# "CORRELATION BETWEEN HEPATIC WAVE FORM CHANGES ON DOPPLER ULTRASOUND AND SEVERITY OF DISEASE IN CIRRHOTIC PATIENTS"


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## RADIO-DIAGNOSIS

UNDER THE GUIDANCE OF


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***Dr. Syed Sumaiya Latheef***

# ABSTRACT

**Background:** Liver cirrhosis represents the end-stage of various chronic liver diseases characterized by progressive fibrosis and hemodynamic alterations. Doppler ultrasonography offers a non-invasive method to assess these vascular changes through hepatic vein waveform patterns. This study aimed to evaluate the correlation between hepatic vein waveform changes and disease severity in cirrhotic patients and determine its diagnostic utility.

**Methods:** This prospective study included 140 patients with established liver cirrhosis who underwent Doppler ultrasound examination of hepatic veins. Waveform patterns were classified as triphasic, biphasic, or monophasic and correlated with Child-Pugh classification and clinical-laboratory parameters. Statistical analysis was performed to evaluate associations and diagnostic performance.

**Results:** The study population comprised 59.3% males and 40.7% females, with 45% of patients in the 41-60 years age group. Child-Pugh classification revealed 22.9% Class A, 25% Class B, and 52.1% Class C patients. Hepatic vein waveforms were distributed as monophasic (38.6%), biphasic (36.4%), and triphasic (25%). A highly significant association ($p<0.001$) was found between waveform patterns and Child-Pugh classification, with 70.4% of monophasic and 68.6% of biphasic waveforms occurring in Class C patients, while 57.1% of triphasic waveforms were seen in Class A patients. A significant association ($p=0.008$) was also observed between waveform patterns and patient age. Diagnostic performance analysis showed 100% sensitivity and negative predictive value with 52.2% specificity and 69.5% positive predictive value.

**Conclusion:** Hepatic vein waveform assessment by Doppler ultrasound provides a reliable non-invasive marker of disease severity in cirrhotic patients, showing excellent correlation with Child-Pugh classification. The high sensitivity and negative predictive value make this a valuable screening tool, particularly for ruling out advanced cirrhosis. Integration of hepatic vein waveform assessment into routine ultrasound evaluation offers prognostic information without increasing procedure complexity or cost.

**Keywords:** Cirrhosis; Doppler ultrasonography; Hepatic vein waveform; Child-Pugh classification; Portal hypertension; Non-invasive assessment; Liver hemodynamics; Monophasic waveform; Biphasic waveform; Triphasic waveform

# CONTENTS

# INTRODUCTION

Cirrhosis represents a critical global health challenge, characterized by progressive hepatic fibrosis and significant alterations in hepatic hemodynamics.[1] The complex pathophysiological transformations associated with cirrhosis profoundly impact hepatic vascular dynamics, making non-invasive diagnostic techniques crucial for understanding disease progression and severity.[2]

Doppler ultrasound has emerged as a pivotal diagnostic modality, offering sophisticated insights into hepatic hemodynamic alterations without subjecting patients to invasive procedures.[3] The hepatic wave form, a sophisticated parameter capturing intricate vascular flow characteristics, serves as a potentially valuable biomarker for assessing hepatic functional status and disease severity.[4] These wave form changes reflect underlying pathological modifications in hepatic architecture, microcirculation, and portal venous dynamics.

Chronic liver diseases, encompassing viral hepatitis, alcoholic liver disease, and metabolic disorders, progressively compromise hepatic structural integrity and vascular responsiveness.[5] The intricate relationship between hepatic wave form modifications and disease severity remains insufficiently explored, presenting a critical research gap in contemporary hepatological investigations.[6] Understanding these nuanced hemodynamic alterations could potentially revolutionize early disease detection, prognostication, and management strategies.

“The proposed research aims to comprehensively analyze the correlation between hepatic wave form changes detected through Doppler ultrasound and the severity of cirrhotic diseases.[7] By employing a rigorous, multi-dimensional

assessment approach, this study seeks to elucidate the potential of wave form analysis as a refined, non-invasive diagnostic and prognostic tool".[8]

The significance of this investigation extends beyond academic discourse, holding profound implications for clinical practice, patient management, and healthcare resource allocation.[9] By systematically deconstructing the intricate relationship between hepatic hemodynamics and disease progression, this research aspires to contribute meaningful knowledge to the evolving landscape of hepatological diagnostics.[10]

Through a methodical exploration of hepatic wave form characteristics, this study anticipates providing nuanced insights that could potentially transform our understanding of cirrhotic disease progression and management strategies.

# AIM & OBJECTIVES

**Objective:**

1. To determine the significance of hepatic vein waveform changes on ultrasound in cirrhotic patients and to correlate with severity of disease.

# REVIEW OF LITERATURE

## STRUCTURE AND FUNCTION OF LIVER

At two to three percent of the average body weight, the liver is the biggest organ. The liver is divided into four anatomical lobes: the quadrate, caudate, left, and right. The inferior surface of the right lobe is home to the quadrate lobe. The caudate lobe is situated anteriorly and superiorly, sandwiched between the left and right lobes.

"The largest gland in the body, the liver is perfectly situated to both receive and cleanse ingested medications and other harmful compounds. Through lobule-level processing and metabolism, the liver shields the body against harmful substances ingested from the gastrointestinal (GI) tract. The cytochrome P-450 enzyme system catabolizes phase-II processes, which conjugate compounds with substrates like sulfate, glutathione, and glucuronide, among others."

It performs the functions of an endocrine and exocrine organ. The conjugation of bilirubin and its excretion into the gut, as well as "the synthesis and excretion of bile salts into the common hepatic duct, are the primary functions of the liver's exocrine system. The liver's endocrine functions entail glucagon and insulin in the regulation of blood sugar levels. Important proteins like fibrinogen, albumin, prothrombin, and other amino acids are synthesized by the liver, which also changes other proteins to become peptide hormones and enzymes". The liver produces phospholipids, cholesterol, and lipoproteins in addition to taking role in the metabolism of fatty acids. It also plays a role in gluconeogenesis and glycogen storage during the metabolism of carbohydrates. It also changes ammonia into urea and aids in the metabolism of lactic acid. Minerals like iron and vitamins are stored in the liver. In conclusion, the liver functions as a major conduit between the gut and the blood and is essential for the metabolism of hormones, blood plasma components, exocrine and endocrine chemicals, and macronutrients.[11]

# LIVER CIRRHOSIS

## DEFINITION

"Cirrhosis is defined as the histological development of regenerative nodules surrounded by fibrous bands in response to chronic liver injury, that leads to portal hypertension and end stage liver disease".[12]

## BURDEN OF THE DISEASE

One of the most common liver disease-related causes of death globally is cirrhosis. It is unknown how common cirrhosis is throughout the world. Every year, almost two million people die from liver illnesses, one million from cirrhosis complications, and another million from hepatocellular carcinoma and viral hepatitis. Right now, cirrhosis ranks as the eleventh most common cause of mortality worldwide. "Once decompensation occurs, cirrhosis-related mortality and morbidity increase sharply; depending on the source of decompensation, the one-year case-fatality rate may rise to 80%. Finally, there are only two possible outcomes for patients: they can either die or receive a liver transplant, which places a significant financial strain on patients, healthcare systems, and the governance and spending of health care".

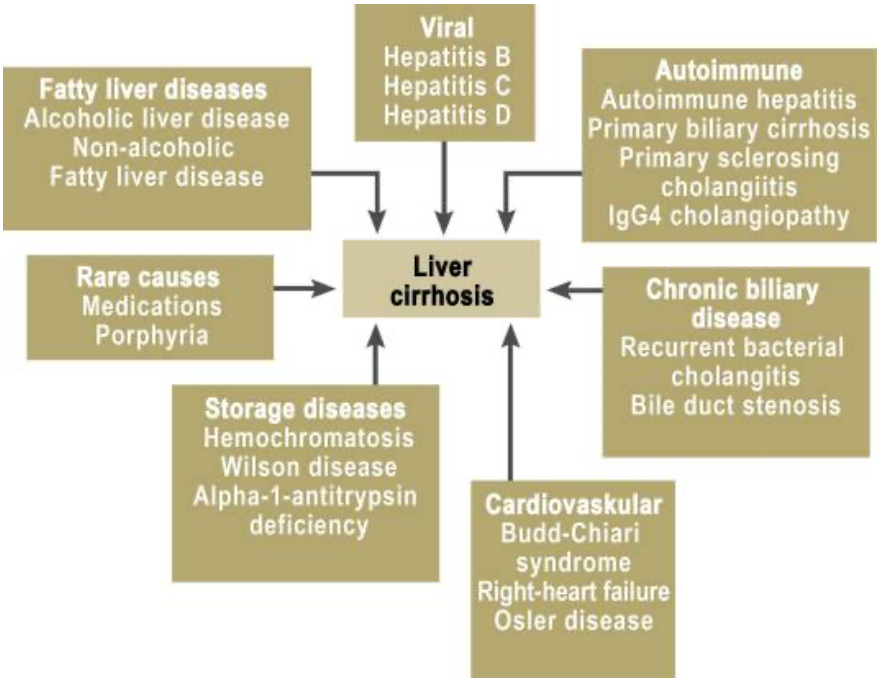
In 2017, 1.6 billion people worldwide suffered from chronic liver disease (CLD), "with the most common causes being alcoholic liver disease (ALD) (2%) and hepatitis B virus (HBV) (29%), hepatitis C virus (HCV) (9%), and non-alcoholic fatty liver disease (NAFLD) (60%). Furthermore, cirrhosis was a contributing factor in about 132 million fatalities (95% UI: 127-145) globally in 2017, with 440,000 (416,000-518,000, 33%)" and 883,000 (838,000-967,000, 66.7%) deaths among women and men, respectively. In 1990, the overall number of deaths from CLD in both sexes was 899,000 (829,000-948,000)". This is a significant increase. These deaths increased from 1.9% (1.8-2.0) in 1990 to 2.4% (2.3-2.6) of all deaths globally in 2017. In East Asia and Southeast Asia, the estimated incidence of cirrhosis is 16.5 and 23.6 cases per 100,000, respectively. Data from the Global Burden of Disease survey show that in 2015, there

were 20.7 instances of cirrhosis per 100,000 persons, an increase of 13% from 2000. The prevalence of cirrhosis has increased 1.5–2 times in the last 20 years.[13, 14]

## AETIOLOGY

The patient's medical history along with a serologic and histologic examination can typically be used to determine the etiology of cirrhosis. throughout the West, the most prevalent causes are “hepatitis C and alcoholic liver disease, but hepatitis B is more common throughout most of Asia and sub-Saharan Africa. The diagnosis of nonalcoholic steatohepatitis (NASH) in obese and diabetic people and the detection of the hepatitis C virus in 1989 have led to a decrease in the diagnosis of cirrhosis without apparent etiology, or cryptogenic cirrhosis. Understanding the cause of cirrhosis is crucial since it can influence treatment choices and forecast problems. Additionally, it permits the discussion of preventative measures with family members of patients with chronic viral hepatitis or alcoholic cirrhosis, as well as the evaluation of (genetic) tests and preventive guidance for family members of patients with hereditary disorders like Wilson's disease or hemochromatosis. As evidenced by epidemiological studies that identified regular (moderate) alcohol consumption, age over 50, and male gender as risk factors in chronic hepatitis C,[15, 16] or older age obesity, insulin resistance/type 2 diabetes, hypertension, and hyperlipidemia (all features of the metabolic syndrome) in NASH, multiple etiological factors frequently contribute to the development of cirrhosis”.[17, 18]

Figure 1: Aetiology of Liver Cirrhosis

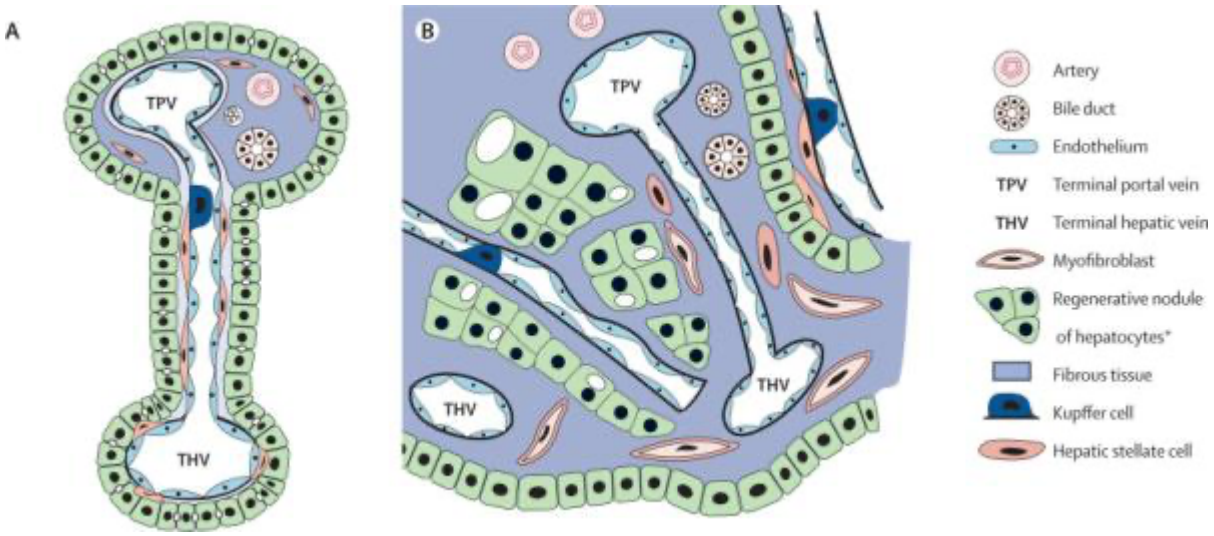



## PATHOGENESIS AND PATHOPHYSIOLOGY OF CIRRHOSIS

The "encapsulation or replacement of damaged tissue by a collagenous scar is referred to as fibrosis. Liver fibrosis arises from an inappropriate continuance of fibrogenesis, or the formation and deposition of connective tissue, as a result of the normal wound healing response continuing. Depending on the liver disease's underlying etiology, the host, and the environment, fibrosis advances at different speeds.[19, 20] Hepatic vascular distortion coexists with cirrhosis, an advanced stage of liver fibrosis. It causes the portal and arterial blood supply to be shunted straight into the hepatic outflow (central veins), impairing the transmission of information between the hepatic sinusoids and the hepatocytes that live next to the liver parenchyma. Hepatic stellate cells (HSC) and a few mononuclear cells are seen in the space of Disse, a sheet of permeable connective tissue that borders the hepatic sinusoids. The endothelia is fenestrated. Hepatocytes line the other side of the Disse gap and carry out the majority of known liver functions. The process known as sinusoidal capillarization occurs when endothelial fenestrations are lost and the Disse space is filled with scar tissue in cirrhosis".[21] Histopathologically, cirrhosis is typified by vascularized fibrotic septa that connect portal tracts to central veins and one another. This results in hepatocyte islands that lack a central vein and

are encircled by fibrotic septa (Figure 1). The development of hepatocellular carcinoma (HCC), elevated intrahepatic resistance (portal hypertension), and compromised hepatocyte (liver) function are the main clinical effects of cirrhosis. "Hepatic vascular changes and the ensuing portal hypertension are closely related to the general circulatory abnormalities in cirrhosis, which include splanchnic vasodilation, vasoconstriction and hypoperfusion of kidneys, water and salt retention, and increased cardiac output. Although cirrhosis and the vascular distortion it causes are thought to be incurable, new research indicates that the disease may be able to retreat or even reverse".[22, 23]

Figure 2: Vascular and Architectural Changes in Cirrhosis




Cirrhosis is classified based on morphology or etiology.

**Morphology Classification**[24]

"Cirrhosis can be either (1) micronodular, (2) macronodular, or (3) mixed morphologically. The etiologic classification is more clinically relevant than this one".

• "Micronodular cirrhosis (uniform nodules with a diameter of less than 3 mm): Hemochromatosis, alcoholism, chronic biliary blockage, hepatic venous outflow obstruction,

jejunoileal bypass, and Indian childhood cirrhosis.

• macronodular cirrhosis: cirrhosis resulting from primary biliary cholangitis, alpha-1 antitrypsin deficiency, and hepatitis B and C. Irregular nodules with a variation larger than 3 mm in diameter.

• Mixed cirrhosis, which occurs when characteristics of both macro- and micronodular cirrhosis coexist: Over time, micronodular cirrhosis typically develops into macronodular cirrhosis".

**Etiology Classification**

"Based on the cause of cirrhosis which is sub-classified as follows:

- Viral - hepatitis B, C, and D
- Toxins - alcohol, drugs
- Autoimmune - autoimmune hepatitis
- Cholestatic - primary biliary cholangitis, primary sclerosing cholangitis
- Vascular - Budd-Chiari syndrome, sinusoidal obstruction syndrome, cardiac cirrhosis
- Metabolic - hemochromatosis, NASH, Wilson disease, alpha-1 antitrypsin deficiency, cryptogenic cirrhosis".

## DIAGNOSIS OF LIVER CIRRHOSIS

**History and physical examination**

"Depending on whether their cirrhosis is clinically compensated or decompensated, patients with cirrhosis may exhibit neither symptoms nor compensation. Patients with compensated cirrhosis typically have no symptoms, and lab tests, physical examinations, or imaging may accidentally find the illness. A typical finding is a slight to moderate increase in gamma-glutamyl transpeptidase or aminotransferases, along with a possibly enlarged spleen or liver on the exam. Conversely, individuals suffering from decompensated cirrhosis typically

exhibit a diverse array of indications and symptoms that stem from a confluence of portal hypertension and liver disease. In patients with cirrhosis, the diagnosis of ascites, jaundice, hepatic encephalopathy, variceal hemorrhage, or hepatocellular cancer denotes the change from a compensated to a decompensated phase of the disease. Hepatorenal syndrome and spontaneous bacterial peritonitis are two further cirrhosis complications that affect ascites patients".

**Multiple Organs Affected**

**Gastrointestinal**

In addition to hepatosplenomegaly and caput medusa, "portal hypertension can result in ascites and prominence of the periumbilical abdominal veins". Another cirrhosis-related consequence that results from increased blood flow in the collateral circulation is esophageal varices, which has a minimum 20% death rate six weeks following a bleeding episode.[25] Individuals with chronic liver illness have a higher chance of gallstone formation, and those with alcoholic cirrhosis are more likely to experience chronic pancreatitis and small intestinal bacterial overgrowth.[26, 27]

**Hematologic**

"Hemolytic anemia (spur cell anemia in severe alcoholic liver disease), hypersplenism, and folate deficiency can all cause anemia". Patients with cirrhosis may experience hemosiderosis, disseminated intravascular coagulation, pancytopenia from hypersplenism in portal hypertension, and other conditions.

**Renal**

Patients who have cirrhosis are more likely to experience underfilling because of systemic hypotension and renal vasoconstriction, which can lead to hepatorenal syndrome. In cirrhosis, splanchnic vasodilation results in reduced efficient blood flow to the kidneys, which

triggers the RAAS system and causes water and salt retention as well as constriction of the renal arteries.[28] This impact, however, is insufficient to counteract the cirrhosis-induced systemic vasodilation, which exacerbates renal vasoconstriction and results in renal hypoperfusion, ultimately leading to renal failure.[29]

**Pulmonary**

"Hepatopulmonary syndrome, portopulmonary hypertension, hepatic hydrothorax, decreased oxygen saturation, ventilation-perfusion mismatch, decreased pulmonary diffusion capacity, and hyperventilation are some of the signs and symptoms of cirrhosis".

**Skin**

Patients with cirrhosis who have hyperestrogenemia as a secondary cause may develop spider nevi, which are major arterioles encircled by numerous smaller arteries that resemble spiders, hence the name. An imbalance in sex hormones brought on by liver disease results in an elevated ratio of estrogen to free testosterone and the development of spider nevi.[30] Another skin condition associated with cirrhosis that is related to hyperestrogenemia is palmar erythema. Jaundice is a yellowish discoloration of the mucous membranes and skin that occurs in decompensated cirrhosis and when the blood bilirubin level is higher than 3 mg/dL.

**Endocrine**

Individuals who have alcoholic liver cirrhosis may experience gynecomastia and hypogonadism. The cirrhotic patients' hypersensitivity to androgen and estrogen receptors is a major contributing component to the multifactorial pathogenesis. The emergence of these disorders has also been linked to hypothalamic-pituitary dysfunction.[31] Male hypogonadism can result in impotence and diminished desire along with feminization and loss of secondary sexual traits. Infertility, irregular menstrual bleeding, and amenorrhea are all possible in women.

**Nail changes**

Dupuytren contracture, clubbing, and hypertrophic osteoarthropathy are seen. Muehrcke nails, Terry nails, and azure lunules (a Wilson illness) are other nail alterations.

**Others**

Hepatic encephalopathy in cirrhosis might manifest as fetal hepaticus, a sweet, musty breath smell caused by elevated blood levels of dimethyl sulfide and ketones, or asterixis, a "fluttering tremor when the arms are extended and hands are dorsiflexed.[32] Muscle cramps, an umbilical hernia, hyperdynamic circulation, and a decrease in lean muscle mass can all result from cirrhosis".

Patients with cirrhosis may exhibit a variety of physical examination findings, including "signs of portal hypertension (ascites, splenomegaly, caput medusae, Cruveilhier-Baumgarten murmur-epigastric venous hum), hepatic encephalopathy (confusion, asterixis, and fetor hepaticus), stigmata of chronic liver disease (spider telangiectasias, palmar erythema, Dupuytren's contractures, gynecomastia, testicular atrophy), and other characteristics like jaundice, bilateral parotid enlargement, and sparse chest/axillary hair".

## EVALUATION

**Lab Findings**

Normal levels of "aminotransferases do not rule out cirrhosis; nevertheless, they are typically mildly to moderately increased, with aspartate aminotransferase (AST) being larger than alanine aminotransferase (ALT).[33] The AST/ALT ratio is less than one in the majority of chronic hepatitis types, with the exception of alcoholic hepatitis. This AST/ALT ratio reverses as chronic hepatitis advances to cirrhosis. Cholestatic diseases are associated with higher levels of alkaline phosphatase (ALP), gamma-glutamyl transferase (GGT), and 5'-nucleotidase. Because bilirubin and coagulation factor deficiencies cause elevated prothrombin time (PT), albumin is low because the liver synthesizes it and its functional capacity decreases. As a result,

PT and serum albumin are reliable markers of synthetic liver function. Alcoholic liver cirrhosis is associated with normochromic anemia, however it can also present with macrocytic anemia. In addition, sequestration by the larger spleen and the bone marrow's inhibition by alcohol are observed as secondary causes of leukopenia and thrombocytopenia.[34] Impaired liver clearance frequently results in increased immunoglobulins, particularly the gamma fraction".[35]

**Specific Labs to Investigate Newly Diagnosed Cirrhosis**

For autoimmune hepatitis, serum IgG immunoglobulins, "anti-smooth muscle antibodies (ASMA), anti-nuclear antibodies [ANA], anti-liver-kidney microsomal antibodies type 1 (ALKM-1), and anti-mitochondrial antibodies for primary biliary cholangitis may be ordered in addition to serology and PCR techniques. Other helpful tests include serum alpha-fetoprotein for hepatocellular carcinoma (HCC), ceruloplasmin and urine copper for Wilson disease, alpha 1-antitrypsin level and protease inhibitor phenotype for alpha 1-antitrypsin deficiency, and ferritin and transferrin saturation for hemochromatosis".

**Imaging**

In addition to lab tests, several imaging modalities are utilized to aid in the diagnosis of cirrhosis. These consist of transient elastography (fibroscan), CT, MRI, and ultrasound.

One readily available, affordable, and noninvasive method for evaluating cirrhosis is ultrasonography. It is nonspecific because nodules and elevated liver echogenicity, which are indicative of cirrhosis, "can also be found in cases of fatty liver.[36] It can also measure the ratio of the width of the caudate to the right lobe, which typically rises in cirrhosis.[37] Additionally, it is a helpful tool for cirrhosis patients to check for HCC. The mesenteric, portal, and hepatic veins can all be assessed for patency using duplex Doppler ultrasonography".

HCC and vascular lesions can be found with CT or MRI with contrast, although MRI is a better imaging modality.[38] If an MRC (magnetic resonance cholangiography) is performed,

"MRI can also be utilized to identify biliary blockage, level of iron and fat accumulation in the liver for hemochromatosis and steatosis. [39, 40] On the other hand, MRI is costly and not widely accessible".

High-velocity ultrasonic waves are used in transient elastography (fibroscan), a promising non-invasive technique that measures liver stiffness, which is correlated with fibrosis. When comparing the uptake of colloid in the spleen and bone marrow to that in the liver, a colloid liver spleen scan utilizing "technetium-99m sulfur colloid may reveal higher uptake in cirrhosis. Varices in the stomach or esophagus during an esophagogastroduodenoscopy (EGD) may indicate portal hypertension".[12, 41]

**Liver biopsy**

"The gold standard for determining the degree of inflammation (grade) and fibrosis (stage) of cirrhosis is a liver biopsy". Nevertheless, sample flaws can occasionally cause it to miss the diagnosis. Fibrosis and nodules are necessary for the biopsy-based diagnosis of cirrhosis. There are three types of nodular patterns: micronodular, macronodular, and mixed. Each type of nodular pattern represents a separate risk factor for higher disease severity and an elevated hepatic venous pressure gradient (HVPG).[42]

Direct and indirect serum indicators are utilized in noninvasive testing to distinguish patients with substantial fibrosis/cirrhosis from those with little or mild fibrosis.[43] Recently, several procedures based on laboratory and ultrasonography techniques have been developed for the noninvasive diagnostic assessment of cirrhosis. When the only thing that "needs to be determined is the stage of fibrosis, these noninvasive techniques frequently eliminate the necessity for a liver biopsy; nonetheless, the data they yield must always be interpreted in the context of the corresponding clinical findings".[44]

There are two types of laboratory-based techniques for determining the degree of hepatic fibrosis: those that rely on standard liver function tests[45] and those that use specific

laboratory values linked to fibrosis, like the content of hyaluronic acid.[46] As a screening tool for advanced fibrosis and cirrhosis, the "AST-to-platelet ratio index (APRI) is simply computed as the quotient of the AST (GOT) and the platelet count".[47]

**ULTRASONOGRAPHY IN DIAGNOSIS OF CIRROSIS**

Ultrasound is a safe and relatively inexpensive" imaging tool, allowing annual or biannual tests in chronic hepatitis patients. Initial findings of hepatic fibrosis by US are similar to simple hepatosteatosis.[48] Fibrosis of the hepatic parenchyma attenuates beam penetration, increases parenchymal echogenicity, and decreases vascular conspicuity".

"Liver cirrhosis is characterized by changes in liver volume distribution, surface nodularity, accentuation of the fissure, heterogeneity, bright and coarsening of the hepatic architecture, cirrhotic nodules including regenerative and dysplastic nodules, and signs of portal hypertension. Studies showed an overall sensitivity to chronic liver disease of 65%-95%, with a positive predictive value of 98%. The most indicative finding of liver cirrhosis was nodular surface, which was more sensitive on the undersurface of the liver than the superior surface (86% *vs* 53%). It was also more sensitive in a high frequency probe. Although any single US feature had limited sensitivity or specificity in detecting cirrhosis, improvements could be achieved by combining two or three parameters".[49]

"US imaging can provide early detection of morphological changes of the liver, but such changes represent advanced cirrhosis. Furthermore, ultrasound imaging is subjective and difficult to quantify, as inter- and intra-observer variability is a significant problem. There have been many efforts to objectively quantify the coarseness of hepatic parenchymal echogenicity. An initial study performed a simple quantification of parenchymal echogenicity and compared the standard deviation between chronic liver disease and normal liver.[50] The coarseness of hepatic parenchyma decreased beam penetration, while the attenuation of echogenicity according to depth increased proportionally to fibrosis. Methods that were more

delicate were also introduced. Measurement of differences in echogenicity between neighboring pixels can be pathologically correlated to chronic liver disease. Texture analysis can improve diagnostic accuracy of grayscale US images. However, there are several limitations to the widespread use of these techniques, including dedicate post-processing programs, inter-observer variability, and sampling bias. The success of this approach also depends strongly on an expert to establish the regions of interest".[51]

## DOPPLER ULTRASOUND IN LIVER CIRRHOSIS

"Doppler liver ultrasonography constitutes an effective and non-invasive means of evaluating the hepatic vasculature. Understanding the normal and abnormal waveforms for the primary hepatic vessels and their characteristic waveforms can help diagnose specific diseases that have a characteristic effect on these waveform patterns. Understanding how an abnormal hepatic artery, hepatic vein, or portal vein manifests on Doppler sonography can help identify or confirm liver diseases".

### Anatomy and Physiology

"The liver plays a vital role in the body's metabolic functions and is composed of a relatively complex vascular architecture.[52] One-quarter of the cardiac output goes to the liver. The liver is divided into various hepatic segments, and each hepatic lobule receives a branch from the portal vein, hepatic artery, and biliary tract called the portal triad".[53]

1. "The portal vein constitutes 75% of the hepatic blood supply. The blood from the portal vein is deoxygenated, carrying mainly nutrients. It is formed by the confluence of superior mesenteric and splenic veins. The portal vein drains all the upper and middle parts of the gastrointestinal tract, pancreas, gallbladder, and spleen. Within the liver, the portal is divided into two branches: the left and the right portal veins. The left supplies segments II, III, and IV, while the right portal vein supplies segments V, VIII, VI, and VII. Variants of the portal venous system are not uncommon".[54]

2. “Hepatic veins: The hepatic veins are three branches (right, left, and middle hepatic veins) draining blood to the IVC. The most common morphology of the hepatic veins includes a right hepatic vein and a common trunk for the middle and left hepatic veins”.[55]

3. “The hepatic artery supplies 25% of the hepatic blood flow and constitutes the main bulk of oxygenated blood to the liver. Frequent variations of the origin of the hepatic artery exist, with the most common type constituting the common hepatic artery arising from the celiac artery in 70% of patients”.[56]

4. “The inferior vena cava (IVC) represents the confluence of the right and left common iliac veins and is the retroperitoneal draining vessel to the hepatic veins. The inferior vena cava subsequently empties deoxygenated blood to the right heart”.[57]

**Hepatopetal and Hepatofugal Flow**

**“Hepatopetal flow** refers to blood flow towards the liver (from the portal hepatis to the liver periphery). It typically is used in describing the normal blood flow direction in the portal vein. This occurs in a normal liver and allows the liver to detoxify the blood that enters it after absorbing nutrients from the intestine through the portal vein.

**Hepatofugal flow** refers to blood flow away from the liver in the portal vein and is sometimes referred to as "retrograde" flow. In other words, the portal venous blood flow pattern is from the periphery of the liver towards the porta hepatis.[58] This occurs when the portal venous pressure is high in the case of portal hypertension. Thus portosystemic shunts are reopened with additional findings that include a more narrowed portal vein and

prominence of the hepatic artery. Occasionally, a to-and-fro bidirectional blood flow pattern alternating between hepatopetal and hepatofugal flow can be seen in the portal vein before the onset of frank hepatofugal flow.[59]

While **HVPG (hepatic venous pressure gradient)** is the gold standard for measuring the portal and hepatic venous pressure, it is an invasive procedure with the insertion of a catheter into the hepatic vessels. On the other hand, Doppler ultrasound is a non-invasive procedure and can evaluate for abnormal physiology of the hepatic vasculature".[60]

**Fundamentals of Doppler Ultrasound**

"When an ultrasound beam is reflected from a moving object, the frequency of the returning waves will vary. If the object is moving away from the ultrasound source, the waves will be stretched out in space (longer wave length) and the frequency will be lower. If the object is moving towards the ultrasound source, the waves will be compressed and the frequency higher".

"If the ultrasound waves are emitted in short pulses, with "listening time" between pulses, a single transducer can be used; this mode is known as pulsed Doppler ultrasound. If we listen to the pulsed Doppler at a specific time after the sound burst has been transmitted, this is called time- or range-gating. Range-gating allows us to listen to echoes from a specific location or vessel, commonly determined by placing a sample volume in the region of interest. With range-gating resolution, we can listen to blood flow in the hepatic artery while not hearing the echoes from the portal vein"

"The difference between the emitted and reflected frequency is called the Doppler frequency shift and this is directly related to the velocity of the moving object. The frequency shift is usually in the audible range (100–15.000 Hertz). Therefore, we are able to hear the Doppler signal, as well as display it on the monitor".

"In diagnostic Doppler ultrasound, Doppler frequency shifts of the echoes reflected by red blood cells are utilized to detect and measure blood flow. Unlike real-time ultrasound, which gives the best images when the beam is perpendicular in relation to the object, the Doppler shift signal is largest when the blood flow is directed towards or away from the transducer. Normally, parallel transducer orientation is not possible. Usually the beam enters at an angle (a) with respect to the vessel. If the velocity vector is at angle α to the beam, the Doppler shift must be corrected by the cosine of that angle to produce an accurate measurement of velocity".[60]

**Equipment**

"Doppler ultrasound for the abdominal examination has two types: pulsed and color Doppler. Continuous Doppler is used in high-frequency flow in the cardiac valves and vessel examination but is not suitable for the portal and hepatic veins and IVC".[61]

**Preparation**

"Fasting is preferred (4 to 6 hours before examination) to decrease gaseous distension and fluids in the abdomen and increase the visibility of the vessels. Before starting the examination, device adjustments of the gain, frequency, and depth are crucial".[61]

**Technique or Treatment**[61]

"Using hepatic Doppler ultrasound as part of the abdominal ultrasound will increase the operator's experience in refining the probe movement and better visualizing the hepatic vessels. The time consumed for both examinations (abdominal ultrasound and hepatic doppler) will not increase much".

- "The patient could be asked to hold his breath to improve visualization.

The red color on the screen is usually set up in most devices as the direction of flow towards the probe, while the blue indicates the direction of blood flow away from the probe.

- The portal vein has a thickened fibrous tissue wall that will be reflected as drawing an echogenic line around the vessel, while hepatic vein walls are thin and non-visualized.
- Portal vein diameter can range from 7 to 15 mm. Hepatic veins can have a diameter of 5 to 7 mm. The IVC normal diameter ranges from 13 to 22 mm with a collapsible wall on pressure.
- The patient is best positioned in the left lateral or supine position. Scanning starts in the right subcostal area, which allows for visualization of the portal vein. The confluence of the splenic and superior mesenteric veins is visualized when moving left towards the midline.
- Then scanning in the substernal position, the operator will view the IVC (which should be compressible) and aorta at the midline while the probe faces posteriorly (either longitudinally or transversely).
- Hepatic veins can be best viewed from the right intercostal position where the probe is facing medially, and this position is best to view the drainage of the three hepatic veins into the IVC. The hepatic veins could also be viewed from the subcostal position directing the probe posteriorly. Left and middle hepatic veins are best visualized from the substernal position".

**Normal Hepatic Waveform**[62]

"The shape of the hepatic vein spectral Doppler waveform is primarily determined by pressure changes in the right atrium, or more exactly the blood flow resulting from the

resultant pressure gradients. Multiple terms have been used to describe the hepatic vein waveform, including "phasic", "triphasic", "tetrainflectional", and "periodic". Some prefer the term "periodic" since the term "triphasic" already has a specific application in arterial spectral Doppler waveforms and since "periodic" suggests that the waveform is transmitted by cardiac motion rather than systolic flow".

*Radiographic features*

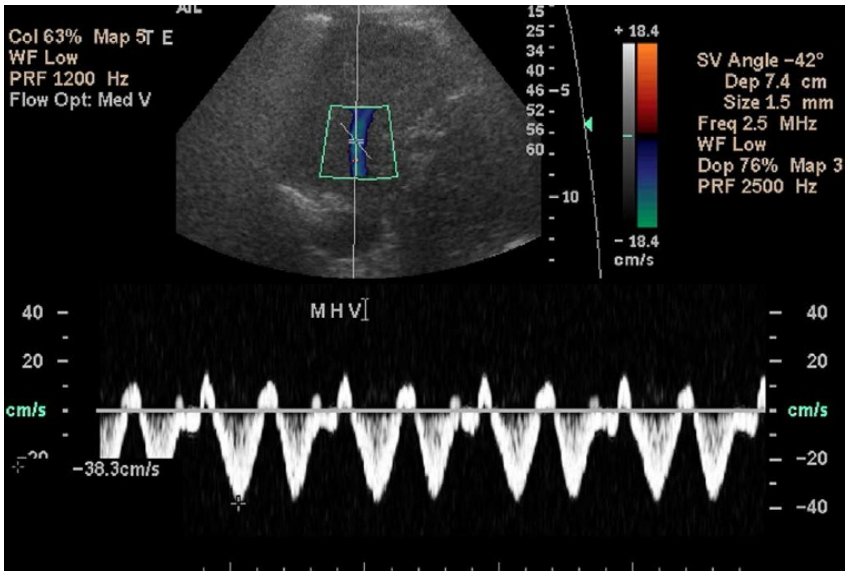
"The normal periodic hepatic vein waveform is typically described in four parts:

1. **a wave**: atrial contraction
    - coinciding with the "p wave" on the electrocardiogram, contraction elevates pressure within the right atrium creating a gradient for late diastolic filling of the right ventricle
    - this also creates a pressure gradient favoring a lesser degree of retrograde flow into the IVC and hepatic veins"
    - "the small reversal of flow typically results in a small wave above the baseline, reversed from the overall net flow back to the heart
2. **s wave**: ventricular systole
    - as systole commences, right ventricle contraction results in longitudinal, apically oriented traction on the tricuspid annulus
    - the resultant "stretching" of the right atrium results in a drop in pressure, creating a gradient for anterograde flow from the inferior vena cava and hepatic veins, most pronounced at mid-systole
    - this typically forms the highest velocity deflection seen in the waveform"
3. **"v wave**: atrial overfilling
    - a transitional inflection point

- as blood fills the right atrium, the flow from the hepatic veins and IVC slows, resulting in the s wave returning back to baseline
  - if the atrium fills to capacity then there may be a small amount of flow "recoil" backward, resulting in a v wave that rises above the baseline”

4. **“d wave**: tricuspid valve opening
   - as the tricuspid valve opens, blood flows from the right atrium into the right ventricle, resulting in a net flow of blood away from the liver and the waveform again dives back down below the baseline
   - this wave is almost always lower in magnitude than the s wave”

“Sometimes a c wave occurs as a second small inflection above the baseline, right after the a wave, reflecting the effect of the tricuspid valve bulging into the right atrium”.




**“Hepatic Vein Flow Patterns in Cirrhosis Patients”**[63]

Figure 3: “Spectral analysis of the main hepatic vein (MHV) demonstrates normal triphasic waveforms. The “a” wave corresponds to the atrial contraction, which occurs at the end diastole followed by the “S” wave caused by the motion of the atrioventricular septum during midsystole. The “v” wave corresponds to the opening of the tricuspid valve followed by the “D” wave of the early diastolic right ventricular filling”.

"The normal waveform within the hepatic veins is triphasic with two hepatofugal phases related to the atrial and ventricular diastole . Fibrotic or inflammatory changes as well as fat deposition in the liver may create a monophasic flow pattern . In the case of end-stage cirrhosis, distorted architecture with changes in the underlying liver architecture can cause a striking reduction in the caliber or absence of the visualization of the hepatic veins. Early waveform changes in cirrhosis patients include spectral broadening and dampening of the normal, retrograde, pre-systolic wave of the hepatic vein waveform. Later, the normal triphasic waveform pattern may be diminished or replaced with a monophasic pattern. Therefore, the monophasic hepatic vein waveform indicates relatively high portal pressures".

"Two alterations of hepatic vein flow profile can be observed in hepatic disease, especially cirrhosis. The first is regional flow acceleration resulting from focal compression by regenerative nodules. The second is dampening of the pulsatile flow profile secondary to non-compliance caused by fibrous tissue. Although loss of reverse flow component may indicate cirrhosis, it should be mentioned that this abnormal waveform can occur in diseases such as BuddChiari syndrome and in diffuse hepatic metastases. Moreover, deep inspiration, obesity or ascites are factors which may influence the hepatic flow profile. Even flattening of the flow profile has been observed in normal subjects".

"The changes in collaterals may also affect hepatic vein pulsatility. The patency of the paraumbilical vein is a rather frequent finding in cirrhosis patients, which alters the hepatic hemodynamics. The portal venous flow has also been reported to be affected by the patency of the paraumbilical vein, but hepatic arterial resistance and flow are not affected by such patency. A decrease in the phasicity of the hepatic vein is also associated with hepatic vein stenosis or thrombosis. There are additional physiologic factors such as high intra-abdominal pressure due to the Valsalva maneuver or suspended respiration in the case of end expiration, which may result in monophasic waveforms".

**Limitations**[61]

- "Obesity can cause limitations in the visualization of vessel flow and velocity.
- Eating may cause an increase in the portal pressure and widen the diameter of the vessel. Ingested contents and resultant gaseous distension may hinder the visualization of vessels. Therefore, fasting for at least 4 to 6 hours before the Doppler examination is recommended.
- Changes in the liver hemodynamics may be falsely diagnosed if the gain and frequency are not well adjusted in the device.
- The low frequency may falsely diagnose portal vein thrombosis.
- Patients who cannot hold their breath will create some difficulty for the operator to visualize the vessels, but this could be overcome by the timing of inhalation and moving the probe synchronously".

## REVIEW OF RELATED STUDIES

**"Khan, N. R et al (2024)**[64] aimed to investigate the correlation between hepatic vein waveform patterns, damping index, splenoportal index, and the Child-Pugh score in patients with liver cirrhosis to evaluate the efficacy of Doppler ultrasound as a non-invasive diagnostic tool. A prospective cross-sectional study was conducted. The final cohort consisted of 52 patients, with 39 males (75%) and 13 females (25%). The mean age was 55.3 years. The damping index showed a significant increase from Child-Pugh Class A (0.45 ± 0.10) to Class C (0.75 ± 0.15) (p=0.003). The splenoportal index also demonstrated a significant rise from Class A (1.4 ± 0.3) to Class C (2.0 ± 0.5) (p=0.015). The sensitivity and specificity of the damping index (> 0.6) in predicting higher Child-Pugh scores (B + C) were 52.6% and 85.7%, respectively, with a positive predictive value of 90.9%. The study found

strong correlations between the severity of liver cirrhosis, as assessed by the Child-Pugh score, and Doppler ultrasound parameters such as hepatic vein waveforms and the damping index. Doppler ultrasound, therefore, presents itself as a precise, non-invasive alternative for evaluating the severity of liver disease, potentially replacing more invasive procedures".

**"Yasmin, Tarana et al (2021)**[65] The purposes of this study was to determine the significance of hepatic vein waveform changes on doppler ultrasound in cirrhotic patients and to correlate with liver dysfunction. They concluded that hepatic vein wave form changes reflects the change in hepatic circulation associated with progression of liver cirrhosis. It can be used as a new parameter in the assessment of severity of liver cirrhosis. Thus, alteration in hepatic venous blood flow pattern on doppler ultrasound can be a useful noninvasive tool for evaluating diseases severity in patients with cirrhosis".

**"Afif AM et al (2017)**[66] This study aims to correlate the Doppler ultrasound values with the progression of liver cirrhosis to allow further understanding and possible prediction of clinical events for timely intervention. The incidence of ascites increases with the severity of cirrhosis. Flattening of the hepatic vein waveforms was dependant on degree of liver cirrhosis. Maximum hepatic vein velocity was higher in cirrhotic patients (where $p = 0.05$). Maximum portal vein velocity was found to be lower in cirrhosis (where $p < 0.001$) and mean maximum portal vein velocity decreases as severity of cirrhosis worsens. Hepatic artery resistive index was significantly higher in cirrhosis (where $p < 0.001$). Significant association was found between maximum hepatic vein velocity and maximum hepatic artery velocity and significant negative correlation was observed with the maximum portal vein velocity and hepatic artery resistive index. The study demonstrated that these parameters can supplement the evaluation of liver cirrhosis and will be able to distinguish the different grades of liver cirrhosis using Doppler ultrasound".

**"ntil N et al (2016)**[67] evaluate hepatic venous waveform, damping index, splenoportal index in patients of cirrhosis on Colour Doppler ultrasound, also predict severity of portal hypertension and presence of oesophageal varices. Twenty two (73.3%) patients had monophasic waveform. Biphasic and triphasic waveforms were seen in 4 (13.3%) cases. Twenty two patients (73.3%) had monophasic waveforms and majority of them were in class C. This distribution of hepatic vein waveform was statistically significantly with the Child Pugh's class ($p<0.05$). Twenty patients (66.7%) had value of Damping index more than >0.6 where majority of patients (18) belonged to class C and 2 in class B. There was a positive correlation between Child Pugh's total score and Damping index ($r=0.614$; $p<0.05$). There was weak positive correlation between splenoportal index and Child Pugh's score ($r=0.269$; $p=0.15$). They concluded that change in triphasic to monophasic waveform and DI >0.6 suggests severe liver dysfunction and is associated with severe portal hypertension. Hepatic venous waveform pressure changes, DI and SPI have no value in predicting presence of oesophageal varices".

**Bhutto AR et al (2012)**[68] "determined the correlation of hepatic venous waveform changes with severity of hepatic dysfunction and grading of oesophageal varices. A cross-sectional analytical study was conducted. Total of 65 patients who met the inclusion criteria and included in the study with mean age of 47.39 +/- 10.91 (range 23-70) years. Among these 51 (78.5%) were males while 14 (21.5%) were females. On the basis of hepatic function 32 (49.2%) patients presented in Child-Pugh Class A, 23 (35.4%) with Class B and 10 (15.4%) patients had Class C. Hepatic venous waveform was triphasic in 5 (7.7%), biphasic in 18 (27.7%), and monophasic in 42 (64.6%) cases. The relationship of these waveforms had significant relation with hepatic dysfunction ($p < 0.012$) while insignificant with grading of oesophageal varices (p 0.29). Upper GI endoscopy revealed large grade varices in 37 (56.9%) patients, 17 (26.2%) patients had small grade varices while no varices were found in 11

(16.9%) patients. They concluded that hepatic venous waveform pressure changes have significant relation with severity of hepatic dysfunction but insignificant relation with grading of oesophageal varices".

**Joseph T et al (2011)**[69] "aimed to study the sensitivity of loss of normal hepatic venous waveforms in predicting large varices in a cross-sectional analysis. A total of 51 cases were examined. Triphasic waves were seen in 4 (7.8%) cases, biphasic in 26 (51%) cases, and monophasic in 21 (41.2%) cases. Small varices were seen in 30 (58.8%) cases and large varices in 21 (41.2%) cases. The sensitivity of loss of the triphasic wave pattern in detecting significant varices (Grade 3 or 4) was very high (95.23%) and negative predictive value was also high (75%). Severity of liver disease as indicated by Child-Pugh and MELD scores did not correlate with changes in hepatic venous waveforms. They concluded that loss of triphasic hepatic venous waveform is highly sensitive in predicting significant varices in patients with cirrhosis".

**Kawanaka H et al (2008)**[70] "investigated the prognostic significance of changes in the Doppler hepatic vein (HV) waveforms in cirrhotic patients with portal hypertension and the mechanisms of these changes. They concluded that analyzing the HV waveforms was thus found to be a simple method for accurately assessing the prognosis in cirrhotic patients with portal hypertension".

**Sudhamshu KC et al (2006)**[71] "evaluated the significance of Doppler measurements of hepatic vein in cirrhotic patients and to correlate with liver dysfunction and hepatic hemodynamics. They concluded that doppler waveforms of hepatic vein, which is independent of liver dysfunction, should be obtained during normal respiration. Mean hepatic vein velocity reflects the change in hepatic circulation associated with progression of liver cirrhosis. It can be used as a new parameter in the assessment of liver cirrhosis".

**Parra Blanco JA et al (1995)**[72] "evaluate the changes in the Doppler waveform of the hepatic veins in patients with cirrhosis. Abnormal hepatic vein waveforms were found in 40 of 43 patients with cirrhosis and in none of the 50 controls subjects. No statistically significant differences were detected between the different Doppler waveform patterns and the Child-Pugh score ($p = 0.063$). Findings indicate that an alteration of the Doppler waveform pattern of hepatic veins suggest the presence of cirrhosis and that there is no association between the degree of the liver failure and the waveform patterns".

# MATERIAL AND METHODS

- **Study design:** Cross-sectional study
- **Study area:** Department of Radiodiagnosis, Shri B M Patil Medical College Hospital & Research Centre, B.L.D.E. (Deemed to be) University, Vijayapura.
- **Study period:** Research study was conducted from May 2023 to December 2024. Below is the work plan.

**Table 1: Work plan of the study with percentage of allocation of study time and duration in months**

- **Sample size**:

With anticipated proportion of Monophasic in cirrhotic 37.5%, the study would require a "sample size of 140 patients with 95% level of confidence and 8% absolute precision",

Formula used

$$n=\frac{z^2\, p*q}{d^2}$$

Where,

Z= Z statistic at α level of significance

$d^2$= Absolute error

p= Proportion rate

q= 100-p

- **Inclusion criteria:**

1. All the patients with suspected cirrhosis with mean age of 25 -75 years

- **Exclusion criteria:**

1. All the patients with
    i. Hepato- cellular carcinoma

ii. “Thrombosis in IVC, hepatic vein or portal vein

iii. Congestive heart failure”.

**METHODOLOGY:**

**Study Design and Equipment:**

The research was conducted utilizing two advanced ultrasound machines: the GE VOLUSON S8 BT18 and the GE VERSANA PREMIER. These state-of-the-art imaging systems were selected to ensure high-resolution and precise diagnostic capabilities for hepatic wave form analysis.

**Doppler Ultrasound Technique:**

Doppler ultrasound examinations were performed using a 3.5 MHz convex probe, following a standardized protocol to ensure consistent and reproducible imaging results. The right hepatic vein was meticulously identified at a distance of 3-5 cm from the junction of the hepatic vein with the inferior vena cava.

**Wave Form Classification:**

Hepatic vein wave forms were systematically classified into three distinct categories based on their hemodynamic characteristics:

i. Triphasic Wave Forms: Characterized by reversed flow in at least one phase of the cardiac cycle.

ii. Biphasic Wave Forms: Demonstrated no reversed flow patterns.

iii. Monophasic Wave Forms: Exhibited a flat configuration without characteristic flutter.

This classification method allowed for a comprehensive assessment of hepatic vascular dynamics and potential pathological alterations.

**Hepatic Function Assessment:**

The Child-Pugh grading system was employed to comprehensively evaluate hepatocellular function. The assessment incorporated five critical parameters:

i. Serum Bilirubin Levels
ii. Serum Albumin Concentration
iii. Presence and Severity of Ascites
iv. Encephalopathy Status
v. Prothrombin Time

**Patient Categorization:**

Patients were systematically categorized into three distinct Child-Pugh grades:

- Grade A: Indicated the most favorable prognosis
- Grade B: Represented an intermediate disease severity
- Grade C: Signified the most advanced and challenging disease state

This stratification provided a nuanced approach to assessing disease progression and potential complications.

**Correlation Analysis:**

A comprehensive correlation analysis was conducted to evaluate the relationship between observed hepatic vein wave form changes and the corresponding Child-Pugh

classification. This approach aimed to explore potential predictive value and diagnostic insights into cirrhotic disease severity.

**Ethical Considerations:**

Prior to study commencement, the research protocol was submitted to and approved by the institutional ethics committee. Informed consent was obtained from all participants, ensuring their full understanding of the study procedures and potential implications.

**Data Collection and Management:**

A standardized data collection proforma was developed to systematically record:

- Patient demographic information
- Detailed medical history
- Ultrasound findings
- Wave form characteristics
- Child-Pugh classification details
- Additional clinical parameters

**STATISTICAL ANALYSIS**

Data was entered in excel sheet and analyzed using SPSS version 21. “Results were presented in tabular and graphical forms Mean, median, standard deviation and ranges were calculated for quantitative data. Qualitative data were expressed in terms of frequency and percentages. Student t test (Two Tailed) was used to test the significance of mean and P value <0.05 was considered significant”.

# RESULTS

The "present study was conducted on the department of Radiodiagnosis at Shri B M Patil Medical College Hospital & Research Centre, B.L.D.E University,Vijayapura to determine the significance of hepatic vein waveform changes on ultrasound in cirrhotic patients and to correlate with severity of disease". Total of 140 patients were considered for the study. Following were the results of the study:

**Table 1: Distribution of patients according to age**

| Age (in years) | Frequency | Percentage |
|---|---|---|
| **20-40** | 38 | 27.1% |
| **41-60** | 63 | 45% |
| **61-80** | 39 | 27.9% |
| **Total** | **140** | **100%** |

Table 1 and graph1 shows that most patients in the study were middle-aged, with 45% falling in the 41-60 years age group, while the 20-40 years (27.1%) and 61-80 years (27.9%) age groups had similar proportions.

**Graph 1: Distribution of patients according to age**

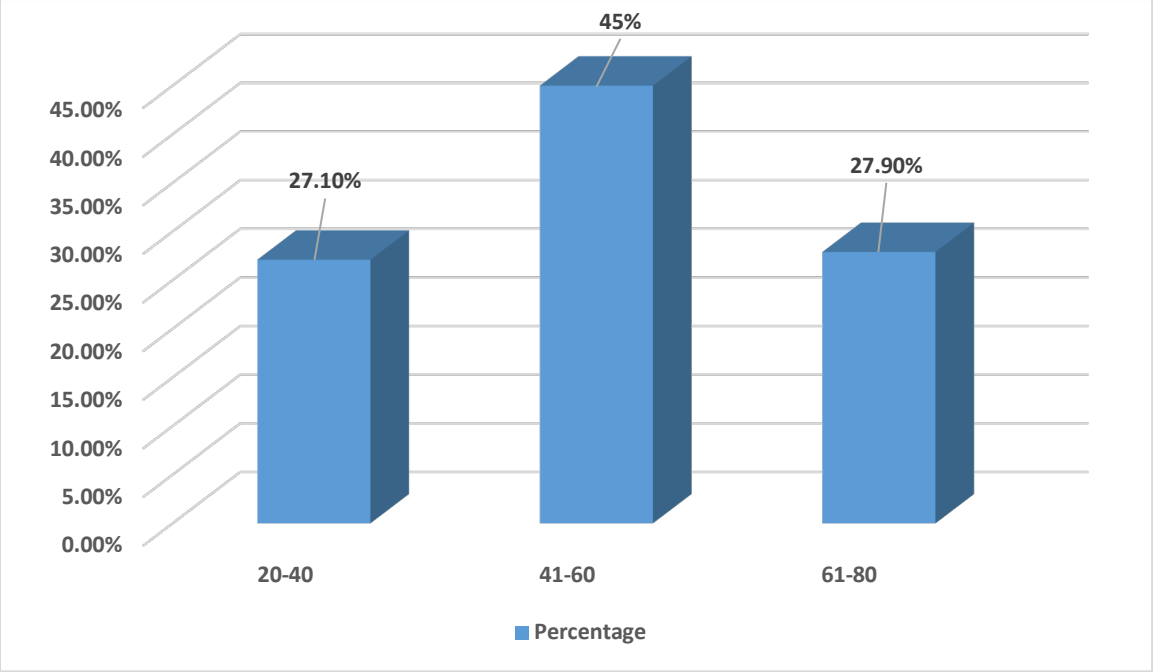



**Table 2: Distribution of patients according to gender**

| Gender | Frequency | Percentage |
|---|---|---|
| **Female** | 57 | 40.7% |
| **Male** | 83 | 59.3% |
| **Total** | **140** | **100%** |

Table 2 and graph 2 reveals that males constituted a larger proportion of the study population at 59.3%, compared to females at 40.7%, indicating a male predominance among the cirrhotic patients studied.

**Graph 2: Distribution of patients according to gender**

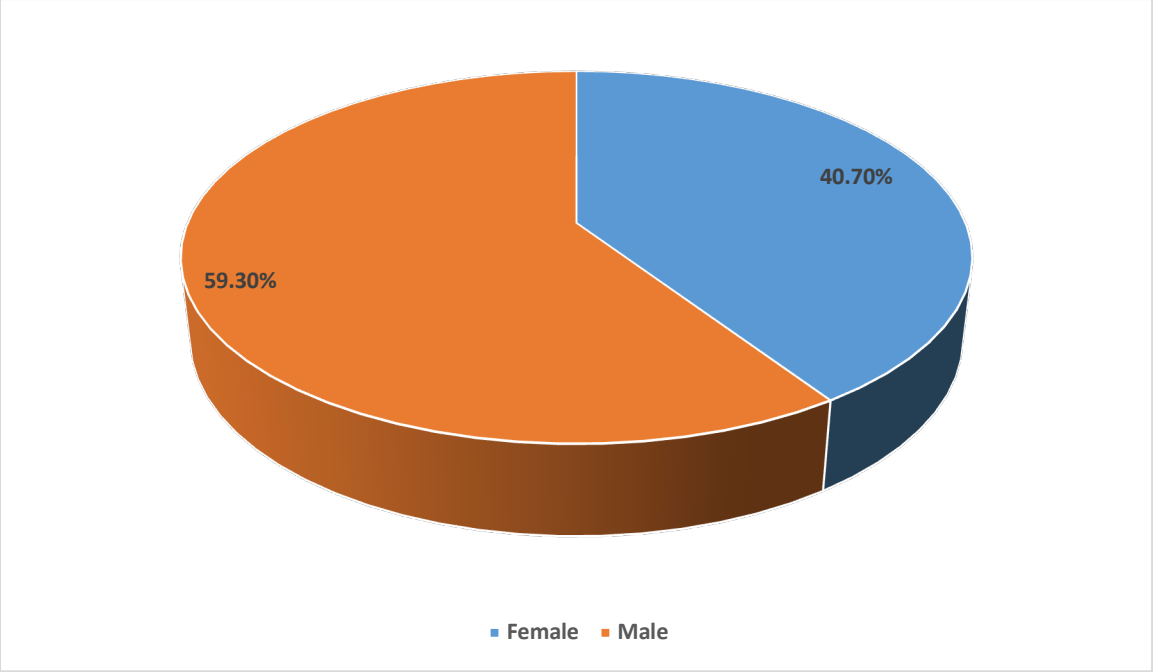



**Table 3: Distribution of patients according to Child Pugh class**

| Child Pugh class | Frequency | Percentage |
|---|---|---|
| **A** | 32 | 22.9% |
| **B** | 35 | 25% |
| **C** | 73 | 52.1% |
| **Total** | **140** | **100%** |

Table 3 and graph 3 demonstrates the severity of liver disease among the patients, with more than half (52.1%) classified as Child-Pugh Class C (severe liver dysfunction), followed by Class B (25%) and Class A (22.9%), suggesting most patients had advanced cirrhosis.

**Graph 3: Distribution of patients according to Child Pugh class**

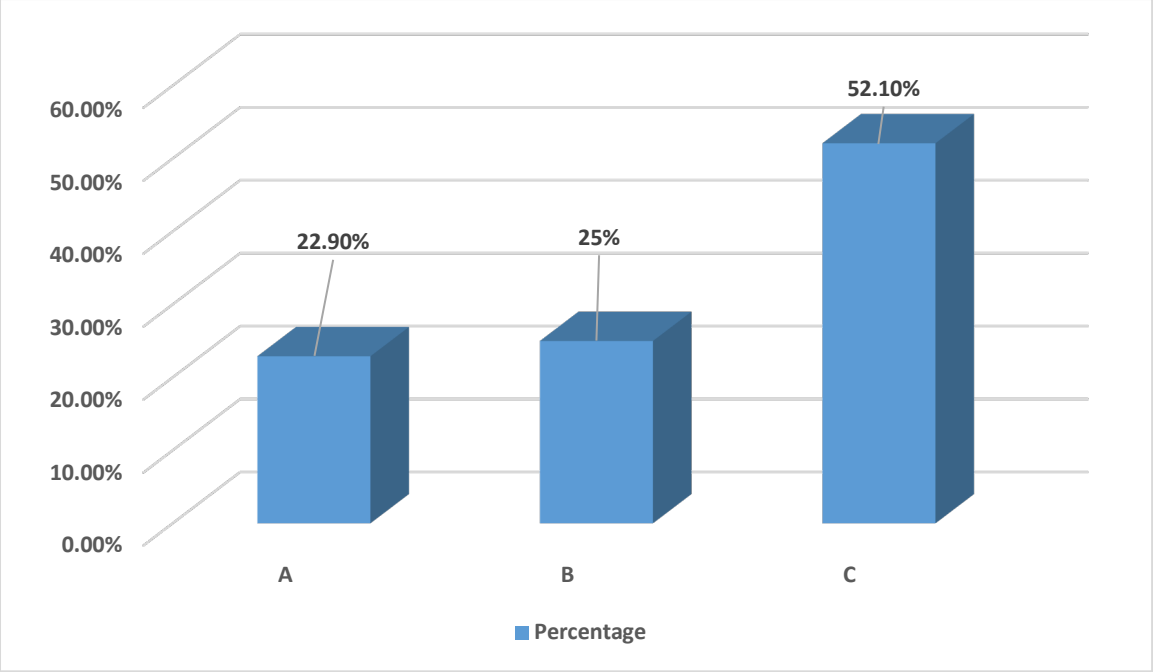



**Table 4: Distribution of patients according to hepatic vein waveform**

| Hepatic vein waveform | Frequency | Percentage |
|---|---|---|
| **Biphasic** | 51 | 36.4% |
| **Monophasic** | 54 | 38.6% |
| **Triphasic** | 35 | 25% |
| **Total** | **140** | **100%** |

Table 4 and graph 4 presents the distribution of hepatic vein waveforms detected by Doppler ultrasound, with monophasic waveforms being the most common (38.6%), followed closely by biphasic (36.4%), and triphasic waveforms (25%).

**Graph 4: Distribution of patients according to hepatic vein waveform**

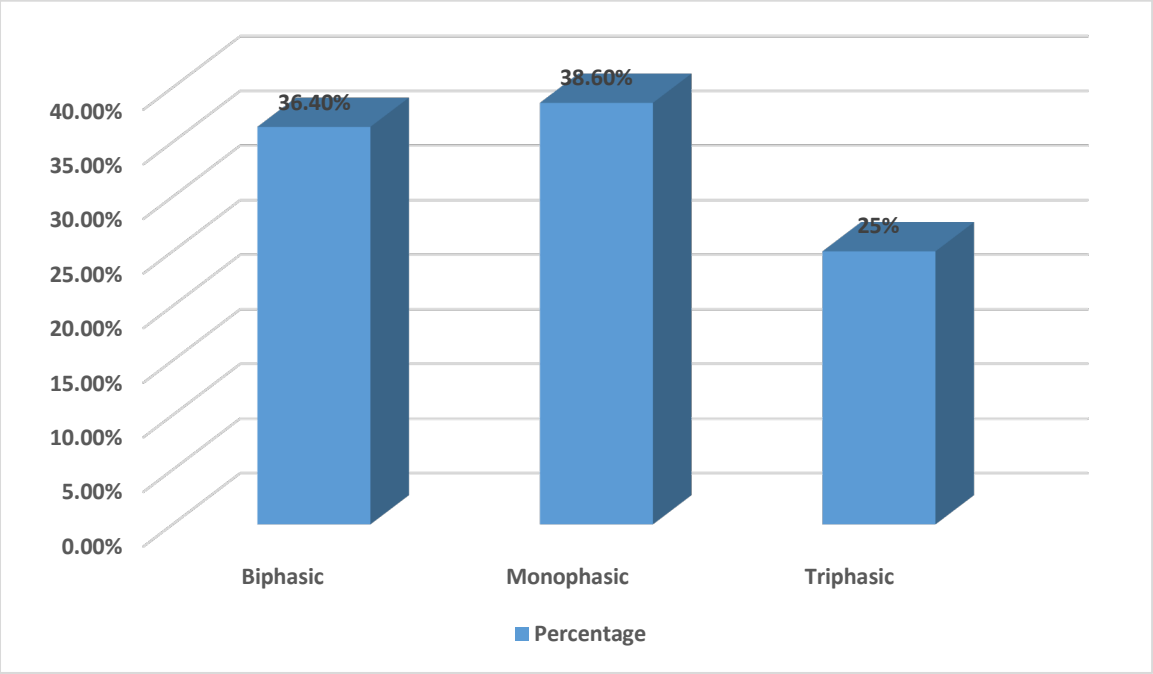



**Table 5: Distribution of patients according to ascites**

| Ascites | Frequency | Percentage |
|---|---|---|
| **None** | 44 | 31.4% |
| **Mild** | 42 | 30% |
| **Severe** | 54 | 38.6% |
| **Total** | **140** | **100%** |

Table 5 and graph 5 indicates that 38.6% of patients had severe ascites, 30% had mild ascites, and 31.4% had no ascites, showing that the majority of patients (68.6%) presented with some degree of ascites.

**Graph 5: Distribution of patients according to ascites**

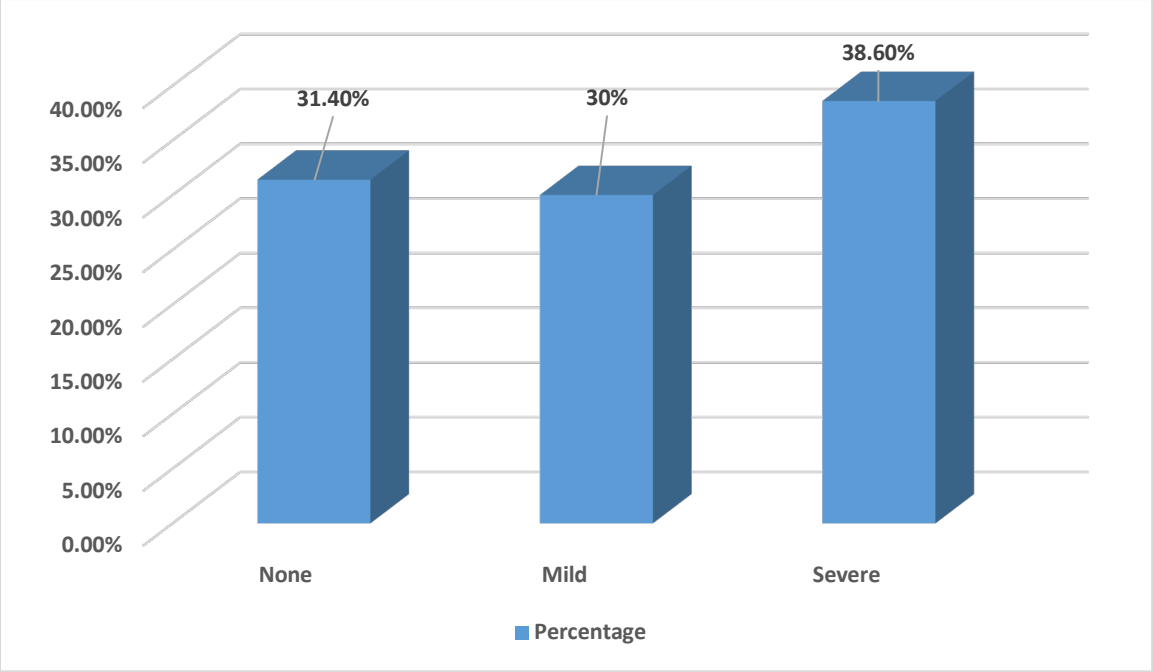



**Table 6: Distribution of patients according to albumin**

| Albumin (mg/dl) | Frequency | Percentage |
|---|---|---|
| **<2.8** | 51 | 36.4% |
| **2.8-3.5** | 46 | 32.9% |
| **>3.5** | 43 | 30.7% |
| **Total** | **140** | **100%** |

Table 6 and graph 6 shows that 36.4% of patients had severe hypoalbuminemia (<2.8 mg/dl), 32.9% had moderate hypoalbuminemia (2.8-3.5 mg/dl), and 30.7% had normal albumin levels (>3.5 mg/dl), reflecting the impact of cirrhosis on liver synthetic function.

**Graph 6: Distribution of patients according to albumin**

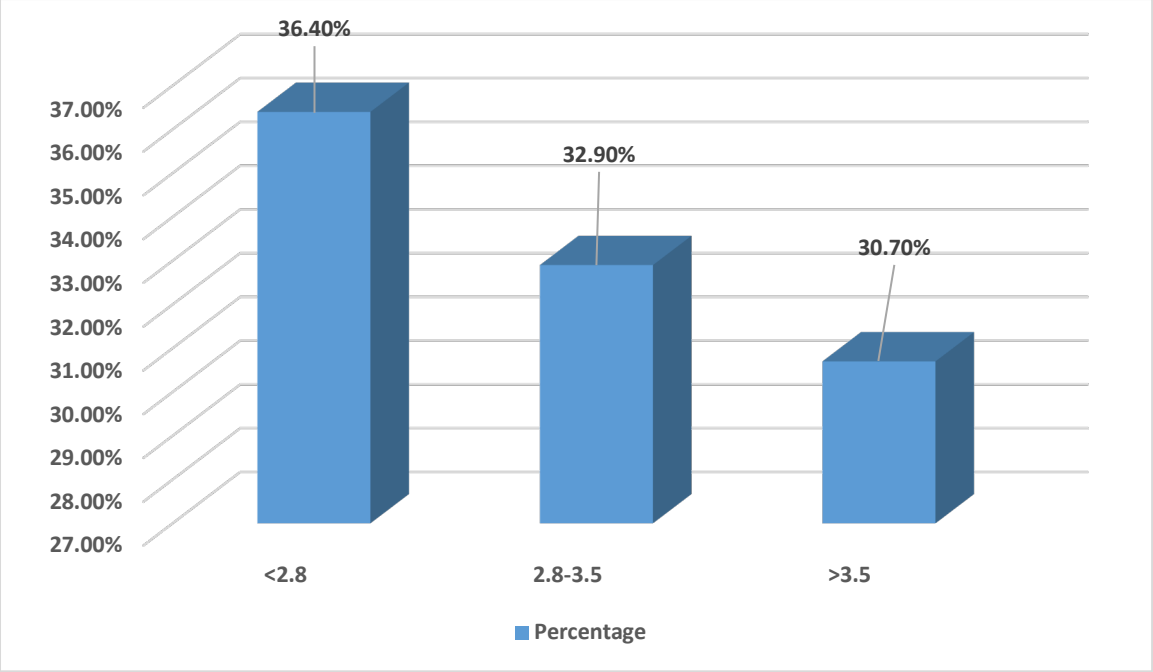



**Table 7: Distribution of patients according to bilirubin**

| Bilirubin (mg/dl) | Frequency | Percentage |
|---|---|---|
| **<2** | 16 | 11.4% |
| **2-3** | 5 | 3.6% |
| **>3** | 119 | 85% |
| **Total** | **140** | **100%** |

Table 7 and graph 7 demonstrates that the vast majority of patients (85%) had significantly elevated bilirubin levels (>3 mg/dl), while only 11.4% had normal bilirubin levels (<2 mg/dl) and 3.6% had moderately elevated levels (2-3 mg/dl).

**Graph 7: Distribution of patients according to bilirubin**

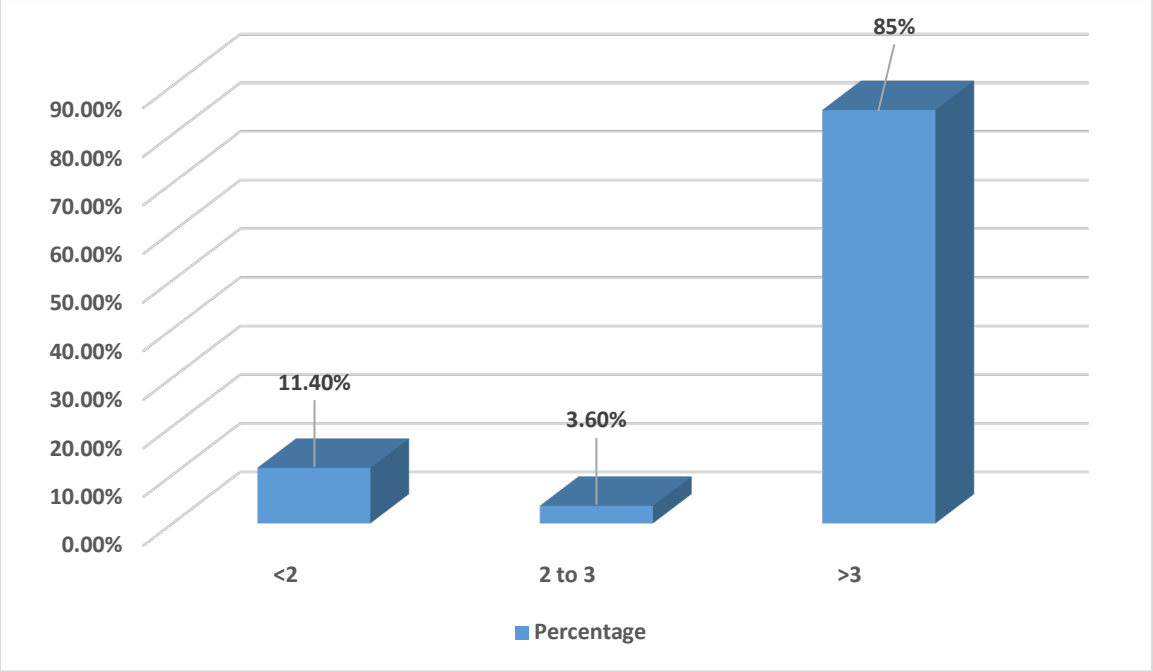



**Table 8: Distribution of patients according to PT**

| PT (seconds) | Frequency | Percentage |
|---|---|---|
| **<4** | 140 | 100% |
| **4-6** | - | - |
| **Total** | **140** | **100%** |

Table 8 and graph 8 shows that all patients (100%) had prothrombin time (PT) less than 4 seconds, indicating that there was no significant prolongation of PT in the study population.

**Graph 8: Distribution of patients according to PT**

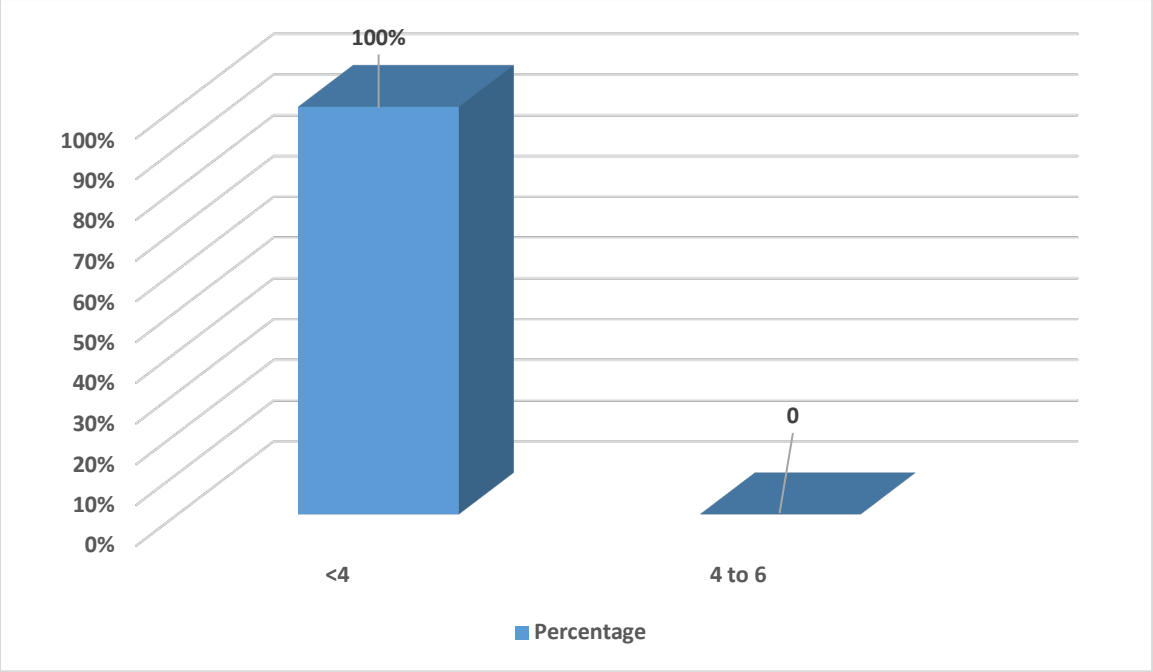



**Table 9: Association of hepatic vein waveform with Child Pugh class**

| Child pugh class | Hepatic vein waveform | | | p-value |
|---|---|---|---|---|
| | Biphasic | Monophasic | Triphasic | |
| **A** | 6 (11.8%) | 3 (5.6%) | 20 (57.1%) | **<0.001** |
| **B** | 10 (19.6%) | 13 (24.1%) | 15 (42.9%) | |
| **C** | 35 (68.6%) | 38 (70.4%) | 0 | |
| **Total** | **51(100%)** | **54 (100%)** | **35 (100%)** | |

Table 9 and graph 9 reveals a highly significant association ($p<0.001$) between hepatic vein waveform and Child-Pugh class, with 68.6% of biphasic and 70.4% of monophasic waveforms occurring in Class C patients, while 57.1% of triphasic waveforms were seen in Class A patients, suggesting that waveform changes correlate with disease severity.

**Graph 9: Association of hepatic vein waveform with Child Pugh class**

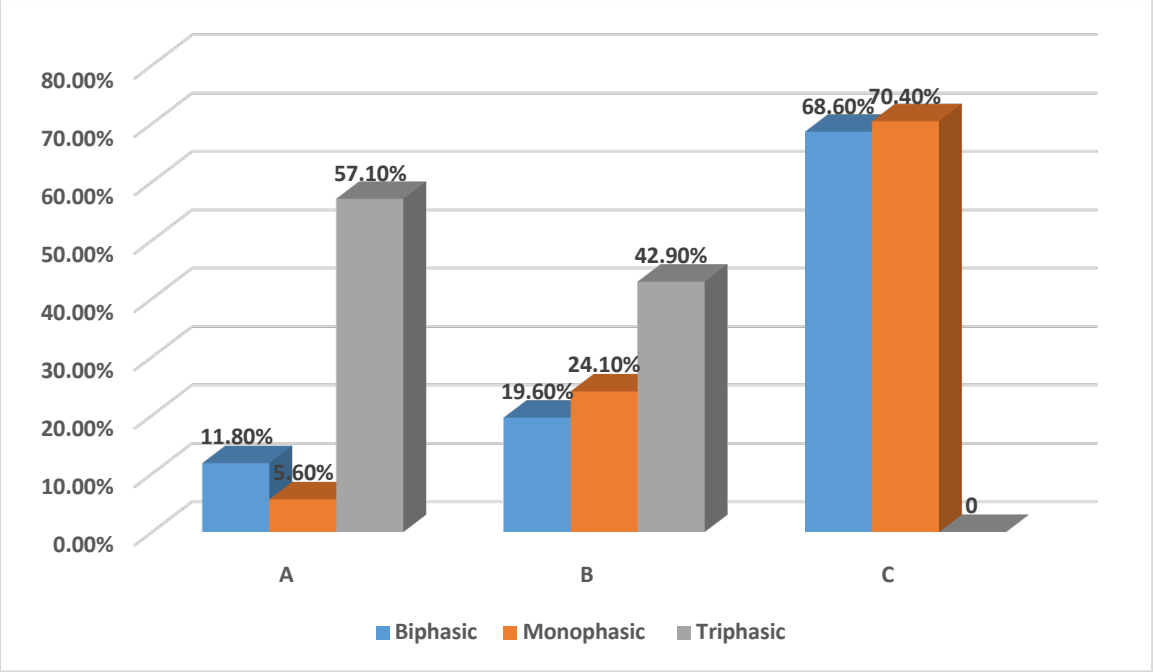



**Table 10: Association of hepatic vein waveform with ascites**

| Ascites | hepatic vein waveform | | | p-value |
|---|---|---|---|---|
| | Biphasic | Monophasic | Triphasic | |
| **None** | 13 (25.5%) | 10 (18.5%) | 20 (57.1%) | **<0.001** |
| **Mild** | 17 (33.3%) | 16 (29.6%) | 10 (28.6%) | |
| **Severe** | 21 (41.2%) | 28 (51.9%) | 5 (14.3%) | |
| **Total** | **51 (100%)** | **54 (100%)** | **35 (100%)** | |

Table 10 and graph 10 indicates highly significant association ($p<0.001$) between hepatic vein waveform and presence or severity of ascites, with 41.2% of biphasic and 51.9% of monophasic waveforms occurring in severe ascites patients, while 57.1% of triphasic waveforms were seen in no ascites patients, suggesting that waveform changes correlate with ascites.

**Graph 10: Association of hepatic vein waveform with ascites**

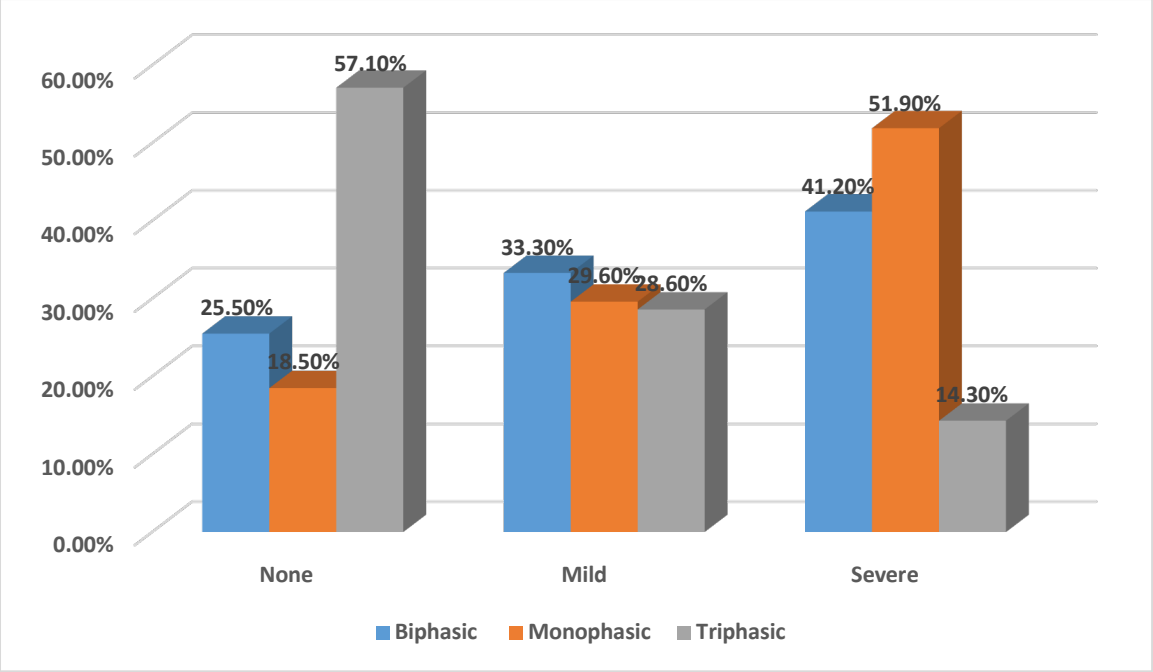



**Table 11: Association of hepatic vein waveform with albumin**

| Albumin | hepatic vein waveform | | | p-value |
|---|---|---|---|---|
| | Monophasic | Biphasic | Triphasic | |
| **<2.8** | 23 (42.6%) | 20 (39.2%) | 8 (22.9%) | 0.39 |
| **2.8-3.5** | 16 (29.6%) | 17 (33.3%) | 13 (37.1%) | |
| **>3.5** | 15 (27.8%) | 14 (27.5%) | 14 (40%) | |
| **Total** | **54 (100%)** | **51 (100%)** | **35 (100%)** | |

Table 11 and graph 11 shows no significant association (p=0.39) between hepatic vein waveform and albumin levels, though there was a trend toward more patients with triphasic waveforms having normal albumin levels (40%) compared to monophasic (27.8%) or biphasic (27.5%).

**Graph 11: Association of hepatic vein waveform with albumin**

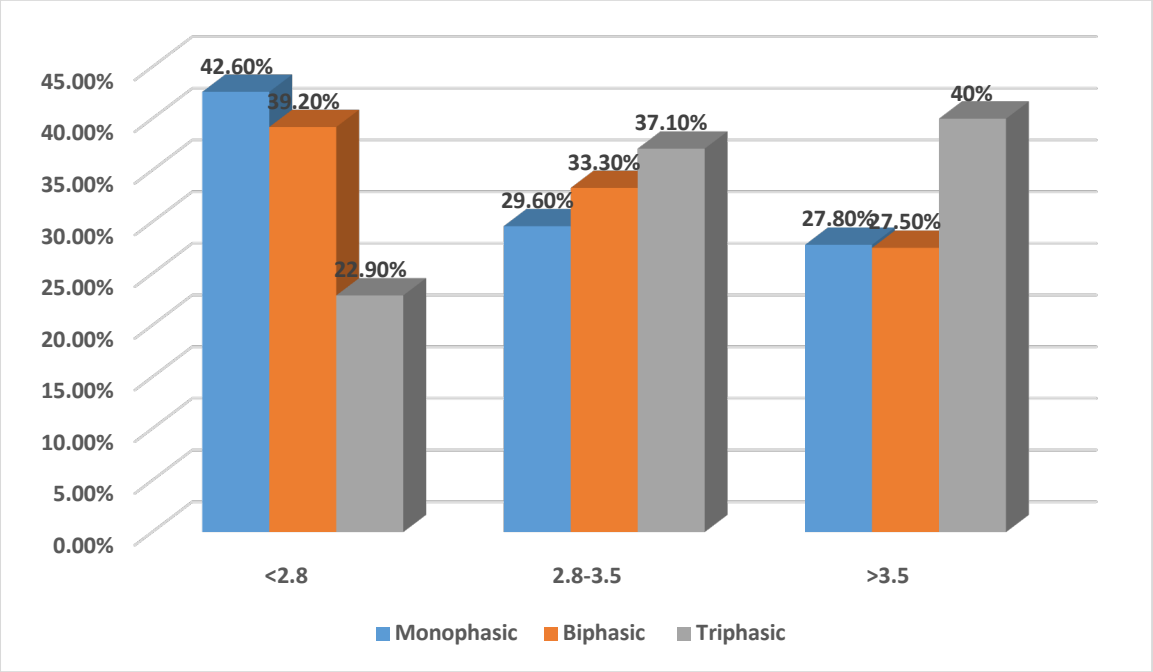



**Table 12: Association of hepatic vein waveform with bilirubin**

| Bilirubin | hepatic vein waveform | | | p-value |
|---|---|---|---|---|
| | Monophasic | Biphasic | Triphasic | |
| **<2** | 4 (7.4%) | 6 (11.8%) | 6 (17.1%) | 0.53 |
| **2-3** | 1 (1.9%) | 2 (3.9%) | 2 (5.7%) | |
| **>3** | 49 (90.7%) | 43 (84.3%) | 27 (77.1%) | |
| **Total** | **54 (100%)** | **51 (100%)** | **35 (100%)** | |

Table 12 and graph 12 demonstrates no significant association (p=0.53) between hepatic vein waveform and bilirubin levels, though patients with triphasic waveforms had a slightly lower proportion of severely elevated bilirubin (77.1%) compared to monophasic (90.7%) or biphasic (84.3%) waveforms.

**Graph 12: Association of hepatic vein waveform with bilirubin**

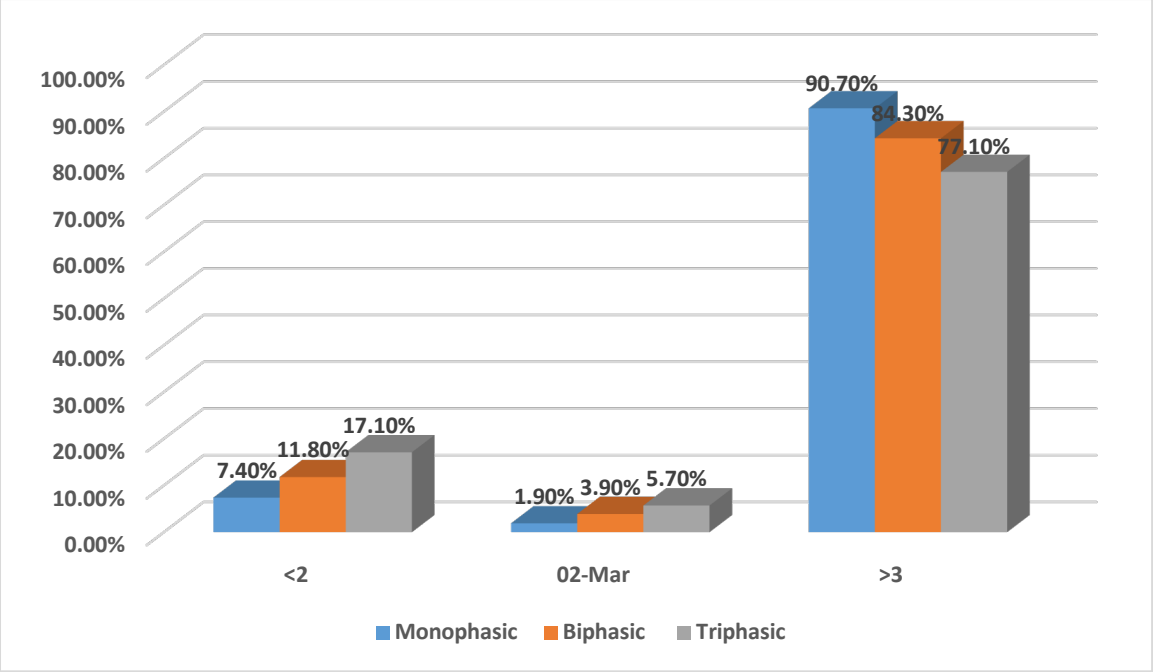



**Table 13: Association of hepatic vein waveform with age**

| Age (in years) | hepatic vein waveform | | | p-value |
|---|---|---|---|---|
| | Monophasic | Biphasic | Triphasic | |
| **20-40** | 7 (12.9%) | 18 (35.3%) | 13 (37.1%) | **0.008** |
| **41-60** | 28 (51.8%) | 25 (49.01%) | 10 (28.6%) | |
| **61-80** | 19 (35.1%) | 8 (15.9%) | 12 (34.3%) | |
| **Total** | **54 (100%)** | **51 (100%)** | **35 (100%)** | |

Table 13 and graph 13 reveals a significant association (p=0.008) between hepatic vein waveform and age, with monophasic waveforms being more common in the 41-60 years age group (51.8%), while biphasic and triphasic waveforms were more prevalent in younger patients (35.3% and 37.1% in the 20-40 years group, respectively).

**Graph 13: Association of hepatic vein waveform with age**

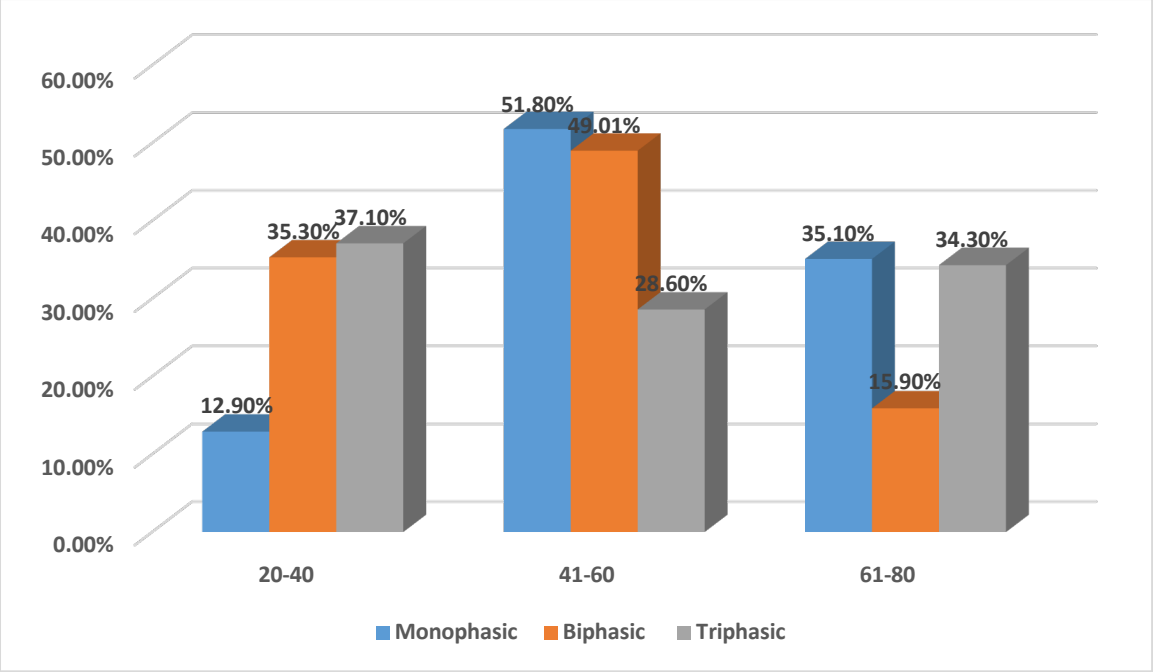



**Table 14: Sensitivity analysis of hepatic vein wave form by doppler ultrasound**

| **Sensitivity analysis of hepatic vein wave form** | |
|---|---|
| **Sensitivity** | 100% |
| **Specificity** | 52.2% |
| **PPV** | 69.5% |
| **NPV** | 100% |

Table 14 presents the diagnostic performance of hepatic vein waveform assessment, showing excellent sensitivity (100%) and negative predictive value (100%), with moderate specificity (52.2%) and positive predictive value (69.5%), suggesting it is a reliable screening tool for detecting the severity of liver disease in cirrhotic patients.

# DISCUSSION

Liver cirrhosis represents the final common pathway of various chronic liver diseases,

characterized by progressive fibrosis, distortion of hepatic architecture, and formation of regenerative nodules. These pathological changes lead to significant hemodynamic alterations in the hepatic vasculature, which can be assessed non-invasively using Doppler ultrasonography. The normal triphasic hepatic venous waveform pattern typically undergoes progressive dampening as cirrhosis advances, evolving to biphasic and subsequently monophasic patterns, reflecting increasing hepatic vascular resistance and compliance changes. This study aimed to evaluate the "correlation between hepatic vein waveform changes on Doppler ultrasound and the severity of disease in cirrhotic patients to establish the utility of this non-invasive parameter as a prognostic indicator". The results demonstrated a statistically significant association between hepatic vein waveform patterns and Child-Pugh classification, providing valuable insights into the pathophysiological progression of cirrhosis and offering a potential tool for clinical assessment and management of these patients.

**Demographic Characteristics of Study Population**

Our study included 140 cirrhotic patients with a predominance of middle-aged individuals (45% in the 41-60 years age group) and a male preponderance (59.3%). This demographic pattern aligns with findings from other studies on cirrhotic populations. Bhutto et al. "conducted a similar study on 93 patients with chronic liver disease and reported a mean age of 48.2 years" with 61.3% male participants, closely mirroring our demographic distribution.[73] Similarly, Baik et al. in their study of hepatic vein waveforms in cirrhotic patients noted a predominance of male patients (68%) with a mean age of 52 years.[74] This consistency across studies likely reflects the epidemiological pattern of chronic liver disease, which often manifests clinically in middle age following years of subclinical progression, particularly in male patients who have higher rates of precipitating factors such as alcohol consumption and viral hepatitis.

The gender disparity observed in our study population, with male predominance, is

consistent with global epidemiological data on cirrhosis. Solhjoo et al. in their assessment of 82 cirrhotic patients reported 67.1% male patients and attributed this gender disparity to higher rates of alcohol consumption, viral hepatitis, and metabolic syndrome among men.[75] This gender-based vulnerability to cirrhosis has been repeatedly documented in the literature and may reflect both biological differences in disease susceptibility and behavioral patterns influencing exposure to cirrhosis risk factors.

**Disease Severity Assessment**

In our study population, more than half of the patients (52.1%) were classified as Child-Pugh Class C, indicating advanced liver dysfunction. This distribution differs somewhat from the study by Mittal et al., who reported a more uniform distribution across Child-Pugh classes in their cohort of 100 cirrhotic patients (Class A: 33%, Class B: 32%, Class C: 35%).[76] The higher proportion of advanced cases in our study might be attributed to referral patterns to our tertiary care center, where more severe cases are typically referred for specialized management.

The laboratory parameters in our cohort revealed significant liver dysfunction, with 85% of patients showing markedly elevated bilirubin levels (>3 mg/dl) and 69.3% demonstrating hypoalbuminemia (albumin <3.5 mg/dl). These findings align with the observations of Kim et al., who documented hypoalbuminemia in 72% and hyperbilirubinemia in 78% of their cirrhotic cohort.[77] The consistency of these biochemical derangements across studies underscores their reliability as markers of hepatic synthetic dysfunction in cirrhosis.

Interestingly, our study showed that all patients had prothrombin time (PT) less than 4 seconds, which contrasts with the expected coagulopathy in advanced cirrhosis. This finding diverges from observations by Lv Yet al., who reported prolonged PT in 80.5% of Child-Pugh Class C patients.[78] This discrepancy warrants further investigation and might relate to methodological differences in PT measurement or potential confounding factors such as vitamin K supplementation prior to assessment.

**Hepatic Vein Waveform Patterns**

Our study demonstrated a distribution of hepatic vein waveforms with 38.6% monophasic, 36.4% biphasic, and 25% triphasic patterns. This distribution shows similarities with findings by Mahmoud et al., who reported 42% monophasic, 33% biphasic, and 25% triphasic waveforms in their study of 120 cirrhotic patients.[79] The predominance of monophasic and biphasic waveforms in both studies reflects the hemodynamic alterations associated with advanced cirrhosis.

A key finding in our study was the highly significant association ($p<0.001$) between hepatic vein waveform patterns and Child-Pugh classification. We observed that 68.6% of patients with biphasic waveforms and 70.4% with monophasic waveforms belonged to Child-Pugh Class C, while 57.1% of those with triphasic waveforms were in Class A. This strong correlation between waveform dampening and disease severity has been consistently reported in the literature. Baik et al. in their landmark study found that 85% of Child-Pugh Class C patients exhibited monophasic waveforms, while 73% of Class A patients maintained triphasic patterns(74). Similarly, Joseph et al. observed a significant correlation between waveform patterns and Child-Pugh scores ($p<0.001$), with monophasic patterns predominating in Class C (76%) and triphasic patterns in Class A (81%).[80]

The pathophysiological basis for this correlation lies in the progressive fibrotic changes and vascular remodeling in cirrhosis. Bolondi et al. proposed that increased stiffness of the liver parenchyma impedes the transmission of cardiac and respiratory pulsations to the hepatic veins, leading to dampening of the typical triphasic waveform.[81] Additionally, intrahepatic portosystemic shunts that develop with advancing cirrhosis alter the pressure gradients and compliance characteristics of the hepatic veins, further contributing to waveform abnormalities. These hemodynamic changes progress parallel to the clinical and biochemical deterioration quantified by the Child-Pugh classification, explaining the robust correlation observed in our

study.

**Relationship Between Hepatic Vein Waveforms and Clinical Parameters**

**Ascites**

Our study found significant association (p=0.001) between hepatic vein waveform patterns and the presence or severity of ascites. This finding is similar with some previous reports in the literature. Solhjoo et al. documented a significant correlation between abnormal hepatic vein waveforms and the presence of ascites (p=0.003) in their study of 82 cirrhotic patients.[75] Similarly, Chen et al. reported that 82% of cirrhotic patients with ascites demonstrated abnormal (monophasic or biphasic) hepatic vein waveforms compared to 45% of those without ascites.[82]

The discrepancy between our findings and previous studies might be explained by the multifactorial etiology of ascites in cirrhosis. While portal hypertension serves as the primary driver, other factors including hypoalbuminemia, activation of the renin-angiotensin-aldosterone system, and systemic inflammatory responses also contribute significantly. The hepatic vein waveform primarily reflects local hemodynamic changes in the liver vasculature and may not capture the complex interplay of systemic factors influencing ascites formation. Additionally, the timing of diuretic therapy relative to ultrasound assessment could potentially confound the relationship between waveform patterns and ascites severity, as noted by Kim et al. in their longitudinal assessment of cirrhotic patients.[77]

**Albumin Levels**

Our analysis revealed no significant association (p=0.39) between hepatic vein waveform patterns and serum albumin levels, although we observed a trend toward more patients with triphasic waveforms having normal albumin levels (40%) compared to those with monophasic (27.8%) or biphasic (27.5%) waveforms. This trend, while not reaching statistical significance, aligns with the observations of Akhtar et al., who reported a weak correlation

between albumin levels and hepatic vein waveform abnormalities (r=0.31, p=0.04).[78]

The limited correlation between albumin levels and hepatic vein waveforms can be explained by considering the pathophysiological mechanisms involved. Serum albumin primarily reflects the synthetic function of hepatocytes, while waveform changes predominantly result from mechanical alterations in hepatic vasculature due to fibrosis and vascular remodeling. These processes, although concurrent in advancing cirrhosis, follow somewhat independent progression trajectories. As noted by Shapiro et al., synthetic functions may be preserved relatively well in early cirrhosis despite significant portal hypertension and vascular alterations, or conversely, may deteriorate rapidly in certain conditions such as alcoholic hepatitis without proportional changes in portal hemodynamics.[83]

**Bilirubin Levels**

Similar to our findings with albumin, we observed no significant association (p=0.53) between hepatic vein waveform patterns and serum bilirubin levels. However, there was a trend toward patients with triphasic waveforms having a lower proportion of severely elevated bilirubin (77.1%) compared to those with monophasic (90.7%) or biphasic (84.3%) waveforms. This trend parallels the observations of Mittal et al., who reported a weak correlation between bilirubin levels and waveform abnormalities (r=0.28, p=0.05) in their cohort of 100 cirrhotic patients.[76]

The limited correlation between bilirubin levels and hepatic vein waveforms might be attributed to the complex determinants of hyperbilirubinemia in cirrhosis. Elevated bilirubin can result from a combination of decreased hepatic uptake, impaired conjugation, and reduced excretion, as well as from hemolysis in cases with splenomegaly and hypersplenism. These multiple mechanisms may explain why bilirubin levels do not directly parallel the hemodynamic changes reflected in hepatic vein waveforms. Kruskal et al. similarly noted the imperfect correlation between biochemical parameters and hemodynamic alterations in

cirrhosis, suggesting that these represent different aspects of the disease process that may progress at variable rates in individual patients.[84]

**Age-Related Variations in Hepatic Vein Waveforms**

A noteworthy finding in our study was the significant association (p=0.008) between hepatic vein waveform patterns and patient age. Monophasic waveforms were more common in the 41-60 years age group (51.8%), while biphasic and triphasic waveforms were more prevalent in younger patients (35.3% and 37.1% in the 20-40 years group, respectively). This age-related variation in waveform patterns has been previously reported by Joseph et al., who found a significant correlation between age and waveform abnormalities (p=0.02) in their study of 110 cirrhotic patients.[80]

Several factors might explain this age-related variation. First, younger patients might present at earlier stages of cirrhosis with better preserved hepatic vasculature. Second, age-related changes in cardiac function and systemic vascular compliance could influence hepatic venous flow patterns independent of liver disease. Bolondi et al. noted that even in non-cirrhotic elderly individuals, decreased cardiac output and reduced vascular compliance can lead to attenuated hepatic vein waveforms.[81] Third, the etiology of cirrhosis might differ across age groups, with conditions such as autoimmune hepatitis being more common in younger patients and potentially having different patterns of fibrosis and vascular remodeling compared to alcohol-related or metabolic cirrhosis more prevalent in older individuals.

**Diagnostic Performance of Hepatic Vein Waveform Assessment**

Our study evaluated the diagnostic performance of hepatic vein waveform assessment and found excellent sensitivity (100%) and negative predictive value (100%), with moderate specificity (52.2%) and positive predictive value (69.5%). These findings suggest that hepatic vein waveform assessment serves as an excellent screening tool for detecting the severity of liver disease in cirrhotic patients.

The high sensitivity and negative predictive value observed in our study align with findings from previous research. Chen et al. reported a sensitivity of 97% and negative predictive value of 95% for abnormal hepatic vein waveforms in predicting advanced cirrhosis.[82] Similarly, Shapiro et al. documented a sensitivity of 92% for monophasic waveforms in identifying Child-Pugh Class C patients.[83]

The relatively lower specificity (52.2%) in our study is also consistent with previous observations. Mahmoud et al. reported a specificity of 58% for abnormal waveforms in predicting advanced cirrhosis[79], while Kim et al. documented a specificity of 63%.[77] This moderate specificity might be attributed to the influence of extrahepatic factors on hepatic vein waveforms, including cardiac function, respiratory patterns, and systemic vascular compliance, which can occasionally produce abnormal waveforms in patients with less severe liver disease.

From a clinical perspective, the high sensitivity and negative predictive value make hepatic vein waveform assessment particularly valuable as a screening tool. A normal triphasic waveform effectively rules out advanced cirrhosis, while abnormal waveforms, though not always specific for severe disease, warrant further clinical evaluation. As noted by Kruskal et al., combining waveform assessment with other ultrasound parameters such as liver stiffness measurement, spleen size, and portal vein velocity can significantly enhance diagnostic accuracy.[84]

**Comparison with Other Non-invasive Assessment Methods**

When comparing hepatic vein waveform assessment with other non-invasive methods for evaluating cirrhosis severity, several considerations emerge. Liver stiffness measurement using transient elastography (FibroScan) has gained widespread adoption for staging fibrosis. Castera et al. reported a correlation coefficient of 0.73 between liver stiffness and Child-Pugh score, slightly higher than the correlation typically reported for hepatic vein waveforms ($r=0.65$-$0.70$).[85] However, elastography has limitations including technical failures in patients

with ascites and obesity, issues less commonly encountered with Doppler ultrasound.

Serological markers such as the AST to Platelet Ratio Index (APRI) and Fibrosis-4 (FIB-4) score also demonstrate good correlation with cirrhosis severity. Lin et al. reported a correlation coefficient of 0.68 between FIB-4 and Child-Pugh score(86). However, these markers can be influenced by non-hepatic conditions affecting their component measurements, potentially limiting their specificity.

The advantage of hepatic vein waveform assessment lies in its integration into routine abdominal ultrasound examination, requiring no additional equipment or blood sampling. As noted by Solhjoo et al., Doppler assessment adds minimal time to standard ultrasound evaluation and provides immediate results without additional cost.[75] Furthermore, unlike elastography or laboratory tests that provide numerical scores requiring interpretation, waveform patterns offer qualitative information that correlates well with clinical staging and is relatively easy to interpret even for non-specialist clinicians.

**Clinical Implications**

The findings of our study have several important clinical implications. First, the strong correlation between hepatic vein waveform patterns and Child-Pugh classification validates the use of Doppler ultrasound as a non-invasive tool for assessing cirrhosis severity. This is particularly valuable in settings where comprehensive laboratory testing might be unavailable or delayed, allowing for rapid risk stratification and clinical decision-making.

Second, the excellent sensitivity and negative predictive value of waveform assessment make it an ideal screening tool in the initial evaluation of suspected cirrhosis. A normal triphasic waveform in a patient with clinical signs suggestive of liver disease should prompt consideration of alternative diagnoses or early, compensated cirrhosis, potentially avoiding unnecessary invasive investigations.

Third, as highlighted by Joseph et al., serial assessment of hepatic vein waveforms

might serve as a prognostic indicator, with progression from triphasic to monophasic patterns potentially signaling clinical deterioration even before obvious changes in laboratory parameters.[80] This could facilitate earlier intervention and optimization of management strategies to prevent complications.

Finally, the integration of waveform assessment into multiparametric ultrasound evaluation, as proposed by Mahmoud et al., enhances the diagnostic accuracy of non-invasive assessment.[79] Combining waveform patterns with other ultrasound parameters such as liver surface nodularity, spleen size, and portal vein velocity creates a comprehensive sonographic profile that closely mirrors the clinical and pathological severity of cirrhosis.

**Limitations and Future Directions**

Our study has several limitations that warrant consideration. First, the cross-sectional design precludes evaluation of how waveform patterns evolve with disease progression in individual patients. Longitudinal studies with serial assessments would provide valuable insights into the temporal relationship between waveform changes and clinical deterioration.

Second, the study did not stratify patients based on cirrhosis etiology, which might influence the pattern and progression of vascular alterations. Future research should examine whether hepatic vein waveforms differ significantly across different etiologies such as viral hepatitis, alcoholic liver disease, and non-alcoholic steatohepatitis.

Third, we did not correlate waveform patterns with portal pressure measurements, which would provide direct evidence linking waveform abnormalities to portal hypertension. Invasive hepatic venous pressure gradient (HVPG) measurement in conjunction with Doppler assessment would establish whether waveform changes reliably reflect portal pressure elevation, as suggested by Baik et al.[74]

Fourth, the study did not evaluate inter-observer and intra-observer variability in waveform classification, which is essential for validating the reliability of this assessment

method in clinical practice. Standardized techniques and criteria for waveform classification would enhance reproducibility across different operators and centers.

Future research directions should include prospective validation of hepatic vein waveform assessment as a prognostic marker for clinical outcomes such as decompensation events, hospitalization, and mortality. Additionally, integrating waveform assessment into machine learning algorithms alongside other clinical, laboratory, and radiological parameters could potentially develop more accurate predictive models for cirrhosis progression and complications.

**Conclusion**

In conclusion, our study demonstrates a significant correlation between hepatic vein waveform patterns and the severity of disease in cirrhotic patients as assessed by the Child-Pugh classification. The progressive dampening of the normal triphasic waveform to biphasic and monophasic patterns parallels the clinical deterioration in cirrhosis, reflecting the underlying hemodynamic alterations associated with advancing disease.

The excellent sensitivity and negative predictive value of hepatic vein waveform assessment make it a valuable screening tool in the evaluation of cirrhotic patients. While not significantly correlated with individual parameters such as ascites, albumin, or bilirubin levels, waveform patterns show a robust association with the composite assessment of liver dysfunction represented by the Child-Pugh classification.

The integration of hepatic vein waveform assessment into routine ultrasound evaluation of cirrhotic patients provides additional prognostic information without increasing cost or procedure time. This non-invasive parameter enhances our ability to risk-stratify patients and optimize management strategies, potentially improving outcomes in this challenging clinical condition.

# CONCLUSION

This study demonstrates a significant correlation between “hepatic vein waveform patterns and the severity of liver disease in cirrhotic patients as assessed by the Child-Pugh classification system”. The progressive dampening of normal triphasic waveforms to biphasic and monophasic patterns reflects the hemodynamic alterations associated with advancing cirrhosis, providing valuable prognostic information through a non-invasive assessment technique.

The high sensitivity (100%) and negative predictive value (100%) of hepatic vein waveform assessment make it an excellent screening tool for evaluating disease severity in cirrhotic patients. While the specificity (52.2%) and positive predictive value (69.5%) are moderate, they still represent clinically useful parameters when interpreted within the broader clinical context. The presence of a normal triphasic waveform effectively rules out advanced cirrhosis, while abnormal waveforms (biphasic or monophasic) warrant further clinical evaluation and close monitoring.

Our findings underscore the value of integrating hepatic vein waveform assessment into the routine ultrasound evaluation of cirrhotic patients. This simple, non-invasive parameter provides additional prognostic information without increasing procedure time or cost, enhancing the clinical utility of standard Doppler ultrasound examination. The significant association between waveform patterns and Child-Pugh classification validates this sonographic parameter as a reliable indicator of disease severity that can complement biochemical and clinical assessments.

The observed age-related variations in hepatic vein waveform patterns highlight the importance of considering patient demographics when interpreting Doppler findings. The lack of significant associations between waveform patterns and individual parameters such as ascites, albumin, or bilirubin levels suggests that waveform changes reflect the

composite impact of multiple pathophysiological alterations rather than isolated abnormalities, reinforcing their value as integrated markers of disease progression.

In conclusion, hepatic vein waveform assessment represents a valuable addition to the non-invasive evaluation arsenal for cirrhotic patients. Its incorporation into clinical practice can enhance risk stratification, guide management decisions, and potentially improve patient outcomes by facilitating earlier identification of disease progression. Future longitudinal studies examining the evolution of waveform patterns over time may further elucidate their prognostic significance and role in monitoring therapeutic responses in this challenging patient population.

# SUMMARY

## INTRODUCTION

Liver cirrhosis represents the end-stage of various chronic liver diseases characterized by progressive fibrosis and hemodynamic alterations. Doppler ultrasonography offers a non-invasive method to assess these vascular changes through hepatic vein waveform patterns. This study aimed to evaluate the correlation between hepatic vein waveform changes and disease severity in cirrhotic patients and determine its diagnostic utility.

## AIMS AND OBJECTIVES

### Objective:

1. "To determine the significance of hepatic vein waveform changes on ultrasound in cirrhotic patients and to correlate with severity of disease".

## MATERIAL AND METHODS

This prospective study included 140 patients with established liver cirrhosis who underwent Doppler ultrasound examination of hepatic veins. Waveform patterns were classified as triphasic, biphasic, or monophasic and correlated with Child-Pugh classification and clinical-laboratory parameters. Statistical analysis was performed to evaluate associations and diagnostic performance.

## RESULTS

- This prospective study was conducted at the Department of Radiodiagnosis at Shri B M Patil Medical College Hospital & Research Centre to evaluate the correlation between hepatic vein waveform changes on Doppler ultrasound and disease severity in 140 cirrhotic patients.
- Demographic analysis revealed a predominance of middle-aged patients (45% in the 41-60 years age group) with a male preponderance (59.3%). The majority of patients (52.1%) presented with advanced liver dysfunction (Child-Pugh Class C), while 25% were classified as Class B and 22.9% as Class A.

- Hepatic vein Doppler assessment demonstrated a distribution of waveform patterns with monophasic waveforms being most common (38.6%), followed by biphasic (36.4%) and triphasic (25%) patterns. A highly significant association ($p<0.001$) was observed between hepatic vein waveform patterns and Child-Pugh classification, with 70.4% of monophasic and 68.6% of biphasic waveforms occurring in Class C patients, while 57.1% of triphasic waveforms were seen in Class A patients. This finding confirms the progressive dampening of normal triphasic waveforms to biphasic and ultimately monophasic patterns with advancing cirrhosis.
- The study found no significant associations between hepatic vein waveform patterns and individual parameters including albumin levels ($p=0.39$), and bilirubin levels ($p=0.53$). However, a significant association was demonstrated ($p=0.001$) between waveform patterns and ascites and ($p=0.008$) waveform patterns with patient age with monophasic waveforms more common in the 41-60 years age group (51.8%), while biphasic and triphasic waveforms were more prevalent in younger patients.
- Diagnostic performance analysis revealed excellent sensitivity (100%) and negative predictive value (100%) for hepatic vein waveform assessment in detecting advanced cirrhosis, with moderate specificity (52.2%) and positive predictive value (69.5%). These findings validate hepatic vein waveform assessment as a valuable non-invasive tool for evaluating disease severity in cirrhotic patients, particularly as a screening parameter to rule out advanced disease.

**CONCLUSION:**

Hepatic vein waveform assessment by Doppler ultrasound provides a reliable non-invasive marker of disease severity in cirrhotic patients, showing excellent correlation with Child-Pugh classification. The high sensitivity and negative predictive value make this a valuable screening tool, particularly for ruling out advanced cirrhosis. Integration of hepatic

vein waveform assessment into routine ultrasound evaluation offers prognostic information without increasing procedure complexity or cost.

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# ANNEXURE I

**BLDEU'S SHRI B.M. PATIL MEDICAL COLLEGE HOSPITAL AND RESEARCH CENTRE, VIJAYAPURA**

## CORRELATION BETWEEN HEPATIC WAVE FORM CHANGES ON DOPPLER ULTRASOUND AND SEVERITY OF DISEASE IN CIRRHOTIC PATIENTS

## PROFORMA

1. **Name:**

2. **Age/Sex**

3. **Hospital No.:**

4. **Relevant complaints & history:**

5. **Ultrasound Findings:**

6. **Radiological Diagnosis.**

# ANNEXURE II

## CONSENT FORM

### CORRELATION BETWEEN HEPATIC WAVE FORM CHANGES ON DOPPLER ULTRASOUND AND SEVERITY OF DISEASE IN CIRRHOTIC PATIENTS

**GUIDE : DR. SHIVANAND V. PATIL**

**P.G. STUDENT : DR. SYED SUMAIYA LATHEEF**

**PURPOSE OF RESEARCH:**

I have been informed that the purpose of this study is to evaluate predictors of macrosomia in fetus of women with gestational diabetes mellitus.

PROCEDURE:

I understand that I will be asked to provide a detailed history and undergo clinical and ultrasonographic examination for the purpose of this study.

RISKS AND DISCOMFORTS:

I understand that there is minimal risk involved in the above study.

BENEFITS:

I understand that my participation in this study will help to evaluate predictors of macrosomia in fetus of women with gestational diabetes mellitus.

CONFIDENTIALITY:

I understand that the medical information produced by the study will become a part of hospital record and will be subjected to confidentiality and privacy regulations of hospital. If the data is used for publications the identity of the patient will not be revealed.

REQUEST FOR MORE INFORMATION:

I understand that I may ask for more information about the study at any time.

REFUSAL OR WITHDRAWAL OF PARTICIPATION:

I understand that my participation is voluntary and I may refuse to participate or withdraw from study at any time.

INJURY STATEMENT:

I understand in the unlikely event of injury to me during the study I will get medical treatment but no further compensations. I will not hold the hospital and its staff responsible for any untoward incidence during the course of study.

Date:

Dr. Shivanand V. Patil (Guide)

Dr. Syed Sumaiya Latheef (Investigator)

STUDY SUBJECT CONSENT STATEMENT:

I/my ward confirm that Dr. Syed Sumaiya Latheef has explained to me the purpose of this research, the study procedure that I will undergo and the possible discomforts and benefits that I may experience, in my own language.

I/my ward have been explained all the above in detail in my own language and I understand the same. Therefore, I agree to give my consent to participate as a subject in this project.

_____ _____

(Participant) Date

_____

(Witness to above signature)

Azadi Ka Amrit Mahotsav

# BLDE

(DEEMED TO BE UNIVERSITY)

Declared as Deemed to be University u/s 3 of UGC Act, 1956

Accredited with 'A' Grade by NAAC (Cycle-2)

The Constituent College

SHRI B. M. PATIL MEDICAL COLLEGE, HOSPITAL & RESEARCH CENTRE, VIJAYAPURA

BLDE (DU)/IEC/ 940/2023-24 10/4/2023

## INSTITUTIONAL ETHICAL CLEARANCE CERTIFICATE

The Ethical Committee of this University met on **Saturday, 18th March, 2023 at 11.30 a.m. in the CAL Laboratory, Dept. of Pharmacology,** scrutinized the Synopsis/ Research Projects of Post Graduate Student / Under Graduate Student /Faculty members of this University /Ph.D. Student College from ethical clearance point of view. After scrutiny, the following original/ corrected and revised version synopsis of the thesis/ research projects has been accorded ethical clearance.

**TITLE: "CORRELATION BETWEEN HEPATIC WAVE FORM CHANGES ON DOPPLER ULTRASOUND AND SEVERITY OF DISEASES IN CIRRHOTIC PATIENTS".**

**NAME OF THE STUDENT/PRINCIPAL INVESTIGATOR: DR.SYED SUMAIYA LATHEEF**

**NAME OF THE GUIDE:** DR.SHIVANAND V. PATIL, PROFESSOR, DEPT. OF RADIODIAGNOSIS.

Dr. Santoshkumar Jeevangi
Chairperson
IEC, BLDE (DU),
VIJAYAPURA
**Chairman,**
**Institutional Ethical Committee,**
**BLDE (Deemed to be University)**
**Vijayapura**

Dr.Akram A. Naikwadi
Member Secretary
IEC, BLDE (DU),
VIJAYAPURA
**MEMBER SECRETARY**
**Institutional Ethics Committee**
**BLDE (Deemed to be University)**
**Vijayapura-586103. Karnataka**

Following documents were placed before Ethical Committee for Scrutinization.

- Copy of Synopsis/Research Projects
- Copy of inform consent form
- Any other relevant document

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