

Original Article

The clinical value of color Doppler ultrasonography in measuring the hemodynamics of liver cirrhosis patients' portal and splenic veins

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Abstract: Objective: To investigate the clinical value of color Doppler ultrasonography (CDUS) in measuring the hemodynamics of liver cirrhosis (LC) patients' portal and splenic veins. Methods: The clinical data of 81 LC patients admitted to our hospital were collected retrospectively and classified into Group A, and the clinical data from 51 healthy volunteers were classified into Group B. All the patients were examined with CDUS, and the ultrasonography images were analyzed. The hemodynamic indices of the portal and splenic veins were compared, and the differences in the hemodynamic indices of the LC patients with varying degrees of esophageal varices and hepatic injuries were analyzed. Results: Group A exhibited higher Q_{pv} , D_{pv} , Q_{sv} , and D_{sv} and lower V_{pv} and V_{sv} than Group B ($P < 0.05$). The Q_{pv} and D_{pv} of the patients with Grade B LC were higher than they were in the patients with Grade A LC and lower than they were in the patients with Grade C LC ($P < 0.05$). The V_{pv} of the patients with Grade B LC was higher than it was in the patients with Grade C LC and lower than it was in the patients with Grade A LC ($P < 0.05$). The Q_{sv} and D_{sv} of the patients with Grade B LC were higher than they were in the patients with Grade A LC and lower than they were in the patients with Grade C LC ($P < 0.05$). The V_{sv} of the patients with Grade B LC was higher than it was in the patients with Grade C LC and lower than it was in the patients with Grade A LC ($P < 0.05$). The patients with mild, moderate, and severe esophageal varices showed lower V_{pv} and V_{sv} and higher Q_{pv} , D_{pv} , Q_{sv} , and D_{sv} than the patients without esophageal varices ($P < 0.05$). Conclusion: CDUS has certain clinical values in measuring the hemodynamics of LC patients' portal and splenic veins and can be used to predict the degrees of hepatic injuries and esophageal varices.

Keywords: Liver cirrhosis, portal vein, splenic vein, hemodynamics, color Doppler ultrasonography, clinical value

Introduction

Clinically, liver cirrhosis (LC) is a common, chronic, and progressive liver disease which occurs following a diffuse hepatic injury as a result of the repeated or long-term action of one or more causes [1]. From the perspective of histopathology, extensive hepatocyte necrosis is observed in LC patients. Specifically, the fibrous septum formation, connective tissue hyperplasia, and nodular hyperplasia of the liver cells lead to the formation of pseudo-lobules or damage to the structure of the hepatic lobules, thereby gradually making the liver harden and deform, and eventually developing into LC [2, 3]. Since the liver has a strong com-

pensatory function in the early stage of LC onset, there are no marked clinical symptoms. With the progression of the disease (POD), the symptoms, such as portal hypertension and damaged hepatic function, appear in the late onset stage of LC, seriously affecting LC patients' quality of life [4, 5].

To date, a hepatic histopathological examination is the most accurate method of diagnosing LC clinically. However, this option causes LC patients to experience trauma and serious complications (e.g., hepatorrhesis and hepatorrhagia) [6, 7]. In recent years, with the progress of medical imaging technologies in China, color Doppler ultrasonography (CDUS) has been

The clinical value of color Doppler ultrasonography

Table 1. Comparison of the general data in the two groups

Data		Group A (n=81)	Group B (n=51)	t/ χ^2	P
Gender (cases)	M	58 (71.60)	36 (70.59)	0.016	0.900
	F	23 (28.40)	15 (29.41)		
Age (years old)		48.19±2.18	48.22±2.13	0.104	0.918
Degrees of esophageal varices (cases)					
	None	11 (13.58)	-	-	-
	Mild	26 (32.10)	-	-	-
	Moderate	23 (28.40)	-	-	-
	Severe	21 (25.93)	-	-	-
Child-Pugh classification of hepatic function (cases)					
	Grade A	30 (37.04)	-	-	-
	Grade B	27 (33.33)	-	-	-
	Grade C	24 (29.63)	-	-	-

Note: - indicates none.

Table 2. Comparison of the hemodynamic indices of the portal veins in groups A and B ($\bar{x} \pm s$)

Group	Q _{pv} (ml/min)	V _{pv} (cm/s)	D _{pv} (cm)
Group A (n=81)	1125.98±12.58*	14.58±0.58*	1.48±0.25*
Group B (n=51)	775.26±6.12	22.08±0.63*	1.01±0.08
t	185.563	69.960	12.997
P	0.000	0.000	0.000

Note: *indicates a comparison with Group B, $P < 0.05$.

Table 3. Comparison of the hemodynamic indices of the splenic vein between groups A and B ($\bar{x} \pm s$)

Group	Q _{sv} (ml/min)	V _{sv} (cm/s)	D _{sv} (cm)
Group A (n=81)	679.89±15.26*	11.259±0.26*	1.18±0.05*
Group B (n=51)	252.16±10.18	15.989±0.38	0.52±0.02
t	27.191	94.592	89.752
P	0.000	0.000	0.000

Note: *indicates a comparison with Group B, $P < 0.05$.

extensively implemented in the diagnosis of LC [8]. CDUS has the advantages of repeatability, low examination cost, non-invasiveness, etc., and is extensively accepted by LC patients [9]. According to most clinical studies, CDUS shows the hemodynamic test results of LC patients' splenic and portal veins with varying degrees of esophageal varices and hepatic injuries [10, 11]. However, there are few clinical studies on the correlation among the different esophageal varices, the degrees of hepatic injuries, and the hemodynamic indices [12].

In view of this, all the LC patients were examined using CDUS for this study. The hemody-

amic indices of the splenic and portal veins, the correlation among the hemodynamic indices, the degrees of esophageal varices, and the hepatic injuries were analyzed, so as to investigate the clinical value of CDUS in diagnosing LC.

Materials and methods

Clinical data

The clinical data of 81 LC patients admitted to our hospital from May 2016 to September 2018 were collected retrospectively and classified into Group A, and the clinical data of 51 healthy volunteers were classified into Group B. Inclusion criteria for Group A: Patients who were diagnosed with LC using imaging and laboratory examinations, and patients with complete medical records. All the patients signed written informed

consents. This study was carried out with the approval of the Ethics Committee of the Third Hospital of Hebei Medical University. Exclusion criteria: patients who withdrew halfway through the study, patients with malignant tumors, acute infectious diseases, mental system diseases, or blood system diseases, patients suffering from severe renal or cardiac insufficiencies, and patients with missing medical records.

Methods

All the subjects were examined using CDUS. A Philips CX50 color Doppler ultrasound system was used. The probe frequency was set to 2-5

The clinical value of color Doppler ultrasonography

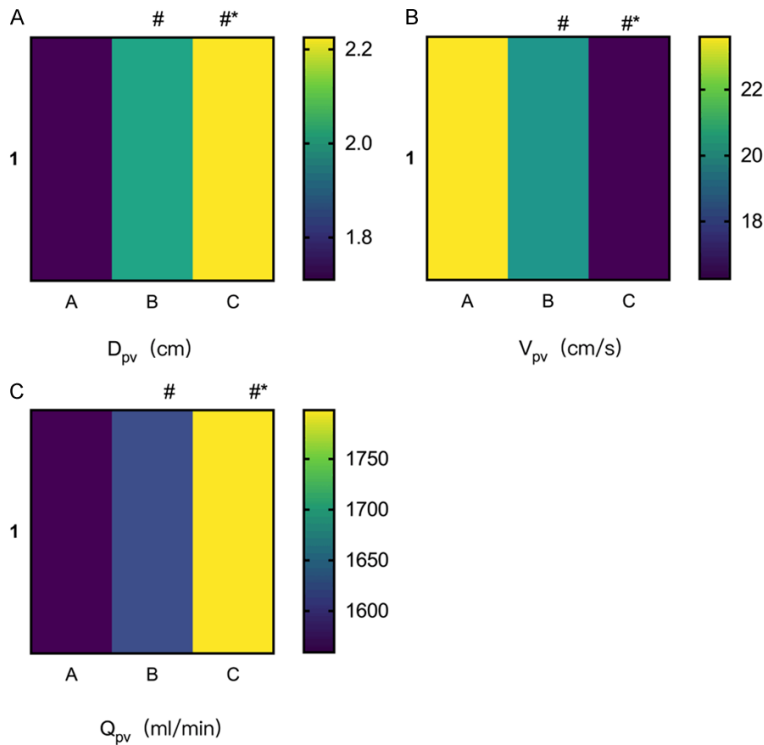


Figure 1. Comparison of the hemodynamic indices of LC patients' portal veins with varying degrees of hepatic injuries. A. Shows that the D_{pv} of patients with Grade C LC was higher than that of patients with grades A and B LC, and the D_{pv} of patients with Grade B LC was higher than it was in the patients with Grade A LC, $P < 0.05$. B. Shows that the V_{pv} of patients with Grade C LC was lower than it was in the patients with grades A and B LC, and the V_{pv} of the patients with Grade B was lower than it was in the patients with Grade A LC, $P < 0.05$. C. Suggests that the Q_{pv} of the patients with Grade C LC was higher than it was in the patients with grades A and B LC, and the Q_{pv} of the patients with Grade B LC was higher than it was in the patients with Grade A LC, $P < 0.05$. # indicates a comparison with patients with Grade A LC, $P < 0.05$. * indicates a comparison with patients with Grade B LC, $P < 0.05$.

MHz, the mode was set to abdominal blood flow, and the sampling volume was controlled to 1-6 mm. No water or food were provided to the subjects 8-12 hours before the examination, and they were examined in a quiet state lying in the left lateral position. The portal vein was measured at the confluence of the portal vein and a point 1.0-1.5 cm away from the portal vein, and the left gastric vein was measured at 2 cm in front of the confluence of portal vein. The included angle between the long axis of the blood vessel and CDUS was controlled to below 60°.

Observational indices

The ultrasonographic images from the two groups were analyzed, and the hemodynamic indices of the portal and splenic veins were compared between the two groups, including

Q_{sv} (blood flow in the splenic vein), V_{sv} (blood flow velocity in the splenic vein), D_{sv} (splenic vein diameter), Q_{pv} (blood flow in the portal vein), V_{pv} (blood flow velocity in the portal vein), and D_{pv} (portal vein diameter). The differences in the LC patients' hemodynamic indices with varying degrees of esophageal varices and hepatic injuries were analyzed [13].

Statistical analysis

SPSS 22.0 was adopted for the statistical analysis, and the measurement data were expressed as the mean \pm standard deviation (mean \pm SD). The data conforming to a normal distribution were analyzed using t tests, and those not conforming to a normal distribution were analyzed using Mann-Whitney U tests. The enumeration data were expressed as [n (%)], and the comparisons of the enumeration data between the groups was carried out using χ^2 tests. $P < 0.05$ indicated a statistical significance.

Results

General data

A Child-Pugh classification of the patients' hepatic functions showed that there were 30 patients with grade A LC, 27 patients with grade B LC, and 24 patients with grade C LC. Endoscopic examinations indicated that there were 11 patients without varicose veins, 26 patients with mild esophageal varices, 23 patients with moderate esophageal varices, and 21 patients with severe esophageal varices. There was no statistically significant difference in terms of age or sex between groups A and B ($P > 0.05$) (Table 1).

Comparison of the portal vein hemodynamic indices between the two groups

The comparisons showed that the Q_{pv} and D_{pv} in Group A were higher than they were in Group B,

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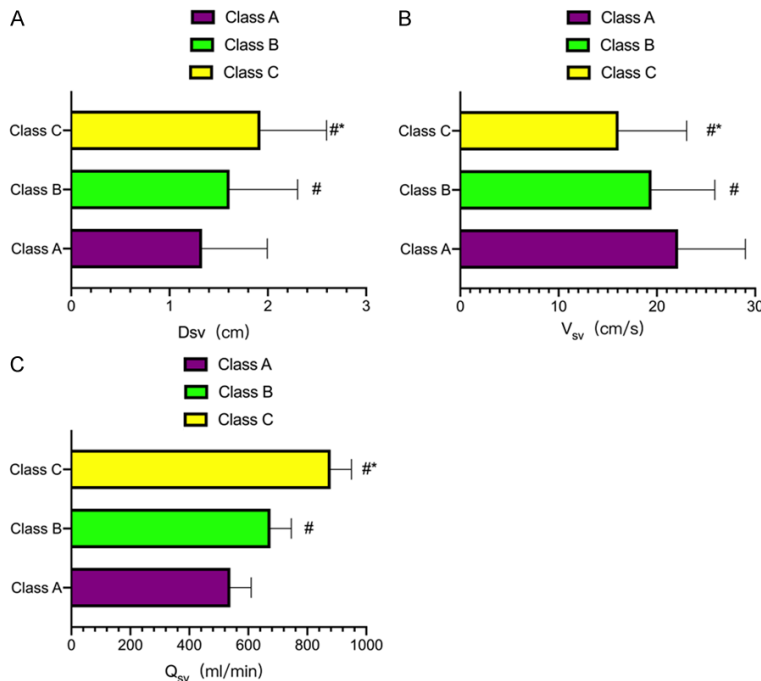


Figure 2. Comparison of the hemodynamic indices of LC patients' splenic veins with varying degrees of hepatic injuries. A. Shows that the D_{sv} of the patients with Grade C LC was higher than it was in the patients with grades A and B LC, the D_{sv} of the patients with Grade B LC was higher than it was in the patients with Grade A LC, $P < 0.05$. B. Reveals that the V_{sv} of patients with Grade C LC was lower than it was in the patients with grades A and B LC, and the V_{sv} of the patients with Grade B was lower than it was in the patients with Grade A LC, $P < 0.05$. C. Indicates that the Q_{sv} of the patients with Grade C LC was higher than it was in the patients with grades A and B LC, and the Q_{sv} of patients with Grade B LC was higher than it was in the patients with Grade A LC, $P < 0.05$. # indicates a comparison with the patients with Grade A LC, $P < 0.05$. * indicates a comparison with the patients with Grade B LC, $P < 0.05$.

and the V_{pv} in Group A was lower than it was in Group B, and the differences were statistically significant ($P < 0.05$) (**Table 2**).

Comparison of the portal vein hemodynamic indices between groups A and B

The comparison showed that the Q_{sv} and D_{sv} in Group A were higher than they were in Group B, and the V_{sv} in Group A was lower than it was in Group B, and the differences were statistically significant ($P < 0.05$) (**Table 3**).

Comparison of the portal vein hemodynamic indices of the LC patients with varying degrees of hepatic injuries

The comparison showed that there were statistically significant differences in the comparison of the patients' Q_{pv} , V_{pv} , and D_{pv} with grades A, B

and C LC ($P < 0.05$). The Q_{pv} and D_{pv} of the Grade C LC patients were higher than they were in the grade A and B LC patients, and the Q_{pv} and D_{pv} of the Grade B LC patients were higher than they were in the patients with Grade A LC ($P < 0.05$). The V_{pv} of the Grade C LC patients was lower than it was in the patients with grades A and B LC, and the V_{pv} of the Grade B LC patients was lower than it was in the Grade A LC patients ($P < 0.05$) (**Figure 1**).

Comparison of the splenic vein hemodynamic indices of the LC patients with varying degrees of hepatic injuries

The comparison suggested that there were statistically significant differences in the comparison of the Q_{sv} , V_{sv} and D_{sv} of the patients with grades A, B, and C LC ($P < 0.05$). The Q_{sv} and D_{sv} of the patients with Grade C LC were higher than they were in the patients with grades A and B LC, and the Q_{sv} and D_{sv} of the patients with Grade B LC were higher

than they were in the patients with Grade A LC ($P < 0.05$). The V_{sv} of the patients with Grade C LC was lower than it was in the patients with grades A and B LC, and the V_{sv} of the patients with Grade B LC was lower than it was in the patients with Grade A LC ($P < 0.05$) (**Figure 2**).

Comparison of the portal vein hemodynamic indices in the LC patients with varying degrees of esophageal varices

The comparison showed that the V_{pv} of the patients with mild, moderate, and severe esophageal varices was lower than it was in the patients without esophageal varices, but the Q_{pv} and D_{pv} of the patients with mild, moderate, and severe esophageal varices were higher than they were in the patients without esophageal varices. When the esophageal varices

The clinical value of color Doppler ultrasonography

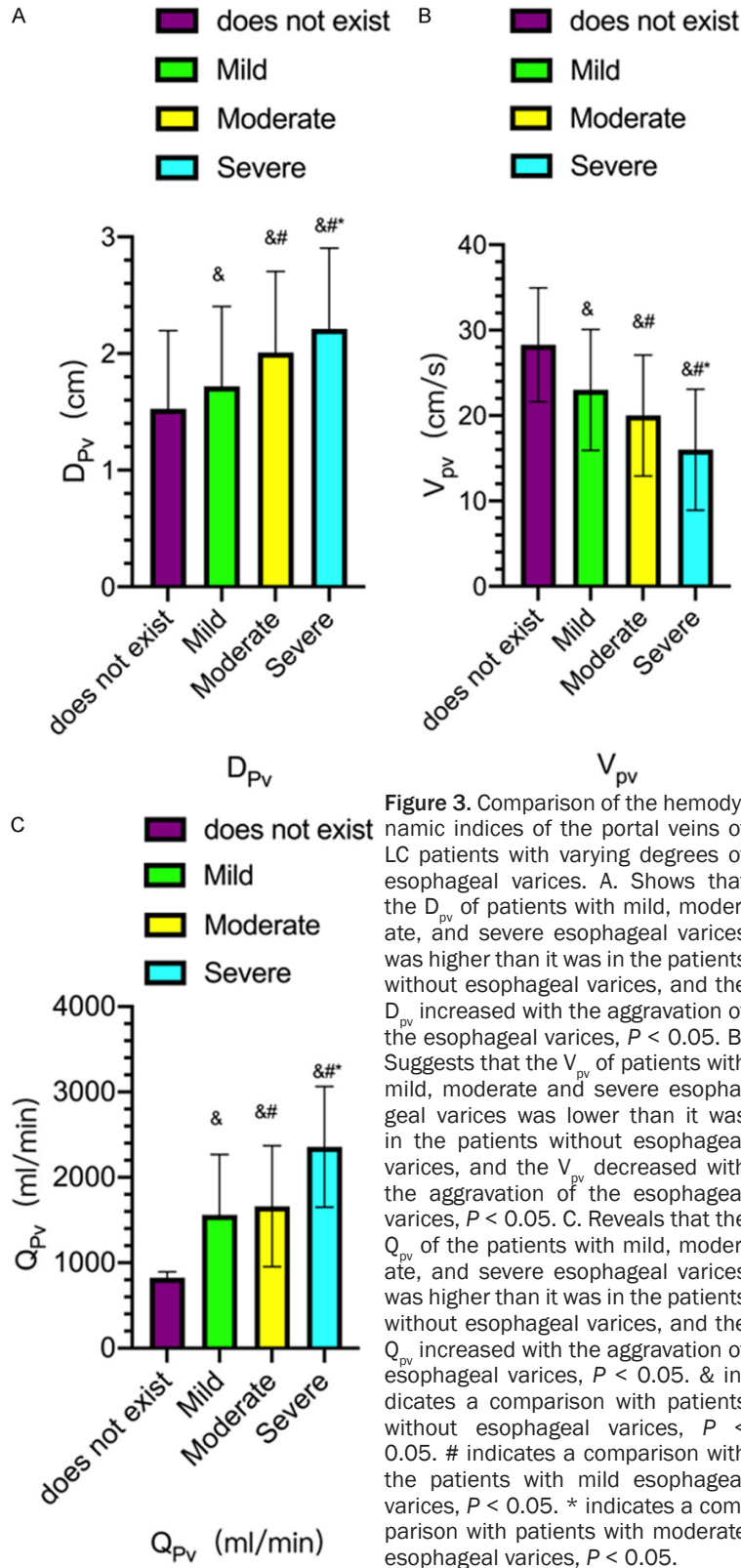


Figure 3. Comparison of the hemodynamic indices of the portal veins of LC patients with varying degrees of esophageal varices. A. Shows that the D_{pv} of patients with mild, moderate, and severe esophageal varices was higher than it was in the patients without esophageal varices, and the D_{pv} increased with the aggravation of the esophageal varices, $P < 0.05$. B. Suggests that the V_{pv} of patients with mild, moderate and severe esophageal varices was lower than it was in the patients without esophageal varices, and the V_{pv} decreased with the aggravation of the esophageal varices, $P < 0.05$. C. Reveals that the Q_{pv} of the patients with mild, moderate, and severe esophageal varices was higher than it was in the patients without esophageal varices, and the Q_{pv} increased with the aggravation of esophageal varices, $P < 0.05$. & indicates a comparison with patients without esophageal varices, $P < 0.05$. # indicates a comparison with the patients with mild esophageal varices, $P < 0.05$. * indicates a comparison with patients with moderate esophageal varices, $P < 0.05$.

were aggravated, the V_{pv} decreased, and the Q_{pv} and D_{pv} increased ($P < 0.05$) (Figure 3).

decompensated period, LC patients will suffer from ascites, secondary infections, upper gas-

Comparison of the splenic vein hemodynamic indices of the LC patients with varying degrees of esophageal varices

The comparison revealed that the V_{sv} of the patients with mild, moderate, and severe esophageal varices was lower than it was in the patients without esophageal varices, and the Q_{sv} and D_{sv} of the patients with mild, moderate, and severe esophageal varices were higher than they were in the patients without esophageal varices. When the esophageal varices were aggravated, the V_{pv} decreased, and the Q_{sv} and D_{sv} increased ($P < 0.05$) (Figure 4).

Comparison of the CDUS images between the healthy volunteers and the LC patients

Our comparative analysis showed that the blood flow velocity in the portal vein of the LC patients was 7.49 cm/s, and the healthy volunteers' blood flow velocity was 15.5 cm/s. The comparison found that the blood flow velocity in the LC patients' portal veins was slower than it was in the healthy volunteers (Figure 5).

Discussion

LC is a chronic progressive disease with a high clinical incidence. Mild splenomegaly, mild jaundice, abdominal distension, and fatigue are the manifestations LC patients experience when they are slightly injured in the liver's compensatory period. When the liver is moderately or severely damaged during the

The clinical value of color Doppler ultrasonography

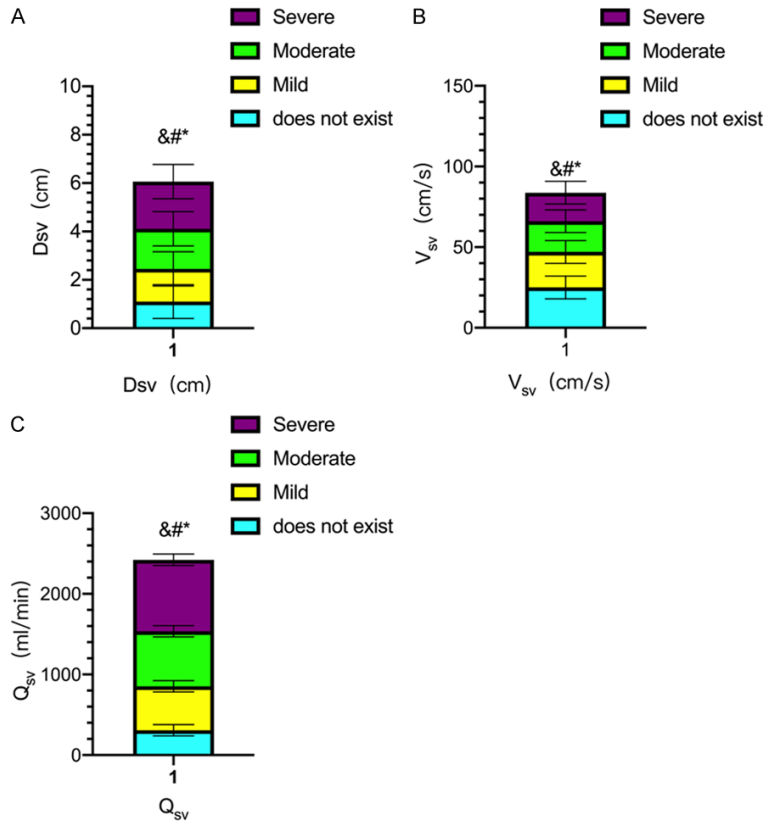


Figure 4. Comparison of the hemodynamic indices of the splenic vein of LC patients with varying degrees of esophageal varices. A. Shows that the D_{sv} of the patients with mild, moderate, and severe esophageal varices was higher than it was in the patients without esophageal varices, and the D_{sv} increased with the aggravation of esophageal varices, $P < 0.05$. B. Suggests that the V_{sv} of patients with mild, moderate and severe esophageal varices was lower than it was in the patients without esophageal varices, and the V_{sv} decreased with the aggravation of esophageal varices, $P < 0.05$. C. Reveals that the Q_{sv} of patients with mild, moderate, and severe esophageal varices was higher than it was in the patients without esophageal varices, and the Q_{sv} increased with the aggravation of the esophageal varices, $P < 0.05$. & indicates a comparison with the patients without esophageal varices, $P < 0.05$. # indicates a comparison with the patients with mild esophageal varices, $P < 0.05$. * indicates a comparison with the patients with moderate esophageal varices, $P < 0.05$.

traintestinal bleeding, portal hypertension, and severe hepatic injuries, seriously threatening their lives [14, 15]. With the progression of LC, there will be hepatic hemodynamic changes to a certain extent. This is a complicated pathological process [16]. To date, the research findings on the blood flow changes in LC patients' portal vein systems vary greatly, and no unified conclusion has been reached yet [17]. The hemodynamic changes in LC patients' portal vein systems may be related to multiple factors, such as the hyperplasia of fibrous tissue in the hepatic lobules and the regeneration of

hepatocytes, which hinder the blood flow in the portal vein from entering the hepatic lobules, eventually leading to portal hypertension [18]. LC leads to increased levels of prostanes, extracellular matrix, vasoactive intestinal peptide, and glucagon in the blood of patients with portal hypertension, promotes the occurrence of hyperdynamic circulation, and significantly reduces the reactivity of the visceral vessels to the vasoconstrictors in circulation [19, 20]. An increase in the portal vein resistance decreases the blood flow velocity in the portal vein. Therefore, increased portal vein resistance is the initial cause of LC patients' portal vein hypertension [21].

CDUS is one of the most implemented options clinically and has some advantages, such as being non-invasive and repeatable [22]. Studies reveal that the CDUS can effectively reflect the hemodynamics of the portal vein system and the main collateral circulation vessels during the diagnosis of LC [23]. In this study, the Q_{pv} , D_{pv} , Q_{sv} , and D_{sv} in Group A were higher than they were in Group B, while the V_{pv} and V_{sv} in Group A were lower than they were in Group B. This suggests that

the hemodynamics of LC patients' portal and splenic vein systems are abnormal. Yin et al. also found that the Q_{pv} , D_{pv} , Q_{sv} and D_{sv} in the observation group were higher than they were in the control group, and the V_{pv} and V_{sv} in the observation group were lower than they were in the control group, indicating abnormal hemodynamics of the portal and splenic vein systems in LC patients [24], findings highly consistent with this study. To investigate its mechanism of action, the blood reflux of LC patients' portal and splenic veins were hindered, the blood vessels of the portal and splenic veins were mark-

The clinical value of color Doppler ultrasonography

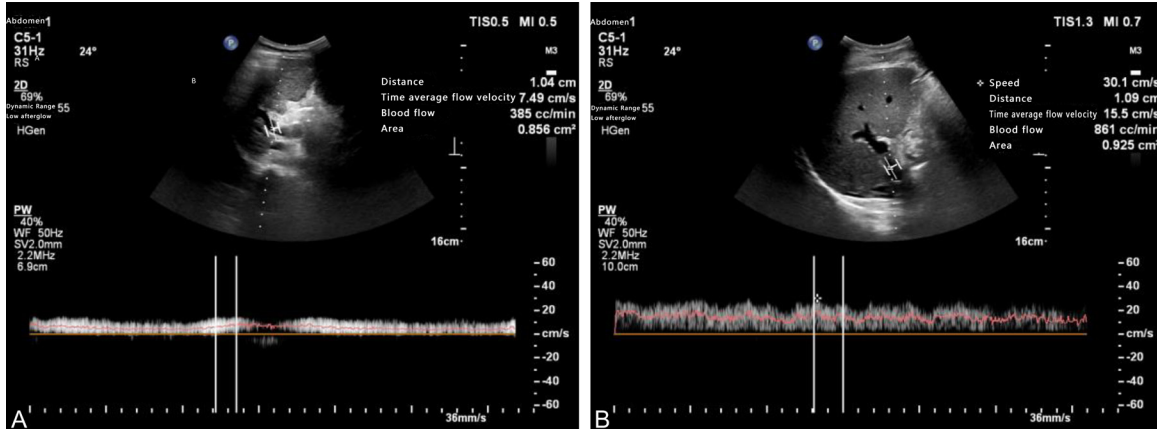


Figure 5. Comparison of the CDUS images from the healthy volunteers and the LC patients. A. Shows the CDUS images of the LC patients, and the blood flow velocity in the portal veins of LC patients was 7.49 cm/s. B. Reveals the CDUS image of the healthy volunteers, and the blood flow velocity in the portal vein of the healthy volunteers was 15.5 cm/s. The comparison suggests that the blood flow velocity in the portal veins of the LC patients was slower than it was in the healthy volunteers.

edly expanded, and the blood flow velocity was gradually decreased. The significant expansion of the blood vessels and the vessel volume resulted in increased Q_{pv} and Q_{sv} . Based on the Child-Pugh classification of hepatic function, the hepatic reserve functions can be classified into grades A, B, and C. A higher grade indicates a weaker hepatic reserve function. With the decrease LC patients' hepatic functions, the inner diameter of the splenic and portal veins and the vascular resistance increases, resulting in blood stasis, esophageal vein dilatation, and hepatic function damages [25]. In this study, with the aggravation of hepatic injuries and esophageal varices, the Q_{pv} , D_{pv} , Q_{sv} and D_{sv} increased, and the V_{sv} and V_{pv} decreased. This suggests that CDUS has certain clinical value in determining the hemodynamics of LC patients' portal and splenic veins and could be used to predict the degree of hepatic injuries and esophageal varices. Based on the investigation of its mechanism of action, the portal vein dilatation and the increased portal vein pressure reduced the blood flow velocity in the portal vein, aggravated the hepatic injuries and the esophageal varices, and increased the vascular resistance and hepatic parenchyma lesions. Therefore, the hemodynamic indices of LC patients' portal and splenic veins can reflect the hepatic function injuries and the degrees of esophageal varices to a certain extent.

In summary, CDUS has a clinical value in determining the hemodynamics of LC patients' por-

tal and splenic veins and can be used to predict the degrees of hepatic injuries and esophageal varices.

Although this study has achieved some results, there is the limitation of its small sample size. Therefore, future in-depth studies with larger sample sizes should be conducted.

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Disclosure of conflict of interest

None.

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The clinical value of color Doppler ultrasonography

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The clinical value of color Doppler ultrasonography

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