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Original research article

Portal vein pulsatility and Spectral width changes in patients with portal hypertension and correlation with severity of liver disease

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Abstract

Background: The use of Doppler ultrasonography has been employed in the evaluation of several hemodynamic parameters of the portal vein, such as flow direction, velocity, and volume, in individuals suffering from portal hypertension. Nevertheless, there is a dearth of comprehensive research on the flow waveform and its pulsatility in these particular circumstances. The objective of this study is to provide a comprehensive description of the pulsatility pattern and Spectral width index in individuals diagnosed with portal hypertension. Additionally, this research aims to assess the correlation between the pulsatility pattern and Spectral width index with the severity of liver disease, as determined by the Child-Pugh classification.

Methods: For the purpose of study, 60 cases of clinically diagnosed Chronic Liver Disease patients and Doppler examination of portal waveform was done.

Results: The normal value for PI in healthy adult's ranges from 0.200 to 0.557. In CLD patients the PI ranges from 0.140 to 0.483 with a mean of 0.28 + 0.09 SD. In Child Pugh Class A the PI was 0.36 + 0.06 SD, in Class B 0.29 + 0.07SD and in Class C 0.20 + 0.04 SD. In this study, the SWI in patients with CLD ranged from 0.608 to 1.00 with mean of 0.87 + 0.10 SD. The SWI in Child Pugh Class A was 0.82 + 0.09 SD, in Class B 0.83 + 0.14 SD and in Class C 0.92 U + 0.07 SD. There is a statistically significant relation found between portal vein pulsatility pattern and Spectral width index in patients with portal hypertension in relation to severity of liver disease.

Conclusion: With increasing severity of the liver disease as graded by Child Pugh class scoring, the pulsatility of portal vein blood flow decreases and Spectral width index increases with increasing severity of liver disease.

Keywords: Portal vein, pulsatility, spectral width changes, portal hypertension, liver disease

Introduction

Portal hypertension syndrome is a frequently encountered progressive complication associated with various hepatic and extra-hepatic disorders, with liver cirrhosis being the primary cause in over 80% of instances. The diagnostic process holds prognostic significance due to the elevated occurrence of haemorrhagic, metabolic, and infectious complications that patients may experience. Therefore, it is crucial to validate clinical suspicion through objective complementary studies, which offer insights into the aetiology and severity of the disease. This, in turn, facilitates the prompt implementation of surgical and medical interventions, ultimately preventing complications.

Ultrasound serves as the initial imaging modality employed to evaluate the hepatic parenchyma and vasculature in individuals with portal hypertension and liver disease. It is a dependable non-invasive method for determining the underlying causes, extent, and associated consequences of these conditions. The user's text does not provide any information to rewrite in an academic manner. The use of Doppler ultrasonography has been employed for the evaluation of diverse hemodynamic parameters of the portal

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vein, such as flow direction, velocity, and volume, in individuals diagnosed with portal hypertension. Nevertheless, there is a dearth of comprehensive literature on the subject of flow waveform and its pulsatility in these particular circumstances. The majority of prior research has focused on the escalation of portal venous pulsatility in connection with certain circumstances, notably those linked to cardiac ailments such as tricuspid regurgitation, heart failure, and constrictive pericarditis.
The available literature on the portal vein pulsatility pattern in the context of portal hypertension and chronic liver disorders is currently somewhat sparse. Furthermore, there is a lack of prior research undertaken on the Indian population that examines the correlation between Doppler parameters and the severity of liver disease. Therefore, this study was undertaken with the aims of assessing the portal vein pulsatility pattern in individuals diagnosed with portal hypertension through the utilisation of doppler ultrasound. Additionally, the study sought to compare the pulsatility pattern and spectral width index in patients with chronic liver disease, as well as to evaluate the potential correlation between the pulsatility pattern and spectral width index with the severity of liver disease.

Material and Methods
A Hospital based cross sectional study was carried out among 60 cases of Portal HTN with Chronic liver disease, referred to the Department of Radio diagnosis at Shri Siddhartha Medical College, Tumkur for a period of 18 months. Subjects were recruited by Convenient Sampling method.

Inclusion criteria: Patients with chronic liver disease and portal hypertension.

Exclusion criteria: Portal vein thrombosis, reversed portal vein flow, Previous scleropathy, band ligation or any surgical intervention and Grade 3 or Grade 4 encephalopathy were excluded from the study.

Methodology: Data was collected among 60 cases of Portal HTN with Chronic liver disease using a pre-structured questionnaire. It consisted of Demographic profile, Clinical profile, laboratory profile and Doppler profile.

The following information was collected for each patient
Age, gender, etiology of liver disease, biochemical parameters (Total bilirubin, serum albumin, prothrombin time).
Diagnosis of CLD was based on a combination of,
1. Clinical data (icterus, ascites, muscle wasting, edema, dilated abdominal veins, cutaneous spider angiomas, and flapping tremors).
2. Laboratory data (decreased serum albumin and prolonged prothrombin time).
3. Ultrasound data (coarsened bright liver echo pattern and nodular liver surface).

Grading of liver disease was done according to the Child classification modified by Pugh [11].

Score	Bilirubin (mg/dl)	Albumin (gm/dl)	PT (Sec)	Hepatic encephalopathy	Ascites (grade)
1.	< 2	> 3.5	1-4	None	None
2.	2-3	2.8-3.5	4-6	1-2	Mild
3.	> 3	< 2.8	>6	3-4	Severe

Child class A: 5-6, B: 7-9, C: >9.

Doppler ultrasound
The portal vein flow waveform was recorded for patients using Doppler ultrasound (Voluson GE 730 Pro Colour Doppler Ultrasound Unit) with a vector transducer operating at 3.5 MHz. The point of measurement was midway between the confluence of the splenic and superior mesenteric veins and the bifurcation of the portal vein.
The Doppler angle, between the axis of the Doppler beam and that of the portal vein, was always $> 60^0$. The sample volume was adjusted to include as much of the lumen as possible without including the vessel wall.
All the patients were kept fasting overnight prior to the sonography. Portal flow measurements were taken in the supine position during expiration. The portal trunk was scanned longitudinally with a vector transducer. The 3-mm sampling marker was shifted to the center of the lumen, 1±2 cm before the bifurcation of right and left branches. We preferred the intercostal approach to keep the angle of insonation below 60°. The portal flow velocity (PFV) in centimeters per second was measured directly, over a given period of time, by the dedicated software supplied with the Doppler equipment.

Portal vein pulsatility was expressed as the Pulsatility index (PI) and was measured as:

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Peak maximum velocity (Vmax)-peak minimum velocity (Vmin)
Mean of peak maximum velocity

Spectral width index (SWI) was measured as:
Peak maximum velocity minimum velocity at the wave base
At the wave envelope vertically below the point of
Peak maximum velocity peak maximum velocity

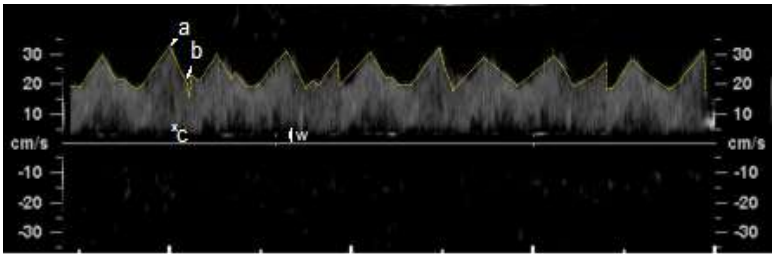

Fig 1

Simplified representation of a portal vein flow waveform as seen on spectral Doppler displays
A - Maximum peak velocity at the wave envelope.
B - Minimum peak velocity.
C - Minimum velocity at the wave base.
W - Window area underneath the flow wave.

On ultrasound examination, following parameters were also noted- liver size, spleen size, portal vein diameter and ascites.
The mean longitudinal diameter of the liver in the midclavicular line suffices to measure liver size.
Portal vein diameter is measured where the portal vein crosses anteriorly to the inferior vena cava.
The spleen was measured in the coronal plane. In the midaxillary line, a cephalocaudal measurement that includes the hilum is taken.

Ethical Issues: Institutional ethical clearance was obtained from the institution Shri Siddhartha Medical College. Informed consent was obtained from all the patients prior to the recruitment in to study.

Statistical Analysis: Data was analyzed using SPSS 22 version software 22 **(**IBM SPSS Statistics, Somers NY, USA). Categorical data was represented in the form of Frequencies and proportions. Chi-square test was used as test of significance for qualitative data. Fischer's exact test was used as test of significance for qualitative data which does not fulfill the criteria for Chi-square test (2x2 tables only). Continuous data was represented as mean and standard deviation. Normality of the continuous data, was tested by Kolmogorov-Smirnov test and the Shapiro-Wilk test. Independent t test was used as test of significance to identify the mean difference between two quantitative variables.
Mann Whitney U test was used as test of significance to identify the Median difference between two quantitative variables with Skewed distribution. ANOVA (Analysis of Variance) was the test of significance to identify the mean difference between more than two groups for quantitative data. Post Hoc Bonferroni test was used to determine the intergroup analysis. Kruskal Wallis test was the test of significance to identify the mean difference between more than two groups for quantitative data with skewed distribution. p value (Probability that the result is true) of <0.05 was considered as statistically significant after assuming all the rules of statistical tests.

Results
A total of 60 subjects underwent Doppler ultrasound examination. Of these 60, 48 were males and 12 were females. Mean age among cases is 44 + 11.5 SD with age ranging from 20-60 years. Etiology of liver disease was hepatitis c virus infection in 18 patients, hepatitis b virus infection in12 patients, alcohol abuse in 26 patients. Of the 60 cases, 24 (40%) cases were in class A, 8 (13.3%) in class B and 28 (46.7%) in class C.

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Table 1: Profile of the Study subjects

		Total	Percent (%)
Age	20-29	9	15.0
	30-39	20	33.8
	40-49	11	18.3
	50-59	12	20.0
	60-69	8	13.3
Sex	Male	48	89.7
	Female	12	18.3
Etiology	Hepatitis C	18	30.0
	Hepatitis B	12	20.0
	Alcoholic Liver Disease	26	43.3
	Idiopathic	4	6.6
Child-Pugh class	A	24	40.0
	B	8	13.3
	C	28	46.7

Table 2: Comparison of Mean values of Spleen size, portal vein diameter according to Child-Pugh scale

Parameters	Child-Pugh class	No.	Mean	SD	Mean Rank	P Value
Spleen Size	A	24	13.68	1.71	9.67	0.478
	B	8	15.00	2.58	21.5	
	C	28	13.69	3.57	18.79	
Portal Vein Diameter	A	24	11.83	2.37	12.79	0.126
	B	8	12.25	3.40	13.88	
	C	28	13.43	2.65	18.29	

In the study there was no significant difference in mean spleen size and Portal vein diameter with respect to Child-Pugh scale of liver disease is significant [Table 2].

Recent meta-analyses found no statistically significant difference between cortical button femoral fixation and cross-pin femoral fixation in terms of clinical outcomes or postoperative knee laxity [4, 5].

Semi-quantification of ascites was done on grey scale abdomen ultrasound examination. Ascites is a frequent finding in portal hypertension. It was seen in 75% of Cases. Of them 25 had mild ascites and 10 had moderate and severe ascites respectively.

In healthy individuals peak maximum velocity (Vmax) ranges from 12.2 cm/sec to 34.0 cm/sec (Mean 21.3 cm/sec + 8.0 SD) and peak minimum velocity (Vmin) ranges from 6.3 cm/sec to 28.2 cm/sec (Mean 14.6 cm/sec + 5.1).

In cases peak maximum velocity (Vmax) ranged from 4.2 cm/sec to 37.9 cm/sec (Mean 19.9 cm/sec +8.0 SD) and peak minimum velocity (Vmin) ranged from 3.5 cm/sec to 19.5 cm/sec (Mean 13.5 cm/sec + 5.8 SD.

There was significant difference in mean Vmax, Vmin and Vmin(b) with respect to Child Pugh Classification [Figure 1].

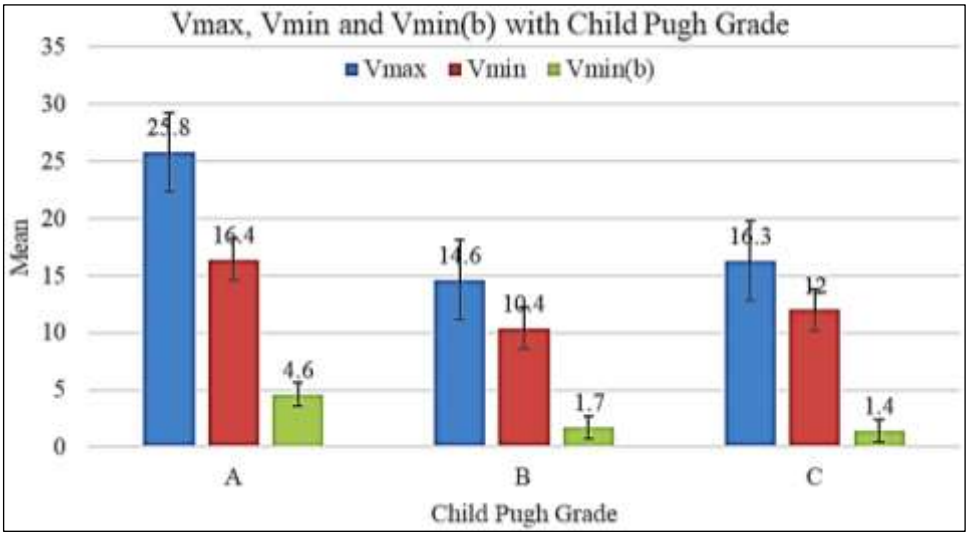

Fig 1: Bar diagram showing Comparison of Mean values of Vmax, Vmin and Vmin(b) in cases according to child-pugh classification

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On the basis of Vmax, Vmin and Vmin (b), Pulsatility index and Spectral width index were calculated. Mean pulsatility index was 0.28 ± 0.09 and spectral width index among cases was 0.87 ± 0.10.
Pulsatility index values are significantly less among cases as compared to normal range and spectral width index is higher among cases as compared to normal range, both parameters being statistically significant [Figure 2].

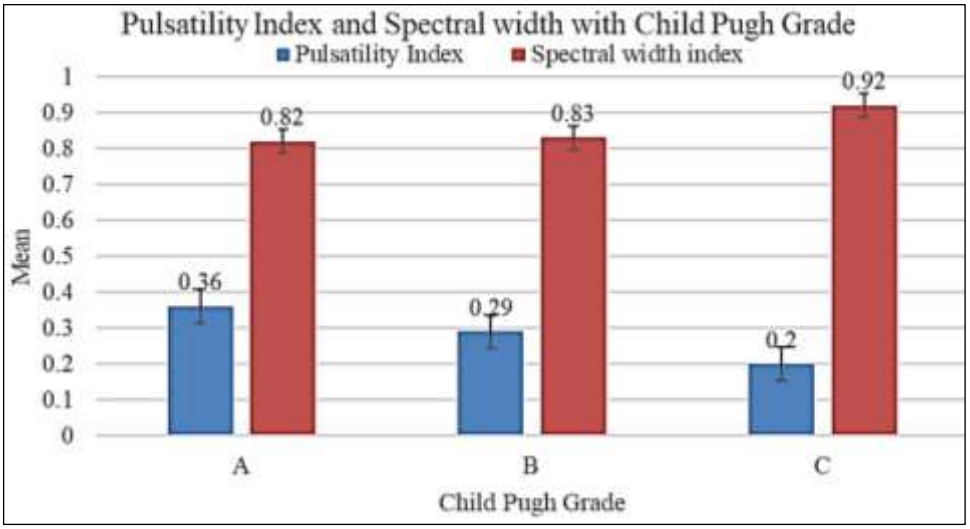

Fig 2: Bar diagram showing Comparison of Mean values of Pulsatility Index and Spectral Width Index according to child-Pugh classification

Discussion:
Portal hypertension is a significant and incapacitating medical disease. There are several factors that contribute to its occurrence, with cirrhosis being the most prevalent among them. It induces a range of haemodynamic changes inside the body, particularly in the abdominal region. Duplex ultrasonography, because to its non-invasive nature, high reliability, and widespread accessibility, serves as the primary modality for the assessment and diagnosis of portal hypertension. It enables the identification of the underlying causes and the detection of associated problems. The current investigation focused on a cohort of 60 individuals who were clinically diagnosed with portal hypertension and then verified with ultrasonography and Doppler research. The study examined a range of results and their respective rates of discovery.
The study revealed that a significant proportion of instances, namely 33.8%, were seen within the age range of 30-39 years. Next frequency was 28% in 50-59 years age group. The male population saw a higher degree of impact compared to the female population, with 80% of males afflicted in contrast to 20% of females. The potential cause for this phenomenon might be attributed to the elevated prevalence of alcohol drinking, which has been linked to the development of cirrhosis and portal hypertension. In the current investigation, it was observed that 75% of the patients exhibited the presence of ascites. The primary cause observed in the majority of cases was cirrhosis. Alcoholic liver disease was observed in the majority of patients, with a prevalence rate of 74%.

Portal vein diameter
Bolondi *et al*. studied 79 cases with portal hypertension and 45 controls. They concluded that portal vein diameter > 13 mm can be considered fairly characteristic sign of portal hypertension [5]. Jeffrey and Weinreb *et al*. studied 107 patients and had similar opinion [6]. Ditchfield *et al*. studied 118 patients diagnosed as portal hypertension using endoscopy, sonography and Doppler signs. They found that portal vein diameter of < 13mm was seen in 42% patients and > 13mm in 58% [7]. Demosthenes D *et al*. are of the opinion that if criteria are met, the portal vein diameter over 13mm is indicative of portal hypertension with specificity of 100% and sensitivity of 45-50% [8]. In the present study portal vein diameter above 13mm was seen in 69% of cases which is correlating with other studies. Diameter of less than 13mm was probably due to development of porto-systemic collaterals decompressing portal venous system.

Flow direction
Ditchfield *et al*. studied 118 cases of portal hypertension who were diagnosed using specific endoscopic sonographic and Doppler signs. They found that reversed flow in portal vein was seen in 3.4-5.3% cases [7]. Alexandra von *et al*. studied 67 men and 42 women. They found direction of portal vein flow was normal in 73%, hepatofugal in 9% and bidirectional in 6% patients.[9] Burcharth F *et al*. studied 108 patients with cirrhosis and portal hypertension. 14.8% of patients had total hepatofugal blood flow in

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their study [10]. In the present study we had 73% hepatopetal flow, 5% bidirectional to and fro flow and 22% hepatofugal flow. The present study had near value, to last study. The discrepancies with first two study may be due to differences in the proportion of patients with advanced disease and limited sample size.

Splenomegaly

Gibson *et al*. studied 111 patients of portal hypertension. They found that sonographically 52% of patients had definitely large spleen and 35% a spleen less than one standard deviation from normal while further 13% had equivocal splenomegaly. They concluded that splenomegaly is an intensive sign of portal hypertension [11]. According to Demosthenes *et al*., mild to moderate splenomegaly (> 13cm) is a common finding in portal hypertension. [8] In the study showed the spleen size and portal vein diameter to be more in patient with chronic liver disease and portal hypertension (p>0.05). Ultrasonography is up to 95% sensitive and up to 98% specific in measuring spleen. In the present study we had 92% of cases showing splenomegaly and 8% did not show enlarged spleen. The study showed the spleen size and portal vein diameter to be more in patient with chronic liver disease and portal hypertension (p>0.05).

Collaterals

Kadir *et al*., studied diagnostic value of real time sonography for portal hypertension in 38 patients. The frequency of detection of collaterals compared to percutaneous trans-hepatic portography, Sonography was 85% for coronary (GEJ), 100% for paraumbilical vein and 10% for short gastric vein [12]. Chawla *et al*., studied one hundred and two patients with different forms of portal hypertension and found that frequency of gallbladder varices was between 13-24% in different forms of portal hypertension [13]. Subrananyam *et al*. studied 40 cases with portal hypertension and collateral, were seen in 88% of cases and GEJ collateral, seen in 64% cases [14]. In the present study various collateral, were seen, GEJ (gastro-esophageal varices and coronary vein) collateral seen in 73% cases, paraumbilical vein in 26%.

Portal vein pulsatility and Spectral width index

Anish Subedee *et al*., [15] in a study, showed that, the mean pulsatility index value between control and cirrhosis group, as well as the difference within different Child classes were statistically significant (p<0.05). None of the patients in control group had complete spectral widening while 76.92% of cirrhotic patients had complete spectral widening (28.5% of Child A, 66.6% of Child B and 100% of Child C). The difference in distribution of complete spectral widening between control and cirrhotic group as well as within the cirrhotic group was statistically significant (p<0.05). Similar results were seen in the present study.

Portal vein flow has been described by Taylor KJW [16] and Keller MS [17] in his earlier reports as being non-pulsatile or continuous by recently, even marked pulsatile hepatoportal flow of the portal vein has been described, particularly in thin subjects with a portal venous pulsatility index of >0.5, with and inverse correlation to body mass. Bolondi L *et al*. in his study of 60 patients affected by liver cirrhosis, found out that, hemodynamically, decrease in pulsatility can be attributed, at least in part, to decreased transmission of right atrial pressure changes through the hepatic veins. [18] A study done by Chawla Y *et al*., showed that the portal vein mean flow velocity decreases in patients with CLD [19]. However, this lowering has been more evident in later stages (Child-Pugh Class C patients). M Barakat *et al*. [20], based on his study along with findings in the two earlier studies, reported that pulsatility index (PI) was significantly lower in CLD patients (mean+/-SD: 0.23+/-0.08) compared with healthy subjects (0.39+/-0.1) (p<0.001) and lower in Child-Pugh class C compared with Child-Pugh class A patients (0.21+/-0.07 vs 0.25+/-0.08, respectively) (p<0.05). The spectral width index was significantly higher in CLD patient's vs healthy subjects (0.91+/-0.16 vs 0.60+/-0.12, respectively) (p<0.001). The difference was also noted in the early stage (Child-Pugh A patients) when compared with healthy subjects (0.88+/-0.17). In conclusion, portal vein pulsatility and spectral width indices can reflect the early hemodynamic changes in CLD patients. These changes become more pronounced with the progression of liver disease.

The study findings correlate with above studies. In the present study, portal vein flow wave in patients with CLD becomes less pulsatile than in normal individuals. PI ranges from 0.140 to 0.483 with a mean of 0.28 + 0.09 SD. The decrease in portal vein pulsatility is evident even in the earlier stages of the liver disease. In Child Pugh Class A the PI was 0.36 + 0.06 SD, in Class B 0.29 + 0.07SD and in Class C 0.20 + 0.04 SD. (p>0.05). Present study shows, the spectral width index in patients with CLD ranged from 0.608 to 1.00 with mean of 0.87 + 0.10 SD. In Child Pugh Class A the SWI was 0.82 + 0.09 SD, in Class B 0.83 + 0.14 SD and in Class C 0.92 U + 0.07 SD. There were three patients in which complete spectral broadening was noted and spectral width index was 1.00 and all three patients belonged to Child Pugh class C. (p>0.05).

Conclusion

Portal hypertension is a commonly seen clinical disease characterised by several aetiologies and a range of associated consequences. Duplex ultrasonography is considered the most effective non-invasive

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diagnostic tool for evaluating portal hypertension. It enables the assessment of hemodynamic parameters, facilitates the diagnosis of portal hypertension and aids in determining its aetiology, severity and associated consequences. The utilisation of Duplex Doppler ultrasonography may possess significant merit in terms of identifying patients who might benefit from more frequent monitoring.

The findings of the study suggest that a reduction in the pulsatility index serves as a good diagnostic for detecting initial hemodynamic alterations in individuals with cirrhosis and portal hypertension. Moreover, these changes become increasingly prominent as the severity of the disease progresses. Likewise, the existence of comprehensive spectral broadening serves as a robust indicator of heightened illness severity. Understanding these various flow patterns can give further insights that can strengthen the diagnosis of cirrhosis, aid in the classification of its severity, and provide prognostic information to guide treatment decisions. Nevertheless, while evaluating a cirrhotic patient during a regular imaging follow-up, the radiologist possesses an advantageous vantage point to see shifts in patterns that might potentially indicate changes in hemodynamics. These changes may serve as indicators of either deteriorating or improving liver function.

Several studies have highlighted the significant utility of Doppler ultrasonography in the evaluation of liver transplantation, particularly in assessing portal venous pulsatility as a sensitive and specific indicator of portal hypertension in patients with end-stage liver disease. This discovery has the potential to assist in the clinical care of this particular patient population, particularly in determining the optimal timing for temporary palliation of portal hypertension and subsequent liver transplantation. Therefore, the use of Doppler screening for cirrhotic patients as part of regular ultrasonography might provide greater advantages.

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