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

Ran Hui1, Zhe Li1, Zongjie Liu1, Xiuping Liu2, Heping Deng1

1Department of Ultrasound Medicine, The Third Hospital of Hebei Medical University, Shijiazhuang 050051, Hebei Province, China; 2Department of Obstetrics and Gynecology, The Third Hospital of Hebei Medical University, Shijiazhuang 050051, Hebei Province, China

Received September 28, 2020; Accepted November 17, 2020; Epub March 15, 2021; Published March 30, 2021

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 lower than it was in the patients with Grade C LC and higher 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 lower than it was in the patients with Grade C LC and higher 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 compensatory 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., hepatorrhexis 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

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 hemodynamic 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 MHz.
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 the 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

- $Q_{pv}$ (blood flow in the splenic vein), $V_{pv}$ (blood flow velocity in the splenic vein), $D_{sv}$ (splenic vein diameter), $Q_{sv}$ (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 ± standard deviation (mean ± 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 were carried out using $X^2$ tests. $P < 0.05$ indicated a statistical significance.

**Results**

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,
The clinical value of color Doppler ultrasonography

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

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

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, $P < 0.05$.
The clinical value of color Doppler ultrasonography

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

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).
The clinical value of color Doppler ultrasonography

Am J Transl Res 2021;13(3):1692-1700

Trointestinal 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 prostates, 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-

![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, $P < 0.05$.]
The clinical value of color Doppler ultrasonography

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 $V_{pv}$ and $V_{sv}$ decreased. This suggests that CDUS has certain a clinical value in determining the hemodynamics of LC patients’ portal and splenic veins and could 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.

Acknowledgements

This work was supported by the Hebei Medical Science Research Project: Research on Ultrasonic Diagnosis Technology of Liver Fibrosis Based on Ad-BN Adaptive Deep Convolutional Neural Network (grant number 20190610) and the Hebei Medical Science Research Project: Evaluation of real-time pulse wave velocity of the carotid artery for early warning of ischemic stroke (grant number 20201037) and the Hebei Medical Science Research Project: Ultrasonographic contrast study of plantar fascia in patients with knee and hip osteoarthritis (grant number 20190658).

Disclosure of conflict of interest

None.

Address correspondence to: Heping Deng, Department of Ultrasound Medicine, The Third Hospital of Hebei Medical University, No. 139, Ziqiang Road, Shijiazhuang 050051, Hebei Province, China. Tel: +86-0311-88603369; E-mail: hrfairy@163.com
The clinical value of color Doppler ultrasonography

References


[18] La Mura V, Braham S, Tosetti G, Branci F, Bitto N, Moia M, Fracanzani AL, Colombo M, Tripodi A and Primignani M. Harmful and benefi-
The clinical value of color Doppler ultrasonography


