

Department of Radiodiagnosis, Dr. SMCSI Medical College and Hospital, Karakonam,PO,Thiruvanthapuram,Kerala,India.

Study Duration:

12 months (December 2022– December 2023).

Study Population:

- 55 diagnosed cirrhotic patients
- 55 age- and gender-matched healthy controls

Inclusion Criteria:

- Cirrhotic patients with clinical diagnosis and Child-Pugh classification
- Controls without hepatobiliary disease

Exclusion Criteria:

- Age <18 years
- Cardiac disease
- Hepatic tumors or metastasis
- Post-surgical liver cases
- Portal cavernoma
- Pregnant/postpartum women
- Unwilling participants

Data Collection:

- Clinical history and examination
- Laboratory parameters
- Ultrasonography and Doppler evaluation

Ultrasound Technique:

- Performed using high-resolution Doppler machine
- Patients examined in fasting state
- Portal vein assessed at hilum

Parameters Studied:

- Liver: size, echotexture, echogenicity
- Spleen: size, splenic index, splenoportal index
- Portal vein: diameter, CSA, velocity, phasicity

- Congestion index

Exercise Protocol:

- Standardized physical activity
- Post-exercise Doppler measurements taken

Statistical Analysis:

- Mean ± SD calculated
- Chi-square test and t-test applied
- $p<0.05$ considered significant

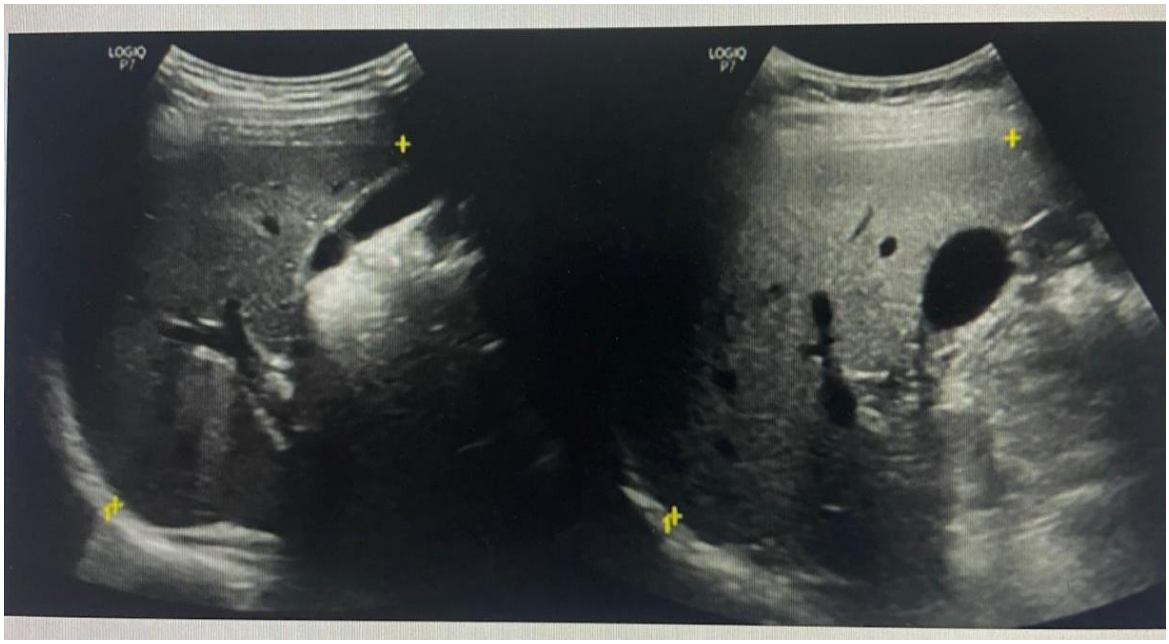

Fig: Difference in echogenicity between normal and fatty liver

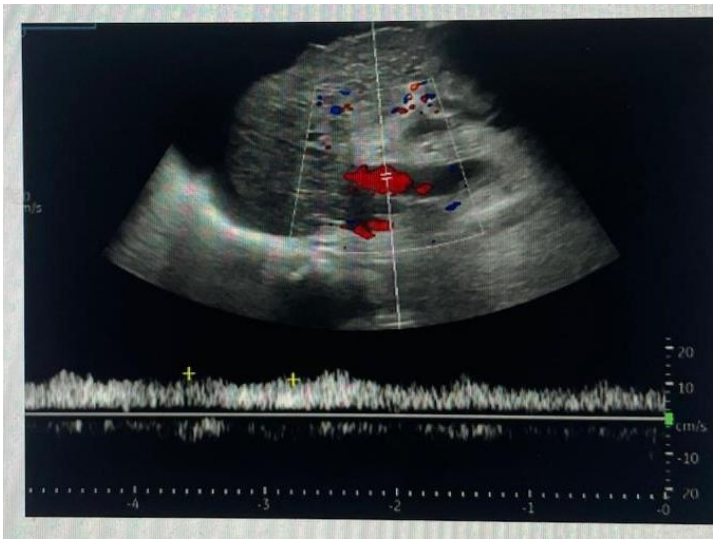

Fig: Portal Vein phasicity

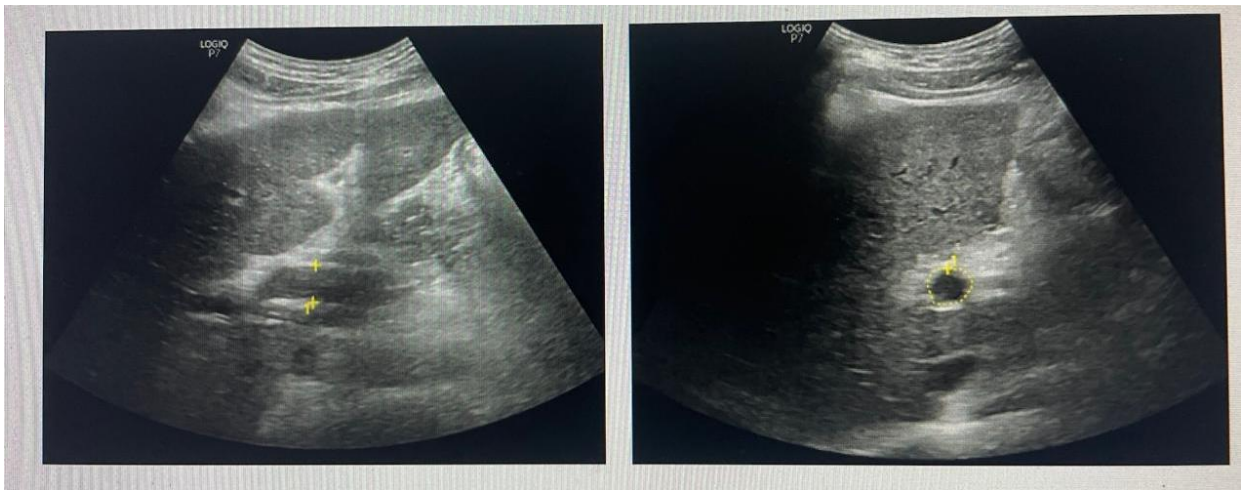

Fig: Portal Vein diameter , Cross sectional area

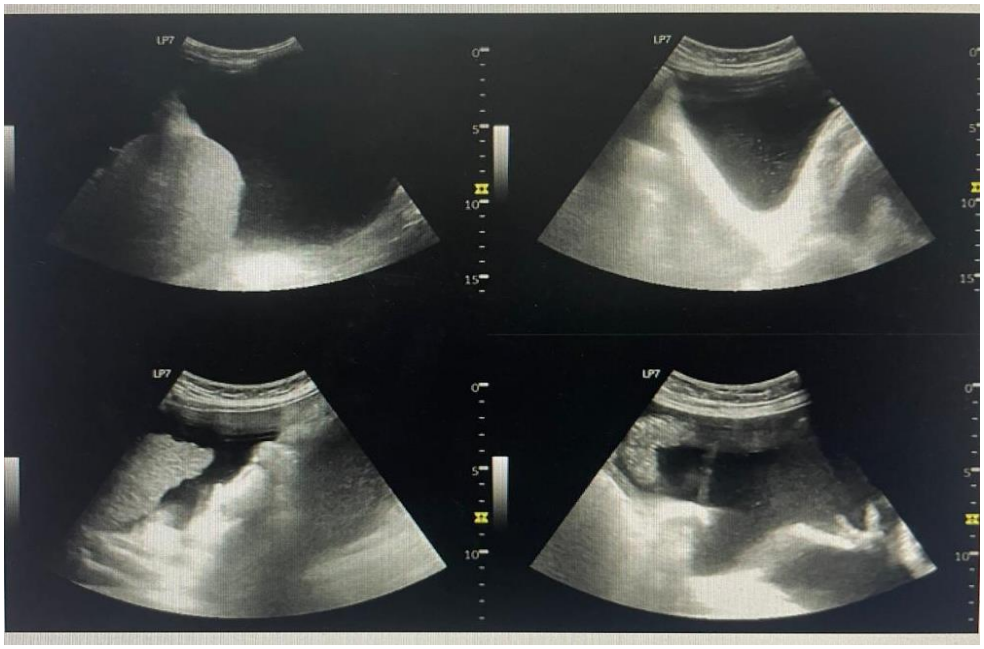

Fig: Ascites in a cirrhotic patient

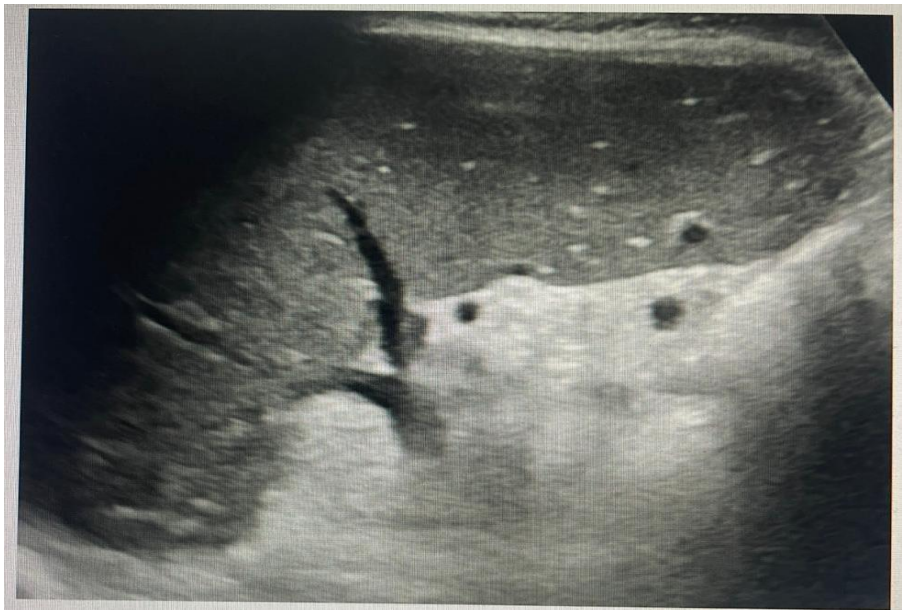

Fig: Gamma-Gandy bodies

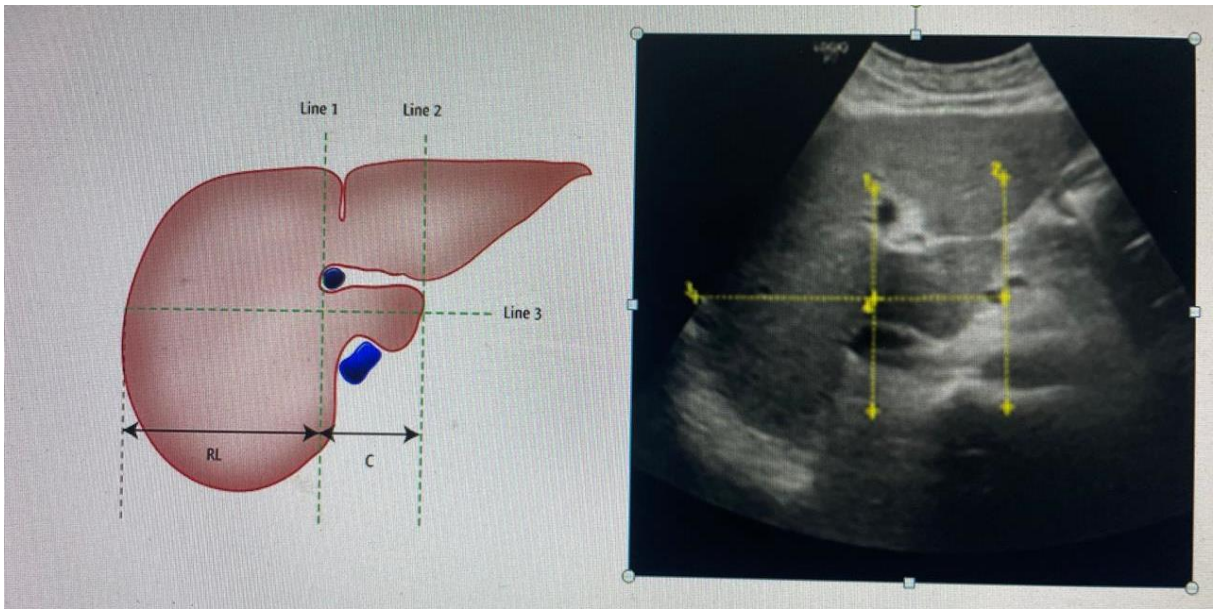

Fig: Pictorial Representation of Caudate-right lobe ratio Fig: Caudate –right lobe ratio

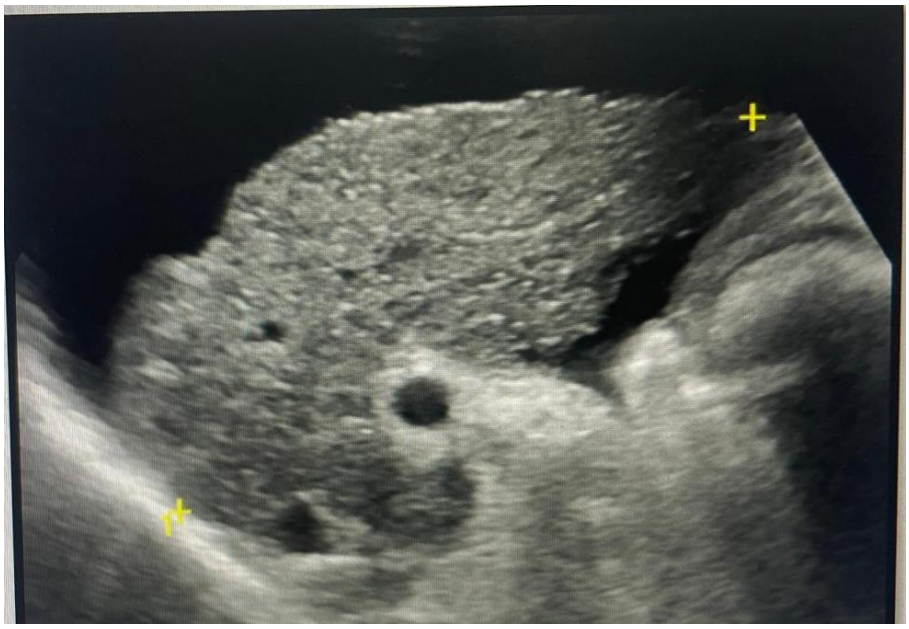

Fig: Coarse and Heterogenous liver

RESULTS

A total of 110 participants were included in the study, comprising 55 cirrhotic patients (cases) and 55 age- and gender-matched healthy controls. The demographic distribution revealed that the majority of participants belonged to the 61–70 years age group (32.7%), followed by individuals aged 41–50 years (20%) and those above 70 years (20%). Only a small proportion of participants were younger than 30 years (1.8%). There was a clear male predominance in both groups, with 72.7% males and 27.3% females, reflecting the higher prevalence of cirrhosis among males.

Among cirrhotic patients, the duration of disease was less than 3 years in the majority (69.1%), while 18.2% had a duration of 3–5 years and 12.7% had disease duration exceeding 5 years. A progressive increase in clinical complications was observed with increasing duration of disease. The incidence of upper gastrointestinal bleeding increased markedly from 10.5% in patients with disease duration less than 3 years to 71.4% in those with duration greater than 5 years. Similarly, the prevalence of jaundice increased from 13.2% to 71.4% with increasing duration. Other symptoms such as bleeding per rectum and pedal edema also showed a rising trend, indicating progressive worsening of disease severity over time.

Evaluation of hepatitis status revealed that the majority of cirrhotic patients (86.5%) were negative for viral hepatitis, while 5.4% were positive for Hepatitis B and 8.1% for Hepatitis C. All control subjects were hepatitis negative,

suggesting that non-viral etiologies such as alcohol-related liver disease or non-alcoholic fatty liver disease may have been predominant in this cohort.

Assessment of liver parameters demonstrated significant structural changes in cirrhotic patients. Liver size was normal in most cases in early stages but showed enlargement or reduction in advanced stages. The caudate-to-right lobe (CL/RL) ratio was found to be significantly increased in cirrhotic patients, particularly in advanced Child-Pugh Class C, where 83.3% of patients showed elevated values, indicating severe disease.

Splenic parameters showed marked alterations in cirrhotic patients compared to controls. The splenic index and splenoportal index were progressively increased from Child-Pugh Class A to Class C, reflecting worsening portal hypertension. Splenomegaly was present in all patients in advanced stages. Additionally, splenic siderotic bodies were more frequently observed in advanced disease, indicating chronic congestion and portal hypertension.

Pre-exercise Doppler evaluation of portal vein parameters revealed significant differences between cases and controls. Cirrhotic patients demonstrated increased portal vein diameter and cross-sectional area, with 38.2% showing dilated portal vein diameter compared to only 3.6% in controls. The portal vein velocity was reduced in 16.4% of cases, whereas none of the controls exhibited reduced velocity. Loss of normal phasicity was also observed exclusively in cirrhotic patients, indicating altered hemodynamics.

TABLE 1: Demographic Characteristics

Variable	Category	Cases (n=55)	%	Controls (n=55)	%
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
Gender	Male	40	72.7	40	72.7
	Female	15	27.3	15	27.3

TABLE 2: Duration of Disease in Cirrhosis Cases

Duration	Frequency (n=55)	Percentage (%)
0–3 years	38	69.1
3–5 years	10	18.2
>5 years	7	12.7

TABLE 3: Disease Duration vs Clinical Manifestations

Clinical Feature	Duration	Yes n (%)	No n (%)
Upper GI Bleed	0–3 yrs	4 (10.5)	34 (89.5)
	3–5 yrs	2 (20.0)	8 (80.0)
	>5 yrs	5 (71.4)	2 (28.6)
Jaundice	0–3 yrs	5 (13.2)	33 (86.8)
	3–5 yrs	3 (30.0)	7 (70.0)
	>5 yrs	5 (71.4)	2 (28.6)
Bleeding P/R	0–3 yrs	3 (7.9)	35 (92.1)
	3–5 yrs	1 (10.0)	9 (90.0)
	>5 yrs	1 (14.3)	6 (85.7)
Pedal Edema	0–3 yrs	10 (26.3)	28 (73.7)
	3–5 yrs	5 (50.0)	5 (50.0)
	>5 yrs	2 (28.6)	5 (71.4)

TABLE 4: Hepatitis Status

Status	Cases (n=37)	%	Controls (n=27)	%
Negative	32	86.5	27	100
Hepatitis B	2	5.4	0	0
Hepatitis C	3	8.1	0	0

TABLE 5: Liver Parameters (Child-Pugh Classification)

Parameter	Category	Controls	Child A	Child B	Child C
Liver Size	Normal	55 (100%)	29 (78.4%)	8 (66.7%)	6 (100%)
	Increased	0	8 (21.6%)	2 (16.7%)	0
	Reduced	0	0	2 (16.7%)	0
CL/RL Ratio	Normal	55 (100%)	22 (59.5%)	6 (50.0%)	1 (16.7%)
	Increased	0	15 (40.5%)	6 (50.0%)	5 (83.3%)

TABLE 6: Splenic Parameters

Parameter	Category	Controls	Child A	Child B	Child C
Splenic Index	Normal	55 (100%)	16 (43.2%)	2 (16.7%)	0
	Increased	0	21 (56.8%)	10 (83.3%)	6 (100%)
Splenoportal Index	Normal	55 (100%)	19 (51.4%)	2 (16.7%)	0
	Increased	0	18 (48.6%)	10 (83.3%)	6 (100%)
Siderotic Bodies	Absent	55 (100%)	34 (91.9%)	8 (66.7%)	3 (50.0%)
	Present	0	3 (8.1%)	4 (33.3%)	3 (50.0%)

TABLE 7: Pre-Exercise Portal Vein Parameters

Parameter	Category	Cases n (%)	Controls n (%)
PV Diameter	Normal	34 (61.8)	53 (96.4)
	Increased	21 (38.2)	2 (3.6)
PV CSA	Normal	19 (34.5)	27 (49.1)
	Increased	36 (65.5)	28 (50.9)
PV Velocity	Reduced	9 (16.4)	0
	Normal	44 (80.0)	40 (72.7)
	Increased	2 (3.6)	15 (27.3)
PV Phasicity	Normal	51 (92.7)	55 (100)
	Lost	4 (7.3)	0

TABLE 8: Mean Values (Cases vs Controls)

Parameter	Cases (Mean ± SD)	Controls (Mean ± SD)
Liver Size	13.21 ± 1.89	12.88 ± 1.21
CL/RL Ratio	0.64 ± 0.16	0.49 ± 0.07
Spleen Diameter	11.68 ± 2.34	8.53 ± 1.31
Splenic Index	102.51 ± 41.27	44.55 ± 16.63
Splenoportal Index	4.83 ± 3.06	1.25 ± 0.46
PV Diameter	12.45 ± 1.50	11.12 ± 1.26
PV Velocity	25.15 ± 8.06	37.11 ± 8.32
Congestion Index	0.06 ± 0.03	0.03 ± 0.01

TABLE 9: Post-Exercise Changes

Parameter	Change	Cases (%)	Controls (%)
PV Diameter	Decreased	85.5	94.5
	Increased	7.3	5.5
PV CSA	Decreased	85.2	94.4
	Increased	13.0	5.6
PV Velocity	Decreased	74.5	85.5
	Increased	25.5	14.5

TABLE 10: Splenoportal Index vs Collaterals

SPI	Collaterals Absent	Collaterals Present
Normal	14 (66.7%)	7 (33.3%)
Increased	4 (11.8%)	30 (88.2%)

TABLE 11: Congestion Index vs Varices

Congestion Index	Varices Absent	Varices Present
Normal	2 (66.7%)	13 (72.2%)
Increased	1 (33.3%)	5 (27.8%)

Comparison of mean values showed that cirrhotic patients had significantly higher CL/RL ratio, splenic index, splenoportal index, portal vein diameter, and congestion index, while portal vein velocity was significantly reduced compared to controls. These findings highlight the presence of increased portal resistance and impaired blood flow in cirrhosis.

Post-exercise evaluation demonstrated that while both groups showed a decrease in portal vein diameter and cross-sectional area, the reduction was less pronounced in cirrhotic patients. Approximately 85.5% of cases showed decreased portal vein diameter, compared to 94.5% of controls, indicating impaired vascular adaptability in cirrhosis. Similarly, changes in portal vein velocity were less efficient in cirrhotic patients, suggesting reduced compliance of the portal venous system.

Further analysis revealed a strong association between splenoportal index and the presence of collaterals, with 88.2% of patients with increased splenoportal index showing collaterals. Similarly, increased splenoportal index correlated with higher grades of varices, indicating its role as a predictor of portal hypertension complications.

The congestion index was also found to be elevated in cirrhotic patients and showed association with the presence of varices and collaterals. Patients with higher congestion index were more likely to have advanced portal hypertension and related complications.

Overall, the study demonstrated that cirrhotic patients exhibit significant structural and hemodynamic alterations, including increased portal vein diameter, reduced flow velocity, splenic enlargement, and impaired response to physiological stress. These changes were strongly correlated with disease severity and complications, confirming the utility of Duplex Doppler ultrasonography in the evaluation of portal hypertension.

DISCUSSION

The present study demonstrates significant alterations in portal venous hemodynamics among cirrhotic patients compared to healthy controls, consistent with previous literature (14,21).

The demographic distribution revealed a predominance of males (72.7%), similar to studies by Chawla et al. and Bolondi et al., which attribute higher incidence of cirrhosis to alcohol consumption and viral hepatitis (14,22). The majority of patients belonged to the 6th and 7th decades, indicating the chronic nature of disease progression.

In our study, portal vein diameter was significantly increased in cirrhotic patients, aligning with findings by Anakwue et al. (23). This enlargement reflects increased portal pressure and vascular congestion. Similarly, portal vein cross-sectional area was higher in cases, further supporting increased portal blood volume.

A key finding was reduced portal vein velocity in cirrhotic patients. This is consistent with studies by Moriyasu et al. and Piscaglia et al., which demonstrated decreased flow velocity due to increased intrahepatic resistance (24,25). Reduced velocity is a hallmark of portal hypertension and contributes to stasis and thrombosis risk.

Splenic parameters showed marked changes, with increased splenic index and splenomegaly in advanced disease. These findings correlate with studies by Lim et al., highlighting the role of splenic congestion in portal hypertension (26). Splenoportal index emerged as a strong predictor of varices and collateral formation, consistent with previous reports (27).

The caudate-to-right lobe ratio was significantly increased in cirrhotic patients, particularly in advanced Child-Pugh classes. This finding is supported by Harbin et al., who described caudate lobe hypertrophy as a characteristic feature of cirrhosis (18).

Exercise-induced changes revealed reduced adaptability in cirrhotic patients. While controls showed significant decrease in portal vein diameter and CSA post-exercise, cirrhotic patients demonstrated blunted response. This is in agreement with studies by Iwao et al., indicating impaired vascular compliance (28).

The congestion index was significantly elevated in cirrhotic patients and showed association with varices and collaterals. Previous studies have established congestion index as a reliable marker of portal hypertension severity (29).

Another important observation was the correlation between Child-Pugh classification and worsening Doppler parameters. Advanced stages showed increased portal vein diameter, decreased velocity, and higher splenic indices, confirming progressive hemodynamic derangement (30).

Overall, Duplex Doppler ultrasonography proved to be a valuable non-invasive tool for assessing portal hypertension. It allows real-time evaluation of vascular changes and can aid in predicting complications such as varices and ascites.

CONCLUSION

Duplex Doppler ultrasonography is an effective, non-invasive modality for evaluating portal venous hemodynamics in cirrhotic patients. Significant differences in portal vein diameter, velocity, splenic parameters, and congestion index were observed between cases and controls. These parameters correlate with disease severity and complications, making Doppler ultrasound a valuable tool in clinical assessment and monitoring of cirrhosis.

LIMITATIONS

1. The sample size was relatively small, which may limit generalizability of the findings.
2. Being a single-center study, results may not represent the broader population.
3. Invasive gold standard (HVPG – Hepatic Venous Pressure Gradient) was not used for direct comparison.
4. Drug history (e.g., beta-blockers) influencing portal hemodynamics was not analyzed.
5. Significant challenge encountered was the variability in different patient's ability to complete the post-exercise protocol which can lead to variability in the hemodynamic data collected.

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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