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Radiological assessment of chronic liver disease and portal hypertension through ultrasound and Doppler imaging in the Bundelkhand region

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ABSTRACT

Background: Chronic liver disease (CLD) is a progressive condition with major global health implications, especially in resource-limited regions such as Bundelkhand. Portal hypertension, a frequent complication of CLD, significantly impacts morbidity. Ultrasonography combined with Doppler imaging offers a non-invasive, affordable, and accessible method for evaluating hepatic parenchyma and hemodynamics, which is crucial for early diagnosis and management. **Aims and Objectives:** To identify ultrasonographic features of CLD, assess Doppler parameters of portal hypertension, correlate imaging findings with Child-Pugh classification, and determine common etiological factors of CLD in the Bundelkhand population. **Materials and Methods:** A prospective observational study was conducted on 100 CLD patients using ultrasound and Doppler imaging at a tertiary center. Liver morphology, portal vein parameters, and collaterals were assessed and correlated with Child-Pugh scores. Statistical analysis was performed, and ethical clearance was obtained from the institutional ethics committee. **Results:** In this prospective observational study involving 100 patients, the most common etiologies of CLD were alcohol (45%), hepatitis B (20%), and hepatitis C (15%). Ultrasound findings included coarse hepatic echotexture (78%), liver shrinkage (72%), irregular liver surface (66%), splenomegaly (65%), and ascites (50%). Doppler findings revealed portal vein diameter >13 mm in 60%, reduced flow velocity in 58%, hepatofugal flow in 18%, collateral formation in 40%, and reversed splenic flow in 22% of patients. A statistically significant correlation was observed between worsening Child-Pugh class and increasing portal vein diameter ($P<0.001$) as well as declining portal flow velocity ($P<0.001$). **Conclusion:** Ultrasound with Doppler is an effective and reliable tool for assessing CLD and portal hypertension, especially in low-resource settings. Doppler parameters correlate significantly with disease severity and may serve as prognostic indicators.

Key words: Chronic liver disease; Portal hypertension; Ultrasonography; Doppler imaging; Child-Pugh classification

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INTRODUCTION

Chronic liver disease (CLD) encompasses a spectrum of progressive hepatic disorders that culminate in irreversible liver damage, including fibrosis, cirrhosis, and hepatocellular dysfunction. Globally, liver disease is a leading cause of morbidity and mortality, with a significant proportion attributed to chronic liver injury due to viral hepatitis, alcohol abuse, non-alcoholic fatty liver disease (NAFLD), and autoimmune disorders.[1,2] In India, CLD has emerged as a major health-care challenge, with a rising incidence due to the dual burden of infectious and lifestyle-

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related etiologies.[3] The Bundelkhand region, characterized by limited health-care infrastructure and delayed access to specialist services, is particularly vulnerable to the adverse outcomes of late-diagnosed liver disease.[4]

One of the most significant complications of CLD is portal hypertension, defined as elevated pressure in the portal venous system. This hemodynamic alteration leads to a cascade of clinical manifestations such as splenomegaly, ascites, portosystemic collaterals, esophageal varices, and hepatic encephalopathy. Early detection of portal hypertension is crucial in preventing life-threatening complications, improving quality of life, and guiding therapeutic interventions.[5]

Imaging modalities play a central role in the non-invasive diagnosis and monitoring of CLD and its complications. Among these, abdominal ultrasonography (USG) combined with Doppler imaging stands out due to its affordability, accessibility, and diagnostic reliability. USG enables visualization of liver morphology, size, surface irregularities, parenchymal echotexture, and associated findings such as ascites and splenomegaly. Doppler imaging adds a functional dimension by assessing vascular flow parameters – such as portal vein diameter, direction, and velocity of portal flow, hepatic artery resistance index, and the presence of collateral vessels.[6]

Portal vein diameter exceeding 13 mm, reversal of portal venous flow (hepatofugal), decreased flow velocity (<13 cm/s), and visualization of collaterals are key Doppler signs of portal hypertension. The degree of these changes often correlates with the clinical severity of liver disease, as graded by scoring systems such as the Child-Pugh classification or the model for end-stage liver disease (MELD) score. Thus, Doppler sonography not only aids in diagnosing portal hypertension but also serves as a surrogate marker of disease progression.[7]

Aim and objectives

Aim

To evaluate the radiological features of CLD and portal hypertension using ultrasound and Doppler imaging in patients from the Bundelkhand region.

Objectives

1. To identify ultrasonographic features indicative of CLD
2. To assess Doppler parameters associated with portal hypertension
3. To correlate ultrasound and Doppler findings with clinical severity (Child-Pugh classification)
4. To determine the prevalence of common etiological factors in CLD.

MATERIALS AND METHODS

Research design

A prospective observational study was undertaken in the Department of Radiodiagnosis, Maharani Laxmi Bai Medical College, Jhansi, Uttar Pradesh, over a period of 12 months, from November 2023 to October 2024. The study included patients clinically diagnosed with CLD, who were referred for abdominal USG and Doppler evaluation.

Inclusion criteria

- Adults (≥18 years) diagnosed clinically and biochemically with CLD
- Patients provide informed written consent.

Exclusion criteria

- Pregnant women
- Patients with acute liver failure
- Known cases of hepatic malignancy
- Incomplete imaging or clinical data.

Procedure for data collection

All enrolled patients underwent detailed history-taking, clinical examination, and baseline liver function tests. Abdominal USG was performed to assess liver size, surface, parenchymal echotexture, presence of ascites, and splenic dimensions. Doppler ultrasound was used to evaluate portal vein diameter, flow direction, velocity, and the presence of portosystemic collaterals or reversed splenic vein flow. Findings were correlated with Child-Pugh classification.

Ethical considerations

The present study was conducted following the ethical principles outlined in the Declaration of Helsinki. Ethical clearance was obtained from the Institutional Ethics Committee of Maharani Laxmi Bai Medical College, Jhansi.

Statistical analysis

Descriptive statistics were expressed as mean±standard deviation for continuous variables and as number (percentage) for categorical variables. Chi-square test or Fisher's exact test was applied for categorical comparisons. Analysis of variance was used for group comparisons of continuous variables. $P<0.05$ was considered statistically significant.

RESULTS

The demographic profile of the study revealed that the majority of CLD patients were males (64%) and within the age group of 41–50 years (30%) and 51–60 years (25%), reflecting the typical middle-aged presentation of CLD (Table 1). Alcoholic liver disease was the predominant etiology (45%), followed by Hepatitis B (20%), Hepatitis

Table 1: Demographic distribution of the study population

Parameters	Frequency (n=100)	Percentage
Age		
20–30 years	10	10.00
31–40 years	18	18.00
41–50 years	30	30.00
51–60 years	25	25.00
>60 years	17	17.00
Gender		
Male	64	64.00
Female	36	36.00

Table 2: Etiological distribution of chronic liver disease

Etiology	Number	Percentage
Alcoholic liver disease	45	45.00
Hepatitis B	20	20.00
Hepatitis C	15	15.00
Non-alcoholic fatty liver disease	10	10.00
Cryptogenic	10	10.00
Total	100	100

Table 3: Ultrasound findings

Finding	Number (%)
Shrunken liver	72 (72)
Splenomegaly	65 (65)
Ascites	50 (50)
Irregular liver surface	66 (66)
Coarse echotexture	78 (78)

C (15%), and both NAFLD and cryptogenic causes contributing 10% each (Table 2). Ultrasonographic evaluation showed coarse echotexture in 78%, shrunken liver in 72%, irregular surface in 66%, splenomegaly in 65%, and ascites in 50%, all of which are hallmark features of advanced CLD and portal hypertension (Table 3). Doppler studies further supported these findings, with 60% showing portal vein diameter >13 mm, 58% reduced flow velocity, 40% having collateral circulation, 22% with reversed splenic vein flow, and 18% with hepatofugal flow, indicating progressive portal hypertension (Table 4). A significant association was observed between worsening Child-Pugh class and increased portal vein diameter (from 11.8 mm in class A to 14.6 mm in class C) along with decreased portal flow velocity (from 19.2 cm/s to 12.4 cm/s), affirming the prognostic value of Doppler parameters in staging CLD severity (Table 5).

DISCUSSION

This prospective study focused on evaluating the ultrasonographic and Doppler imaging characteristics of CLD and portal hypertension in a tertiary care setting in the Bundelkhand region. A total of 100 clinically diagnosed patients were included, with imaging findings assessed in conjunction with clinical severity using the Child-Pugh classification.

Table 4: Doppler parameters

Doppler finding	Number (%)
Portal vein diameter >13 mm	60 (60)
Reduced portal flow velocity	58 (58)
Hepatofugal flow	18 (18)
Collateral circulation	40 (40)
Reversed flow in the splenic vein	22 (22)

Table 5: Correlation of ultrasonography/Doppler findings with Child-Pugh class

Child-Pugh class	Mean portal vein diameter (mm)	Mean flow velocity (cm/s)	P-value
Class A	11.8±1.2	19.2±2.3	<0.05
Class B	13.5±1.4	15.6±2.0	<0.01
Class C	14.6±1.7	12.4±1.9	<0.001

Demographic profile

The demographic distribution revealed a mean age of 48.5 years, with a peak incidence in the 41–50-year age group (30 patients, 30%), followed by those aged 51–60 years (25 patients, 25%). These findings indicate a predominance of CLD in middle-aged individuals, consistent with the natural history of hepatic fibrosis progression over a decade or longer. Males comprised 64% of the sample, which is in line with previous Indian studies demonstrating higher CLD burden in males due to prevalent alcohol abuse and hepatitis B virus (HBV) infection.

Etiology

The etiological profile identified alcohol as the leading cause of CLD in 45 patients (45%), followed by HBV in 20 patients (20%), hepatitis C virus in 15 (15%), and NAFLD and cryptogenic causes in 10 patients each (10%). This distribution reflects the regional trend where alcohol-induced liver injury predominates. Comparable results were reported by Khawas et al.,[8] where alcoholic liver disease was the most common etiology in their study population, followed by viral hepatitis. The emergence of NAFLD, though still less frequent in our cohort, mirrors its growing prevalence in urban India.

Ultrasonographic features

Ultrasound examination revealed coarse hepatic echotexture in 78 patients (78%), liver surface irregularity in 66 (66%), shrunken liver in 72 (72%), and splenomegaly in 65 (65%). Ascites were observed in 50 patients (50%). These features are pathognomonic of advanced liver disease and portal hypertension. In a study by Baz et al.,[9] splenomegaly and ascites were observed in 49% and 44%, respectively,

correlating with MELD scores and disease severity. The higher incidence in our study may reflect the late presentation of patients in this region.

The finding of a shrunken liver in 72% of cases indicates chronicity of parenchymal damage, while coarse echotexture and surface nodularity are markers of cirrhotic transformation. These sonographic signs have been consistently validated in literature as reliable indicators of cirrhosis when biopsy is unavailable.

Doppler findings

Doppler parameters were critical in the non-invasive assessment of portal hypertension. A portal vein diameter >13 mm was seen in 60 patients (60%), reduced portal flow velocity in 58 (58%), hepatofugal flow in 18 (18%), collateral formation in 40 (40%), and reversed splenic vein flow in 22 (22%). These Doppler abnormalities are key indirect indicators of elevated portal pressure.

Our findings are concordant with those of Möller et al.,[10] who emphasized that a portal vein diameter >13 mm and velocity <15 cm/s are diagnostic markers of portal hypertension. The observed hepatofugal flow and presence of portosystemic collaterals reflect decompensated portal hypertension, usually correlating with higher Child-Pugh or MELD scores.

In comparison, Khawas et al.,[8] noted that Doppler sonography showed increasing sensitivity with worsening CLD stage, reaching 90% in late-stage disease (F4). Their study observed reduced flow velocity in 59% of cases, comparable to our 58% incidence. This supports the strong correlation between Doppler parameters and clinical staging.

Wu et al.,[11] noted that hepatofugal flow and collateral visualization via color Doppler had a sensitivity of 70–83% and specificity >90% for cirrhosis and portal hypertension. Our study demonstrated 18% with hepatofugal flow and 40% with collaterals – lower values possibly attributable to earlier disease in some patients or technical limitations.

Child-Pugh correlation

The progressive deterioration in Doppler parameters with increasing Child-Pugh class in our study was statistically significant. Mean portal vein diameter increased from 11.8±1.2 mm in class A to 14.6±1.7 mm in class C ($P<0.001$), whereas mean flow velocity declined from 19.2±2.3 cm/s to 12.4±1.9 cm/s ($P<0.001$). These trends emphasize the utility of Doppler imaging as a non-invasive proxy for clinical severity.

Möller et al.,[10] similarly found significant correlations between Doppler indices and clinical grading, particularly with hepatic venous pressure gradient (HVPG) measurements and MELD scores. In their study, a damping index >0.6 and a monophasic hepatic vein waveform were predictive of HVPG ≥12 mmHg. Although hepatic vein waveforms were not assessed in our study, the inverse correlation between portal vein velocity and Child-Pugh class reinforces the hemodynamic basis of disease progression.

Baz et al.,[9] reported a similar association, with higher hepatic artery velocity (>60 cm/s in 70% of patients) and reduced portal velocity (<20 cm/s in 59%) corresponding to increased MELD scores. While we did not measure hepatic arterial resistive index, the presence of splenomegaly and ascites in 65% and 50% of our patients, respectively, provides indirect evidence of significant portal hypertension and correlates with Doppler findings.

Role in low-resource settings

In resource-limited settings such as Bundelkhand, where elastography and contrast-enhanced imaging are not routinely available, USG with Doppler remains a cornerstone for early diagnosis and longitudinal monitoring. Although limitations such as operator dependency and interobserver variability exist, the combined interpretation of B-mode and Doppler findings offers substantial diagnostic yield.

The Baveno VII consensus supports liver stiffness measurement and spleen stiffness measurement for stratifying portal hypertension risk. However, these modalities require advanced tools. In our study, portal vein diameter and flow velocity – both easily measurable – showed significant correlation with clinical severity, underscoring their utility where elastography is unavailable.

Peltec et al.,[12] and Crăciun et al.,[13] advocate for multiparametric ultrasound (MPUS), which combines B-mode, Doppler, elastography, and CEUS for accurate CLD assessment. While our setting did not support MPUS, our results support its potential value, especially with further training and infrastructure support.

Diagnostic and prognostic implications

The significance of Doppler ultrasound extends beyond diagnosis – it also serves as a prognostic tool. The presence of hepatofugal flow, reversed splenic vein flow, and portosystemic collaterals suggests decompensated portal hypertension, increasing the risk of variceal bleeding and hepatic encephalopathy. These parameters, when monitored over time, can guide therapeutic interventions such as initiation of non-selective beta-blockers or planning for endoscopy.

Doppler parameters are also useful in monitoring the response to treatment. Crăciun et al.,[13] highlighted that changes in portal and splenic indices reflect hemodynamic improvements post-TIPS or pharmacotherapy. Thus, incorporating Doppler into regular follow-up imaging

protocols could enable early identification of disease progression or treatment failure.

Limitations of the study

This study is limited by its single-center design and relatively small sample size, which may potentially affect the external validity of the findings. The operator-dependent nature of USG and Doppler may introduce inter-observer variability. In addition, the absence of advanced imaging modalities such as elastography or liver biopsy restricts comprehensive hepatic assessment. The cross-sectional study design also precludes evaluation of temporal changes in disease progression or treatment response.

CONCLUSION

Ultrasound combined with Doppler imaging serves as a reliable, non-invasive modality for evaluating CLD and portal hypertension, particularly in resource-limited settings. Key Doppler parameters, such as portal vein diameter and flow velocity, showed significant correlation with disease severity based on the Child-Pugh classification. These findings highlight the utility of Doppler imaging not only in diagnosis but also in prognostication and monitoring of CLD.

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MS and PKP- Definition of intellectual content, literature survey, prepared first draft of manuscript, implementation of study protocol, data collection, data analysis, manuscript preparation and submission of article, concept, design, clinical protocol, manuscript preparation, editing, and manuscript revision, design of study, statistical analysis and interpretation, review manuscript, review manuscript, literature survey, coordination, and manuscript revision.

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