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Doppler Ultrasonography Assessment Of Hepatic Vein And Portal Vein Parameters In Portal Hypertension

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Abstract:
Background*: Portal hypertension is a routinely observed clinical condition that develops due to various hepatic and extrahepatic conditions. The main objective of this study is to assess the hepatic parenchyma and spectrum of vascular hemodynamic changes in patients with portal hypertension using Duplex ultrasonography before and after beta blocker (i.e. Propranolol). Ultrasonography plays an important role in the diagnosis and follows up of Portal hypertension patients.*
Materials and Methods*: In this non randomized controlled study without control, 50 patients of suspected of having portal hypertension on clinical basis belonging to age group of 24 to 87 years. Doppler ultrasound was performed and flow hemodynamics in hepatic veins and portal vein was assessed before and after propranolol.*
Results*: A prospective study involving 50 patients diagnosed with portal hypertension was conducted at S Nijalingappa Medical College and HSK Hospital and Research Centre in Bagalkot, Karnataka, within the Department of Radio-Diagnosis. Male to Female ratio shows a higher prevalence of males, which is linked to Alcoholic Liver Disease. The patients belonged to age group ranging from 24 to 87 years. Patients were then evaluated using Duplex-Doppler Ultrasound with the 3.5 MHz curvilinear transducer. Our research revealed a significant relationship between disease severity and the dampening of hepatic venous waveforms observed through spectral Doppler. Notably, 91% of patients exhibited improvement in their baseline hepatic waveforms, which corresponded with clinical improvements.*
Conclusion: *Portal hypertension is a commonly observed condition with various underlying causes. Doppler ultrasonography is an excellent non-invasive diagnostic method in evaluation of portal hypertension, its causes and its complications like splenomegaly, ascites and collateral vessels.*
Key Word: *Portal hypertension, Ultrasound, Color Doppler study, Propranolol.*

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I. Introduction

Portal hypertension is a routinely observed clinical condition that develops due to various hepatic and extrahepatic conditions. The main objective of this study is to assess the hepatic parenchyma and spectrum of vascular hemodynamic changes in patients with portal hypertension using Duplex ultrasonography. Before and after propranolol therapy, ultrasound plays a key role in diagnosing and following up Portal hypertension patients.

II. Material And Methods

This prospective comparative study was carried out on patients of Department of Radio-Diagnosis at Sri Nijalingappa Medical College and HSK Hospital & Research Center, Bagalkot from April 2023 to January 2025. A total 50 adult subject (both male and females) of aged ≥ 18, years were for in this study.

Study Design: It is a hospital based non randomized controlled study without control.

Study Location: This was a tertiary care teaching hospital based study done in Department of Radio-Diagnosis, at Sri Nijalingappa Medical College and HSK Hospital & Research center, Bagalkot, Karnataka.

Study Duration: April 2023 to January 2025.

Sample size: 50 patients.

Sample size calculation: The sample size was estimated on the basis of a single proportion design. Sample size estimation was done using open epi software version 2.3.1. Formula used: Sample size (n) based on sensitivity = $[DEFF\ X$ Np $(1-p)][dz21-\alpha22\ X$ (N−1)$+p\ X\ (1-p)]$ At 95% confidence level, According to the systematic review conducted by Surekha G 60, The proportion of portal hypertension patients with abnormal biphasic waveforms in Doppler ultrasound 50% = p, At 15%, absolute precision[4], Sample size estimated is 50.

Subjects & selection method: The study population was drawn from patients of suspected of having portal hypertension on clinical basis who presented to Department of Radio-Diagnosis, at Sri Nijalingappa Medical College and HSK Hospital & Research center, Bagalkot, Karnataka.

Inclusion criteria:
1) Patients with Portal hypertension.
2) Patients of both genders and from all age groups referred to the HSK Hospital are included.

Exclusion criteria:
1) Patients with Hepato cellular carcinoma, Hepatic encephalopathy, Thrombosis in IVC, hepatic vein or portal vein, Congestive heart failure.
2) Patients with asthma, chronic obstructive pulmonary disease (COPD), atrioventricular block, intermittent claudication and psychosis.
3) Patients with portal hypertension who are already on propranolol.

Procedure methodology:

After written informed consent was obtained, after receiving approval from Ethical Committee of SNMC, Bagalkot. Patients undergo Ultrasound Doppler of abdomen on Philip EPIQ 5G machine. Scans are acquired with a 5 2MHz curved array transducer. The USG Doppler findings of hepatic vein waveform, Portal vein diameter (size), Direction of flow and PSV are recorded in patients with portal hypertension[1].

All the patients of portal hypertension will be started with oral propranolol after the initial Doppler ultrasonography. The treatment response is studied with Doppler ultrasonography of hepatic vein. All the patients treated with oral Propranolol (PPNL) and follow up hepatic venous waveform is taken every 15 days up to 30 to 60 days.

Patients with portal hypertension were included in this study. There were no limitations to the study with respective age and sex. All the patients were started with oral propranolol after the initial Doppler ultrasonography. The treatment response was studied with hepatic venous waveform. The patients were evaluated using Doppler ultrasound with a 3.5MHz curvilinear transducer (EPIQ 5G). The study was done by a single observer and thus inter observer variation was eliminated.

Doppler traces were obtained in the right or middle hepatic vein at a distance of 3 to 6cms from the junction of the hepatic vein and inferior vena cava. The 3.5MHz curvilinear probe was placed right lateral intercostal approach. Hepatic vein Doppler wave forms were recorded for atleast 5 seconds with end expiration breath holding. In colour Doppler flow mapping, a blue hepatic vein waveform indicates flow away from the probe. A red portal vein waveform signifies that blood is flowing towards the probe. The waveforms of the hepatic vein can be categorized into three types: triphasic (which includes reversed flow in at least one phase), biphasic (showing no reversed flow), and monophasic (characterized by a flat appearance, with or without fluttering). Waveform classification depended on the presence or absence of phasic oscillation. Monophasic waveform is defined as complete loss of normal phasic oscillation[2].

Beta-blockers, such as propranolol and nadolol, are frequently used medications. These drugs are noncardioselective, meaning they affect both the heart and other areas. They decrease blood flow in the portal and collateral systems. This leads to a reduction in cardiac output due to the blocking of beta1-adrenoreceptors. Additionally, there is splanchnic vasoconstriction caused by the blockade of vasodilatory adrenoreceptors in the splanchnic circulation.

Propranolol is given at a starting dose of 20 mg every 12 hours. This dose can be adjusted up or down every 3 to 4 days until there is a 25% decrease in the resting heart rate or the heart rate reaches 55 beats per minute (bpm). Typically, the average dose of propranolol is 40 mg taken twice a day.
Administering more than 320 mg/d is not recommended.

Propranolol should not be used in individuals with asthma, chronic obstructive pulmonary disease (COPD), atrioventricular (AV) block, intermittent claudication, or psychosis. Common side effects include dizziness, tiredness, and shortness of breath during physical activity, bronchospasm, difficulty sleeping, erectile

dysfunction, and lack of motivation. Often, lowering the dosage of propranolol can help manage these side effects effectively.

It is advisable to continue beta-blockers for the duration of the patient's life, as the risk of variceal hemorrhage reverts to that of individuals who have not received treatment once beta-blockers are discontinued.

Statistical analysis:

The Interpretation of results of Hepatic vein doppler wave form between before and after propranolol of 50 patients by Chi-Square Test, The contingency table above provides the following information: the observed cell totals, (the expected cell totals) and (the chi-square statistic for each cell). The chi-square statistic, p-value and statement of significance appear beneath the table, with dependent and independent variables. The chi-square statistic is 25.2579. The p-value is < 0.00001. The result is significant at $p<0.01$.

III. Result

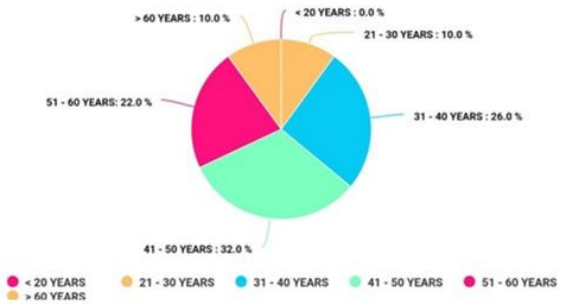
Case series of total no. of Patients – 50, Male Patients – 44, Female Patients – 6,

The predominance of males is attributed to Alcoholic Liver Disease. In the initial assessment, 15 patients exhibited Triphasic Hepatic Venous waveforms, 25 patients displayed Biphasic waveforms, and 10 patients showed Monophasic waveforms. All patients received Propranolol (PPNL), and hepatic venous waveforms were monitored every 15 days. While no improvements were observed within the first 15 days, the majority of patients demonstrated progress by the one-month mark. Out of thirty-five patients, thirty-two demonstrated an improvement in the hepatic venous waveform, which aligns with their clinical progress. Specifically, 91% of patients show improvements both clinically and in Doppler assessments following treatment with Propranolol (PPNL).

Table no1: Distribution of study subjects based on age

Age Group	Frequency (N)	Percentage (%)
< 20 Years	0	00.00
21 – 30 Years	5	10.00
31 – 40 Years	13	26.00
41 – 50 Years	16	32.00
51 – 60 Years	11	22.00
>60 Years	5	10.00
Total	50	100.00
Mean	10.00	
S.D.	4.38	
Min.	24	
Max.	87	

Figure no 1: Distribution of study subjects based on age

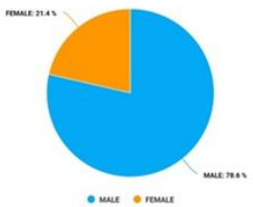


Majority of the study subjects i.e., 16/50 were belonged to age group of 41-50 years (32 %) followed by 13/50, 11/50, 5/50, and 5/50 were belonged to age group of 31-40 (26 %), 51-60 (22 %), 21-30 (5 %), and more than 60 (5 %) years of age respectively. The results of age wise distribution of study subjects was represented in Table 1 and plotted in Figure 1.

Table no 2: Distribution of study subjects based on gender

Gender	Frequency (N)	Percentage (%)
Male	44	88.00
Female	6	12.00
Total	50	100.00

Figure 2: Distribution of study subjects based on gender

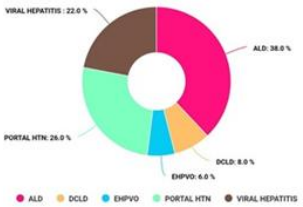


The results of gender wise distribution of study subjects revealed male predominance (44/50; 88 %) as compared to female (6/50; 12 %). The distribution of study subjects based on gender was represented in Table 2 and plotted in Figure 2.

Table 3: Distribution of study subjects based on clinical diagnosis

Clinical Diagnosis	Frequency (N)	Percentage (%)
ALD	19	38
DCLD	4	8
EHPVO	3	6
PORTAL HTN	13	26
VIRAL HEPATITIS	11	22
Total	50	100.00

Figure 3: Distribution of study subjects based on clinical diagnosis



Clinical diagnosis of Alcoholic Liver disease (ALD) was observed in majority of the study subjects i.e., 38 %. Whereas, in 6 % of the study subjects there were Extrahepatic Portal Vein Obstruction (EHPVO) cases noticed. The distribution of study subjects based on clinical diagnosis was represented in Table 3 and plotted in Figure 3.

Table 4: Distribution of study subjects based on portal vein diameter

Diameter	No. of Patients	Percentage (%)
≤ 13 mm	38	76
> 13mm	12	24
Total	50	100

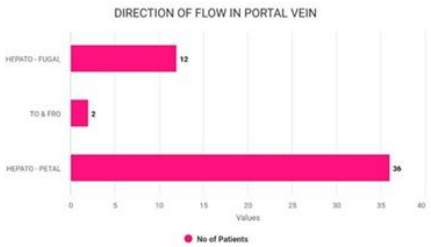
Figure 4: Distribution of study subjects based on portal vein diameter

In 12 patients, the diameter of the portal vein exceeded 13 mm, accounting for 24% of the cases. Conversely, 38 patients had a diameter of 13 mm or less, representing 76% of the cases. The distribution of study subjects based on portal vein diameter was represented in Table 4 and plotted in Figure 4.

Table 5: Distribution of study subjects based on direction of flow in portal vein

Flow in Portal Vein	No. of Patients	Percentage (%)
Hepato - Petal	36	72
To & Fro	2	4
Hepato - Fugal	12	24
Total	50	100

Figure 5: Distribution of study subjects based on direction of flow in portal vein

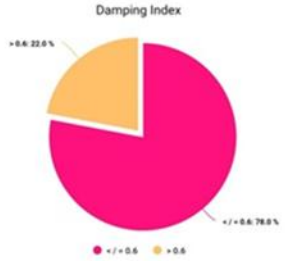


Out of 50 cases 36 patients corresponding to 72%, showed Hepato-petal flow. 24% of 12 cases showed Hepato-fugal flow. 2 corresponding to 4% showed to and fro bidirectional flow. The distribution of study subjects based on portal vein diameter was represented in Table 5 and plotted in Figure 5.

Table 6: Distribution of study subjects based on damping index of hepatic vein

Damping Index	No. of Patients	Percentage (%)
</= 0.6	39	78
> 0.6	11	22
Total	50	100

Figure 6: Distribution of study subjects based on damping index of hepatic vein

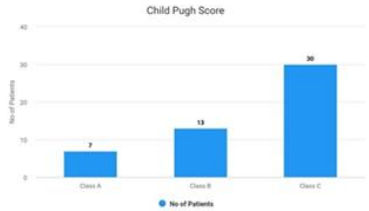


In this present study majority of patients (78%) present with < / = 0.6 damping index of hepatic vein and (22%) had > 0.6 damping index of hepatic vein. The distribution of study subjects based on portal vein diameter was represented in Table 6 and plotted in Figure 6.

Table 7: Distribution of study subjects based on child pugh score

Child Pugh Score	No. of Patients	Percentage (%)
Class A	7	14
Class B	13	26
Class C	30	60
Total	50	100

Figure 7: Distribution of study subjects based on child pugh score

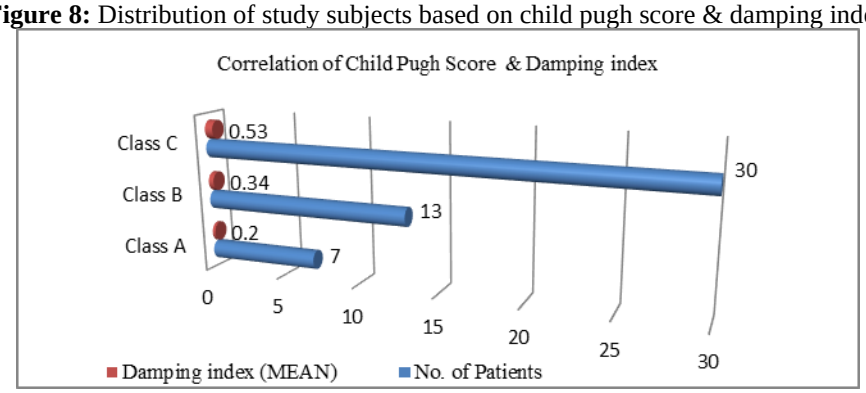


In this present study most of the patients had grade C Child Pugh score (60%). The distribution of study subjects based on child pugh score was represented in Table 7 and plotted in Figure 7.

Table 8: Distribution of study subjects based on child pugh score & damping index

Child Pugh Score	No. of Patients	Percentage (%)	Damping index (MEAN +/- SD)	Range
Class A	7	14	0.2 +/- 0.05	0.2 – 0.35
Class B	13	26	0.34 +/- 0.07	0.48 – 0.7
Class C	30	60	0.53 +/- 0.14	0.3 – 0.8

Figure 8: Distribution of study subjects based on child pugh score & damping index

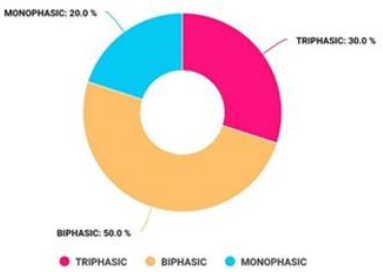


In this present study most of the patients had grade C Child Pugh score (60%) and (78%) patients present with < / = 0.6 damping index of hepatic vein. The distribution of study subjects based on child pugh score & damping index was represented in Table 8 and plotted in Figure 8.

Table 9: Distribution of study subjects based on hepatic vein waveform before propranolol (PPNL)

Hepatic vein waveform before Propranolol (PPNL)	No. of Patients	Percentage (%)
Triphasic	15	30
Biphasic	25	50
Monophasic	10	20
Total	50	100

Figure 9: Distribution of study subjects based on hepatic vein waveform before propranolol (PPNL)

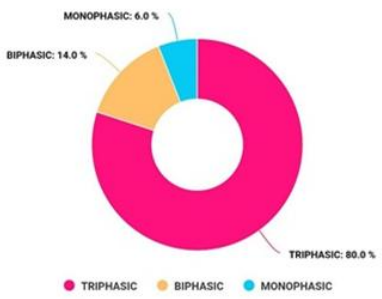


The distribution of study subjects based on Hepatic vein waveform before Propranolol (PPNL) was represented in Table 9 and plotted in Figure 9. Results depicted that hepatic vein waveform were Biphasic waveform in majority of the patients i.e., 50 % (25/50) and Triphasic waveform in 30 % (15/50) of the patients. In 20% (10 out of 50) of the study participants, a monophasic waveform was observed in the hepatic vein.

Table 10: Distribution of study subjects based on hepatic vein waveform after propranolol (PPNL)

Hepatic vein waveform after Propranolol (PPNL)	No. of Patients	Percentage (%)
Triphasic	40	80
Biphasic	7	14
Monophasic	3	6
Total	50	100

Figure 10: Distribution of study subjects based on hepatic vein waveform after propranolol (PPNL)

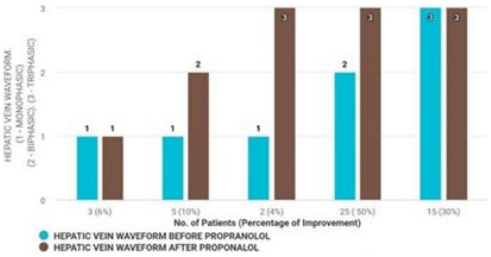


Among the 50 participants in the study, following treatment with oral propranolol, 80% exhibited a triphasic hepatic vein waveform. In contrast, 14% showed a biphasic waveform, while 6% had a monophasic waveform. The distribution of participants categorized by hepatic vein waveform after propranolol treatment is detailed in Table 10 and illustrated in Figure 10.

Table 11: Distribution of study subjects based on hepatic vein waveform before & after propranolol (PPNL)

Hepatic vein waveform		No. of Patients	Percentage (%)
Before Propranolol	After Propranolol (PPNL)		
Monophasic	Monophasic	3	6
Monophasic	Biphasic	5	10
Monophasic	Triphasic	2	4
Biphasic	Triphasic	25	50
Triphasic	Triphasic	15	30
Total		50	100

Figure 11: Distribution of study subjects based on hepatic vein waveform before & after propranolol (PPNL)

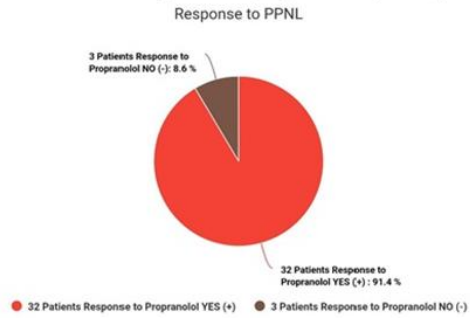


The distribution of study subjects based on Hepatic vein waveform before & after propranolol (PPNL) was represented in Table 11 and plotted in Figure 11. The results indicate that a shift from a Biphasic to a Triphasic hepatic vein waveform occurred in the majority of patients, specifically 25 individuals, representing 50%. Additionally, 2 patients, or 4%, showed improvement from Monophasic to Triphasic, while 5 patients, accounting for 10%, transitioned from Monophasic to Biphasic. Notably, three participants exhibited no changes in their waveform, which constitutes 6%.

Table 12: Distribution of study subjects based on response to propranolol (PPNL)

Response To Propranolol (PPNL)	No. of Patients	Percentage (%)
Yes (+)	32	91
No (-)	3	9
Total	35	100

Figure 12: Distribution of study subjects based on response to propranolol (PPNL)



A response to propranolol was noted in 32 of the 35 participants in the study, accounting for 91%. Conversely, only 3 participants, or 9%, did not respond to the medication. The distribution of participants based on their response to propranolol (PPNL) is illustrated in Table 12 and depicted in Figure 12.

Results			
	BEFORE PPNL	AFTER PPNL	*Row Totals*
TRIPHASIC	15 (27.50) [5.68]	40 (27.50) [5.68]	55
BIPHASIC	25 (16.00) [5.06]	7 (16.00) [5.06]	32
MONOPHASIC	10 (6.50) [1.88]	3 (6.50) [1.88]	13
Column Totals	50	50	100 (Grand Total)

The Interpretation of results of Hepatic vein doppler wave form between before and after propranolol by Chi-Square Test, The contingency table above provides the following information: the observed cell totals, (the expected cell totals) and (the chi-square statistic for each cell).

The chi-square statistic, p-value and statement of significance appear beneath the table, with dependent and independent variables.

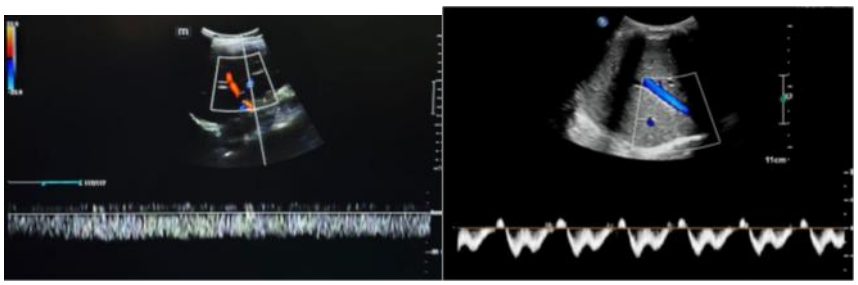
The chi-square statistic is 25.2579. The p-value is < 0.00001.
The result is significant at p<0.01.

Table 13: Interpreting the results of hepatic vein waveform before and after Propranolol by Paired T Test

Before PPNL VS After PPNL	Count	Mean +/- SD	Mean Difference +/- SD	t	P Value
Before PPNL	50	2.1 +/- 0.196	0.68 +/- 0.045	8.7255	<0.0001
After PPNL	50	2.78 +/- 0.151			

The above Table represents the Hepatic vein Doppler waveform, before and after propranolol; the findings are converted wave forms in to number as Monophasic as (1), Biphasic as (2) and Triphasic as (3) with calculated results Mean and Standard Deviations, t value and P value which are less than 0.0001.

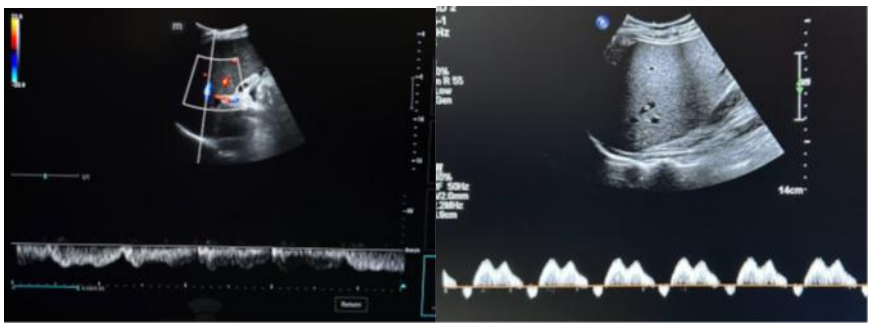
Few doppler ultrasound case images of our study:
Case 1:



Monophasic hepatic venous wave form after treatment
Triphasic hepatic venous wave form after treatment

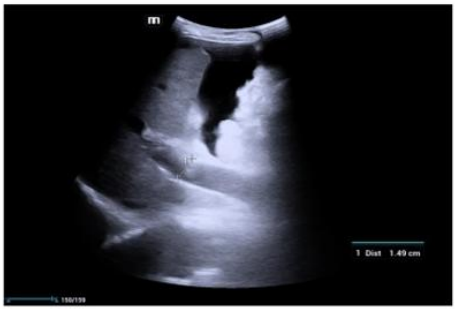
Case 1: A 42 years old male patient came with c/o abdominal distension, pain abdomen, hematemesis and edema of bilateral lower limb since 15 days. Doppler Ultrasonography shows baseline monophasic hepatic wave form, dilated portal vein, Hepato-splenomegaly and mild ascites and further follow up patient after 2 months the Doppler ultrasound of hepatic vein shows triphasic waveform.

Case 2:

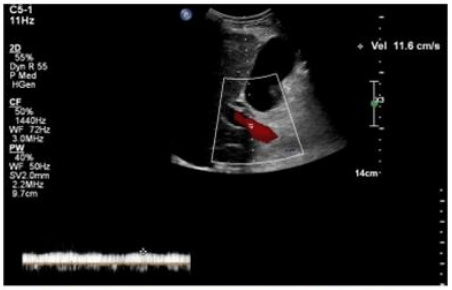


Biphasic hepatic venous wave form before treatment
Triphasic hepatic venous wave form after treatment

Case 2: A 35 years old male patient came with c/o pain abdomen, abdominal distension and vomiting since 15 days. Patient has alcoholic history of 8 years; Ultrasonography Doppler is performed and shows baseline biphasic hepatic waveform, Hepato-splenomegaly and moderate ascites and follow up scan after 2 months treatment propranolol, the Doppler shows triphasic hepatic waveform.



USG image in a patient with Dilated Portal vein measuring 14mm



Color Doppler image in a patient with cirrhosis had increased portal vein diameter 13.7 mm and reduced portal vein velocity (11.6 cm/s)

IV. Discussion

The Doppler waveform of the hepatic vein in healthy individuals typically exhibits a triphasic pattern, influenced by fluctuations in central venous pressure throughout the cardiac cycle[3,10]. In contrast, research has consistently shown that patients with cirrhosis often display abnormal biphasic or monophasic waveforms.[8] Notably, earlier studies have indicated that a monophasic waveform correlates with elevated Child-Pugh scores and a reduced survival rate. Despite this, the connection between hepatic vein Doppler waveform irregularities and portal hypertension remains poorly understood. One investigation revealed a link between hepatic vein waveform abnormalities and hepatic venous pressure gradient (HVPG), noting that as HVPG increased, the hepatic vein waveform tended to become flatter. Additionally, the presence of a monophasic waveform was linked to severe portal hypertension, demonstrating significant sensitivity and specificity within that study group. Therefore, a flattened hepatic vein waveform in cirrhotic patients suggests a strong likelihood of severe portal hypertension.[11,14]

Certain researchers have suggested classifying the hepatic vein waveform into six distinct categories. However, from our perspective, this extensive categorization adds unnecessary complexity and leads to increased variability among observers when trying to identify a specific subtype of the hepatic vein waveform. We believe that the disadvantages of having numerous subtypes surpass the advantages of a slight improvement in differentiation. Consequently, we have chosen to implement a more straightforward system with only three subtypes, which we consider to be more effective for clinical application.[5,9]

Fifty patients diagnosed with Portal Hypertension, Alcoholic Liver Disease, EHPVO, DCLD, and Viral Hepatitis was referred for portal Doppler assessment.

Among these patients, 6 were female (12%) and 44 were male (88%), with no age restrictions applied. A baseline Doppler ultrasound was performed, capturing the hepatic venous waveform. All patients received Propranolol (PPNL), and follow-up evaluations were conducted every two weeks to monitor the response to the medication.

The initial baseline examination revealed triphasic hepatic venous waveforms in 15 patients, biphasic waveforms in 25 patients, and monophasic waveforms in 10 patients.

In a related study, Kemal Arda and colleagues examined 30 patients with chronic liver disease (Child-Pugh class A) alongside 30 healthy controls. Histopathological analysis of biopsy samples confirmed the diagnosis in 17 patients. The study found a significant difference ($p < 0.05$) in the occurrence of abnormal (type I + type II) Doppler waveforms between the control and patient groups. The diagnostic accuracy for patients with biopsy results was 76.47%, compared to 69.23% for those without biopsies.[6]

So, the Monophasic waveform indicates a more severe disease state compared to the Biphasic waveform. Among the 50 patients studied, 38% were clinically diagnosed with Alcoholic Liver Disease, 8% with Decompensated Chronic Liver Disease (DCLD), 6% with Extrahepatic Portal Vein Obstruction (EHPVO), 26% with Portal Hypertension, and 22% with Viral Hepatitis.

All patients received Propranolol (PPNL), and hepatic venous waveforms were monitored every 15 days. No improvements were observed within the first 15 days; however, most patients showed progress after one month.

Specifically, 32 out of 35 patients exhibited improvements in their hepatic venous waveforms, which aligned with clinical improvements. Overall, 91% of patients demonstrated positive changes both clinically and in Doppler assessments following PPNL treatment.

Soon Koo Baikand colleagues conducted a prospective study to examine the relationship between abnormal hepatic vein waveforms observed through Doppler ultrasonography (US) and the hepatic venous pressure gradient (HVPG), as well as the effectiveness of drug treatments in patients with cirrhosis. They found that assessing hepatic vein waveforms via Doppler US is a valuable noninvasive method for evaluating the severity of portal hypertension and the effectiveness of vasoactive medications, such as terlipressin, in patients experiencing portal hypertension and variceal bleeding. Notably, changes in the hepatic vein waveform were closely linked to variations in HVPG. These findings suggest that Doppler waveform analysis of the hepatic vein could serve as a useful.[7,12]

Supplementary tool for assessing the response to vasoactive drugs in cases where HVPG measurement is not possible. For example, if a monophasic waveform changes to a biphasic or triphasic waveform following the administration of β-blockers; it may indicate that theβ-blockers have successfully lowered portal pressure.[13]

In our research, we found no correlation between hepatic venous forms and the hepatic venous pressure gradient (HVPG), which requires an invasive procedure. Numerous studies have established a significant link between the severity of portal hypertension and the alteration of hepatic venous waveforms observed through Doppler ultrasound.

Our study findings revealed that 84% of patients with clinically diagnosed portal hypertension exhibited abnormal HV waveforms.

Among these patients, 53.84% displayed biphasic waveforms, while 30.76% had monophasic waveforms at baseline. Following PPNL, all patients with biphasic waveforms transitioned to triphasic waveforms. Additionally, 75% of those with monophasic waveforms showed improvement, shifting to either biphasic or triphasic forms. However, 99 50% of the baseline monophasic patients did not demonstrate any improvement even after a two-month follow-up.

It is important to note that our study had certain limitations, including being a single observer study and the lack of correlation with HVPG. Furthermore, there was a notable predominance of male participants, which is reflective of the higher incidence of cirrhosis due to alcohol and viral hepatitis among Indian men.

V. Conclusion

Portal hypertension is a commonly observed condition with various underlying causes.

Doppler ultrasonography is an excellent non-invasive diagnostic method in evaluation of portal hypertension, its causes and its complications like splenomegaly, ascites and collateral vessels.

Ultrasound helps in systematic and thorough assessment of liver echotexture, spleen, portal and hepatic circulation.

The classification of hepatic vein Doppler waveforms appears to be more effective than any quantitative Doppler indices regarding reproducibility, ease of use, and accuracy. The qualitative evaluation method for these waveforms is straightforward enough to facilitate its potential adoption in clinical settings.

In our research, 32 out of 35 patients demonstrated an improvement in their hepatic venous waveforms following PPNL, which aligns with the observed clinical enhancements. Specifically, 91% of patients exhibited improvements both clinically and in Doppler assessments after the procedure.

In conclusion, evaluating hepatic vein waveforms through Doppler ultrasound may serve as a valuable supplementary tool for noninvasively assessing the severity of portal hypertension and monitoring responses to vasoactive medications in affected patients.

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