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Original Article

Multi-slice spiral computed tomography portography is valuable to predict esophageal variceal bleeding and hepatic encephalopathy in patients with cirrhosis

Guangrong Dai[1,2], Huifeng Wang[2], Baoli Li[3], Shuixiang He[1], Wenna Liu[4], Jin Zhang[2], Jian Wang[5], Cha Ma[2]

[1]Digestive Department, The First Affiliated Hospital of Xi'an Jiaotong University, Shannxi, P.R. China; [2]Digestive Department, [5]Computed Tomography Diagnostic Department, Yan'an University Affiliated Hospital, Shannxi, P.R. China; [3]Department of Pharmacology, Yan'an University Medical College, Shannxi, P.R. China; [4]Digestive Division III, PLA 153 Hospital, P.R. China

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Abstract: Aims: The present study is to use 64-slice MSCTP to investigate how main portal vein diameter, intrahepatic vein imaging, collateral opening, and the formation of portal vein embolus and hepatic artery-portal vein fistula are related with Child-Pugh staging, esophageal variceal bleeding and hepatic encephalopathy in patients with hepatic cirrhosis. Methods: A total of 64 patients with hepatic cirrhosis who were hospitalized between May 2012 and October 2014 were included in the present study. All patients were scanned using SOMATOM Sensation 64-slice spiral CT scanner. In Maxview workstation, the images were subjected to maximum intensity projection, volume reconstruction and multiplanar three-dimensional reconstruction. The diameters of main portal vein (MPV), intrahepatic left (IHLPV) and right (IHRPV) portal vein, splenic vein (SPV), and left gastric vein (LGV) were measured. In addition, opening of collateral circulation, existence of portal vein embolus, or formation of hepatic artery-portal vein fistula were examined. Double-blind method was used to analyze the lesions of portal vein system. Results: Cirrhosis expanded the diameters of blood vessels in portal vein system. Patients with Child-Pugh grade C had larger diameters of blood vessels in portal vein system compared with those with grade A. Digestive tract bleeding increased the diameters of MPV, SPV, LGV and IHLPV in portal vein system. The diameter of LGV was used for the prediction of EVB. Patients with HE stage III had larger diameters of LGV, SPV, IHLPV and IHRPV than patients with HE stage I. HE staging was correlated with the formation of portal vein embolus and hepatic artery-portal vein fistula in portal vein system. MSCTP grading had consistent grading of cirrhosis lesion severity with Child-Pugh grading. Conclusions: The present study demonstrates that MSCTP is capable of predicting risks for esophageal variceal bleeding and hepatic encephalopathy.

Keywords: Multi-slice spiral computed tomography portography, esophageal variceal bleeding, hepatic encephalopathy, main portal vein, intrahepatic vein

Introduction

Esophageal variceal bleeding (EVB) and hepatic encephalopathy (HE) are serious complications of hepatic cirrhosis, and they may lead to high mortality rate and severely threaten life quality of the patients [1]. The occurrence and development of EVB and HE are closely related with portal vein system diseases, such as collateral circulation of portal hypertension and portal vein embolization [2]. The prevention of EVB and HE in hepatic cirrhosis has become a hot spot in clinical practice.

Three-dimensional reconstruction of images obtained by multi-slice spiral computed tomographyportography (MSCTP) is clear, realistic, and accurate in positioning. It can directly and quickly display all anatomical information of collateral portal vein system, and is recognized as a good method to display blood vessels [3]. In the present study, we use 64-slice MSCTP to investigate howmain portal vein diameter, intrahepatic vein (IHV) imaging, collateral opening, and the formation of portal vein embolus and hepatic artery-portal vein fistulaare related with Child-Pugh staging, EVB and HE.

Table 1. Demographic information and basic clinic feature of the participants

	Bleeding group (n = 30)	Non-bleeding group (n = 34)	χ^2/t	P
Age	50.26±12.32 years	52.14±11.18 years	0.608	0.516
Gender (No. of Males/Females)	22/8	20/14	1.487	0.223
Cirrhosis etiology (No.)			1.879	0.866
Hepatitis B	24	24		
Hepatitis C	1	2		
Alcoholic liver disease	2	3		
Primary biliary cirrhosis	1	1		
Drug-induced cirrhosis	0	1		
Unknown aetiology	2	3		

Materials and methods

Patients

A total of 64 patients with hepatic cirrhosisadmitted at Digestive Department of Yan'an University Affiliated Hospital between May 2012 and October 2014 were included in the present study. All patients were diagnosed with cirrhosis based on disease history, clinical manifestations and imaging examinations, and the diagnostic criteria was in accordance with the "Guideline of Prevention and Treatment for Chronic Hepatitis B (2010 edition)" [4]. HE staging was performed according to West-Haven semi-quantitative mental scale [5]. The exclusion criteria were: i) patients with ligation, disconnection or shunting of esophageal varices; ii) patients with splenectomy; iii) patients with combined hepatic malignant tumors; iv) patients with hepatic cyst or hepatic hemangioma diameter > 3 cm; v) patients with renal dysfunction or iodine allergy [6]. Among the 64 patients, 42 were male and 22 were female, with an age range of 24-72 years and a mean age of 51.30± 11.26 years. All patients with cirrhosis included 48 cases of hepatitis B, 3 cases of hepatitis C, 5 cases of alcoholic liver disease, 2 cases of primary biliary cirrhosis, 1 case of drug-induced cirrhosis and 5 cases of cirrhosis with unknown reasons. In addition, 22 cirrhosis patients had combined HE. According to Child-Pugh grading for hepatic function [7], 26 cases were at grade A, 22 cases were at grade B and 16 cases were at grade C. Control group comprised 36 subjects who were subjected to plain and enhanced computed tomography (CT) scanning due to suspicion of upper abdominal diseases,but had no discovered lesions, including 23 males and 13 females (age range, 21-76 years; mean age, 53.4±9.66 years). Furthermore, 30 patients were classified into digestive tract bleeding group (46.88%) and the other 34 patients were classified into non-bleeding group (53.12%) (**Table 1**). All procedures were approved by the Ethics Committee of Yan'an University. Written informed consents were obtained from all patients or their families.

MSCTP

All patients were scanned using SOMATOM Sensation 64-slice spiral CT scanner (Siemens, Berlin, Germany). The scanning parameters were: tube voltage, 120 kV; tube current, 250 mA; slice thickness, 7.5-10 mm; pitch, 0.983; breath-hold scanning. The scanning range was from the diaphragm to the bilateral iliac crest level. All patients were fasting for 8-12 h before examinations. Before scanning, the patients orally took 500-800 ml clear water to fill the gastrointestinal tract as negative contrast agent. For enhanced scanning, 80-100 mlnonionic contrast agent iohexol (350 g I/L; dose, 1.5-2.0 ml/kg) was injected into elbow vein of upper limbusing binocular high-pressure syringe at a flow rate of 2.8-3.0 ml/s. Dynamic scanning of hepatic arterial phase (20-30 s), portal venous phase (50-60 s; delayed 5-8 s for cirrhosis patients) and balance phase (120-180 s) was performed.

Image analysis

After thin-slice reconstruction, raw image data of portal venous phase were sent to Maxview workstation. Reconstruction slice thickness was 1.25 mm, and spacing between slices was 0.60 mm. In Maxview workstation, the images were subjected to maximum intensity projection, volume reconstruction and multiplanar three-dimensional reconstruction, and the diameters of main portal vein (MPV), intrahepatic left (IHLPV) and right (IHRPV) portal vein, splenic vein (SPV), and left gastric vein (LGV) were measured. In addition, opening of collateral circulation, existence of portal vein embolus, or

Table 2. Diameters of blood vessels in portal vein system in patients of cirrhosis and control groups (cm, means ± standard deviations)

	No. of cases	MPV	SPV	LGV	IHLPV	IHRPV
Cirrhosis group	64	1.68±0.21*	1.45±0.18*	0.53±0.12*	1.21±0.15*	1.26±0.22*
Control group	36	1.18±0.14	0.80±0.09	0.42±0.07	0.95±0.07	0.96±0.11

Note: MPV, main portal vein; SPV, splenic vein; LGV, left gastric vein; IHLPV, intrahepatic left portal vein; IHRPV, intrahepatic right portal vein. *P < 0.05 compared with control.

Table 3. Diameters of blood vessels in portal vein systemin patients with different Child-Pugh grades (cm, means ± standard deviations)

Child-Pugh grades	No. of cases	MPV	SPV	LGV	IHLPV	IHRPV
Grade A	26	1.68±0.15	1.35±0.13	0.48±0.09	1.11±0.13	1.15±0.21
Grade B	22	1.79±0.12	1.47±0.21	0.50±0.07	1.29±0.13	1.26±0.21
Grade C	16	2.01±0.20*	1.57±0.10*	0.59±0.11*	1.36±0.09*	1.45±0.12*

Note: MPV, main portal vein; SPV, splenic vein; LGV, left gastric vein; IHLPV, intrahepatic left portal vein; IHRPV, intrahepatic right portal vein. *P < 0.05 compared with grade A.

Table 4. Diameters of blood vessels in portal vein system in patients with or without digestive tract bleeding (cm, means ± standard deviations)

Digestive tract bleeding	No. of cases	MPV	SPV	LGV	IHLPV	IHRPV
Yes	30	1.78±0.16*	1.54±0.20*	0.62±0.10*	1.28±0.15*	1.29±0.21
No	34	1.60±0.21	1.36±0.13	0.45±0.06	1.15±0.13	1.25±0.23

Note: MPV, main portal vein; SPV, splenic vein; LGV, left gastric vein; IHLPV, intrahepatic left portal vein; IHRPV, intrahepatic right portal vein. *P < 0.05 compared with patients without digestive tract bleeding.

formation of hepatic artery-portal vein fistulawere examined. The diameter of MPV was measured at the middle point of portal vein. The diameter of SPV was measured at 2 cm before the point where SPV entered the portal vein. The diameter of LGV was measured at the widest point within the 2-cm range before the point where LGV entered the portal vein. The diameters of IHLPV and IHRPV were measured at the points that were 1.0-1.5 cm away from MPV. All indicators were measured twice and average values were used.

Grading of cirrhosis

Double-blind method was used to analyze the lesions of portal vein system. The staging of cirrhosis using MSCTP followed the following standard. Grade I: i) grades 4-5 were achieved in intrahepatic portal vein imaging; ii) collateral circulation was mainly open at esophageal gastric fundus vein, or one branch of para-umbilical vein or esophageal peripheral vein was open; iii) hepatic artery-portal vein fistula or portal vein embolus was not formed. Grade II: i) grades 3-4 were achieved in intrahepatic portal vein imaging; ii) in addition to opening of collateral circulation at esophageal gastric fundus vein, 2-3 branches of para-umbilical vein or esophageal peripheral vein were open; iii) some hepatic artery-portal vein fistula or portal vein embolus were not observed. Grade III: i) grades 2-4 were achieved in intrahepatic portal vein imaging; ii) esophageal gastric fundus vein, para-umbilical vein or esophageal peripheral vein were all open; iii) hepatic artery-portal vein fistula or portal vein embolus was mostly formed.

Statistical analysis

All results were analyzed using SPSS21.0 (IBM, Armonk, NY, USA). Measurement data were expressed as means ± standard deviations. The means of two groups were compared using t-test. The means of multiple groups were compared using single factor analysis of variance. Pairwise comparison between groups was performed using Least Significant Difference method. Ordinal categorical variables of two groups of independent data were compared using rank-sum test. Mann-Whitney U test was used to compare data between two groups. Counting data were compared using χ^2 test. Ranked data were compared using Spearman correlation analysis. The area under curve (AUC) of receiver operating characteristic (ROC) curves was used to evaluate the sensitivity and specificity of the

Table 5. Multivariate logistic regression analysis of factors that might contribute to esophageal variceal bleeding and hepatic encephalopathy

	B	S.E.	Wald	df	Sig.	Exp (B)	95.0% C.I. for Exp (B)	
							Lower	Upper
MPV	-0.004	3.416	0.000	1	0.999	0.996	0.001	805.718
SPV	13.425	5.561	5.829	1	0.016	6.770E5	12.510	3.664E10
LGV	36.481	131.799	6.989	1	0.008	6.975E15	1.252E4	3.885E27
IHLPV	19.400	14.242	1.856	1	0.173	2.663E8	0.000	3.532E20
Constant	-62.049	28.247	4.825	1	0.028	0.000		

Table 6. Prediction value of diameters of blood vessels in portal vein system for esophageal variceal bleeding

Blood vessels	Sensitivity (%)	Specificity (%)	Cutoff value	Area under curve	95% confidence interval
MPV	80.0	70.6	1.65	0.759	0.585-0.933
SPV	73.3	70.6	1.45	0.776	0.612-0.941
LGV	93.3	58.8	0.61	0.906	0.793-1.000
IHLPV	53.3	82.4	1.25	0.729	0.555-0.904

Note: MPV, main portal vein; SPV, splenic vein; LGV, left gastric vein; IHLPV, intrahepatic left portal vein.

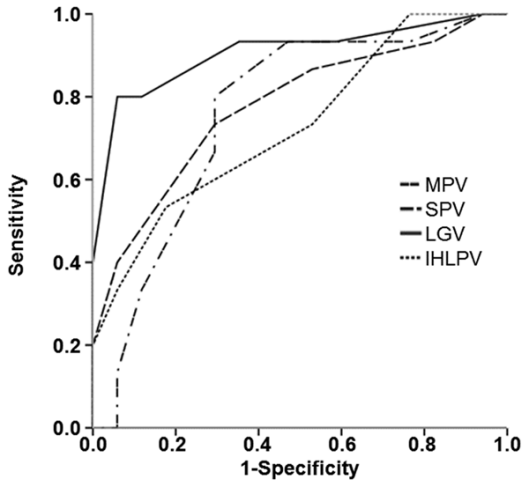

Figure 1. Receiver operating characteristic curves of the diameters of main portal vein (MPV), splenic vein (SPV), left gastric vein (LGV), intrahepatic left portal vein (IHLPV) for the prediction of esophageal variceal bleeding. P < 0.05.

diameters of blood vessels in portal vein system in predicting EVB. Differences with P < 0.05 were considered statistically significant.

Results

Cirrhosis expands the diameters of blood vessels in portal vein system

To measure the diameters of MPV, SPV, LGV, IHLPV and IHRPV, images obtainedby MSCTP were analyzed. The data showed that the diameters of MPV, SPV, LGV, IHLPV and IHRPV in patients with cirrhosis were significantly larger than those of control group (P < 0.05) (**Table 2**). The result suggests that cirrhosis expands the diameters of blood vessels in portal vein system.

Patients with Child-Pugh grade C have larger diameters of blood vessels in portal vein system compared with those with grade A

To examine the relationship between Child-Pugh grading and the diameters of blood vessels in portal vein system, 26 patients with grade A, 22 patients with grade B and 16 patients with grade C were studied. The data showed that the diameters of MPV, SPV, LGV, IHLPV and IHRPV in patients with grade C were significantly larger than those of patients with grade A (P < 0.05). Of note, the diameters of MPV, SPV, LGV, IHLPV and IHRPV were not significantly different between grade A and grade B, or between grade B and grade C (P > 0.05) (**Table 3**). The result indicates that patients with Child-Pugh grade C have larger diameters of blood vessels in portal vein system compared with those with grade A.

Digestive tract bleeding increases the diameters of MPV, SPV, LGV and IHLPV in portal vein system

To determine how the diameters of blood vessels in portal vein system are related with digestive tract bleeding, 30 patients were classified into digestive tract bleeding group and the other 34 patients were classified into non-bleeding group. The data showed that the diameters of MPV, SPV, LGV and IHLPV in patients with digestive tract bleeding were significantly

Table 7. Diameters of blood vessels in portal vein system in patients with different hepatic encephalopathy staging (cm, means ± standard deviations)

Hepatic encephalopathy staging	No. of cases	MPV	SPV	LGV	IHLPV	IHRPV
Stage I	10	1.56±0.10	1.29±0.10	0.50±0.08	1.19±0.13	1.08±0.17
Stage II	7	1.61±0.11	1.37±0.13	0.61±0.07	1.28±0.09	1.27±0.14
Stage III	5	1.49±0.15	1.46±0.05*	0.68±0.08#	1.36±0.05*	1.38±0.08#
F value		10.051	4.380	1.801	4.502	8.220
P value		0.001	0.027	0.192	0.023	0.003

Note: MPV, main portal vein; SPV, splenic vein; LGV, left gastric vein; IHLPV, intrahepatic left portal vein; IHRPV, intrahepatic right portal vein. *P < 0.05; #P < 0.01 compared with stage I.

Table 8. Hepatic encephalopathy staging and lesions in portal vein system

Hepatic encephalopathy staging	No. of cases	No. of cases				
		Esophageal and gastric varices	Paraesophageal varices	Cirsomphalos	Portal vein embolus	Hepatic artery-portal vein fistula
Stage I	10	8	6	5	10	0
Stage II	7	4	4	4	3	2
Stage III	5	3	2	3	4	3

wider than those in patients without digestive tract bleeding (P < 0.05) (**Table 4**). The result suggests that digestive tract bleeding increases the diameters of MPV, SPV, LGV and IHLPV in portal vein system.

The diameter of LGV can be used for the prediction of EVB

To rule out other factors that might contribute to esophageal variceal bleeding and hepatic encephalopathy, wefirst analyzed our data by multivariate logistic regression. The data are shown in **Table 5**. To evaluate the sensitivity and specificity of the diameters of blood vessels in portal vein system in predicting EVB, the AUC of ROC curves was calculated. The data showed that the sensitivity and specificity of LGV in predicting EVB were 93.3% and 58.8% when LGV was larger than 0.61 cm, with the AUC being 0.906 (**Table 6**; **Figure 1**). The results indicate that LGV can be used for the prediction of EVB.

Patients with HE stage III have larger diameters of LGV, SPV, IHLPV and IHRPV than patients with HE stage I

To study the relationship between HE grading and the diameters of blood vessels in portal vein system, the 22 patients with combined HE were subjected to HE staging according to West-Haven criteria. The data showed that the diameters of LGV, SPV, IHLPV and IHRPV in patients with HE stage III were significantly higher than those in patients with HE stage I (P < 0.05). Of note, the diameters of LGV, SPV, IHLPV and IHRPV were not significantly different between stage I and II or between II and III (P > 0.05). In addition, the diameter of MPV was not significantly different between any two stages (P > 0.05) (**Table 7**). These results suggest that patients with HE stage III have larger diameters of LGV, SPV, IHLPV and IHRPV than patients with HE stage I.

HE staging is correlated with the formation of portal vein embolus and hepatic artery-portal vein fistula in portal vein system

To identify the correlation of HE staging with lesions in portal vein system, χ^2 test and Spearman correlation analysis were carried out. The data showed that formation rates of portal vein embolus and hepatic artery-portal vein fistula were significantly different among patients with HE stages I, II and III (χ^2 = 10.410 and 7.033, respectively; P < 0.05). However, the occurrence rates of esophageal and gastric varices, paraesophageal varices and cirsomphalos were not significantly different among the three groups (χ^2 = 1.191, 0.566 and 0.162, respectively; P > 0.05). Correlation analysis showed that HE staging was correlated with the formation of portal vein embolus and hepatic artery-portal vein fistula (r = 0.687 and 0.565, respec-

tively; $P < 0.05$) (**Table 8**). These results indicate that HE staging is correlated with the formation of portal vein embolus and hepatic artery-portal vein fistula in portal vein system.

MSCTP grading has consistent grading of cirrhosis lesion severity with Child-Pugh grading

To evaluate the differences between MSCTP grading and Child-Pugh grading, Mann-Whitney U test was employed. Among all 64 patients, 25 patients were classified into MSCTP grade I, 26 patients were classified into MSCTP grade II, and 13 patients were classified into MSCTP grade III. Mann-Whitney U test showed that the results of Child-Pugh staging (26 cases in grade A, 22 cases in grade B and 16 cases in grade C) were not significantly different from the results of MSCTP grading ($Z = -0.135$, $P > 0.05$). The results suggest that MSCTP grading has consistent grading of cirrhosis lesion severity with Child-Pugh grading.

Discussion

Portal hypertension is a common cause of EVB in cirrhosis. The pathogenesis of portal hypertension is closely related to changes of hemodynamics in hepatic circulation and collateral circulation. The hyperdynamic circulation sustains and aggravates portal hypertension [8], leading to esophageal varices. Esophageal variceal hemorrhage is very dangerous. The incidence of re-bleeding within one year after the first hemorrhage is about 70%, and the mortality rate is 30-50% [9].

The 64-slice MSCTP is able to clearly show the shapes of blood vessels and is widely used in the evaluation of collateral circulation of portal hypertension in patients with cirrhosis. The present study shows that the diameters of MPV, SPV, LGV, IHLPV and IHRPV in cirrhosis patients are significantly larger than those in control group, suggesting that cirrhosis patients have abnormal hemodynamics in portal venous system. In patients with cirrhosis, portal vein blood flow is blocked, the flow rate is slow, the blood vessel is dilated, the volume is increased, and the blood flow of portal and splenic vein is increased.

Child-Pugh staging is commonly used to assess the severity of liver cirrhosis. The risk and prognosis of EVB in cirrhosis are positively correlated with Child-Pugh staging. The present study shows that the diameters of portal vein system vessels in Child-Pugh grade C group are larger than those in grade A, suggesting that portal vein blood flow and resistance are increased when cirrhosis is aggravated, and expand blood vessels in portal vein system. By contrast, the diameters of portal vein system vessels are not significantly different between any other groups, probably due to changes in liver structures, anastomosis between portal vein and hepatic arteries, or hepatic vascular occlusion.

The present study discovers that the diameters of MPV, SPV, LGV and IHLPV are significantly different between patients with and without hemorrhage of digestive tract. However, the diameter of IHRPV is not different between the two groups. This may be due to the reason that IHLPV is easier to be affected by portal hypertension. The present study also shows that LGV has the highest sensitivity and specificity in the prediction of the occurrence of EVB when LGV diameter is greater than 0.61 cm. Song et al. report that prevention of hemorrhage should be concerned when LGV diameter is greater than 0.7 cm [10]. LGV is a main blood supply vessel of esophageal varices, and LGV dilation and blood reflux cause esophageal varices in the presence of portal hypertension. LGV is directly correlated with esophageal submucosal varices in upper gastrointestinal bleeding.

HE is tightly correlated with portal hypertension, portal shunting and collateral circulation [11]. The establishment of portal hypertension and portal collateral circulation causes a large amount of portal venous blood to bypass the liver and flow into systemic circulation. The present study discovers that the formation rate of hepatic artery-portal vein fistula is significantly different among cirrhosis patients with different HE grades, suggesting that hepatic artery-portal vein fistula may increase the risks for HE. This may be due to the reason that hepatic artery-portal vein fistula increases portal venous pressure, promotes the establishment of collateral circulation, and reduces the return of normal portal venous blood into the liver [12]. The present study also shows that cirrhosis patients with different HE grades have significantly different portal vein embolus formation rate, suggesting that formation of portal vein embolus increases the risk for HE. The reason

may be that portal vein embolus blocks the return of portal venous blood into the liver, and portal venous blood flow lower than 629 ml/min may lead to HE. In the meantime, portal vein embolus aggravates hepatic portal hypertension and damages central nervous system. The anastomosis of intrahepatic portal vein and hepatic artery and the formation of hepatic artery-portal vein fistula lead to the return of portal venous blood to the liver and further elevate portal venous pressure. This causes slowdown of blood flow, increase in blood viscosity, and even the formation of portal vein thrombosis.

Portosystemic shunting caused by portal hypertension includes the opening of collateral circulation of esophageal and gastric varices and paraumbilical vein [13]. The present study shows that single esophageal and gastric varices, paraesophageal varices and cirsomphalos are not correlated with HE, but the combination of hepatic artery-portal vein fistula or portal vein embolus suggests the occurrence or aggravation of HE, being consistent with the report by Chu et al. [2].

The results of the present study demonstrate that portal vein system diseases are correlated with the degree of hepatic cirrhosis. As the increase of Child-Pugh grades of cirrhosis, the diameters of LGV, SPV, IHLPV and IHRPV are increased, but MPV diameter has no such a trend. Hu et al. report that the diameter of LGV measured by MSCTP has predictive value for hepatic function and the severity of portal hypertension [14]. Tang et al. discover that SPV observed by MSCTP can be used to evaluate the severity of hepatic cirrhosis [15]. In the present study, the grading of cirrhosis by MSCTP is not significantly different from that by Child-Pugh staging. Our results show that the diameters of LGV, SPV, IHLPV and IHRPV are increased as the increase of HE grades, but the diameter of MPV has no significant change. This may be due to the compensatory mechanism at an early stage of cirrhosis. Even though there has been portal hypertension and portal shunting, MPV does not show significant expansion. When the lesion develops to a certain degree and the compensatory mechanism is broken, MPV is significantly expanded. In conclusion, MSCTP clearly displays vessels with collateral circulation induced by portal hypertension in cirrhosis. The diameters of main portal vein and its branches are of predictive value for EVB, and LGV is a sensitive indicator for predicting EVB. MSCTP can be used to evaluate the risks for EVB and improves preventive effect [16]. In addition, MSCTP shows the severity of hepatic cirrhosis and predicts the risks for HE.

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Disclosure of conflict of interest

None.

Address correspondence to: Shuixiang He, Digestive Department, The First Affiliated Hospital of Xi'an Jiaotong University, No. 76 West Yanta Road, Xi'an 710061, Shannxi, P.R. China. Tel: 86-13991380928; Fax: 86-29-8525580; E-mail: M13891157709_1@163.com

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