Original Article

Changes and influencing factors of liver volume after transjugular intrahepatic portosystemic shunt: a retrospective cohort study

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Background: Liver volume is an important measure of liver reserve and helps to determine the course of liver disease. This study aimed to observe the dynamic changes of liver volume after transjugular intrahepatic portosystemic shunt (TIPS) and analyze the related factors.

Methods: Clinical data of 168 patients who underwent TIPS procedures between February 2016 and December 2021 were collected and analyzed retrospectively. The changes in liver volume after TIPS in the patients were observed, and the independent predictors affecting increases in liver volume were analyzed using a multivariable logistic regression model.

Results: The mean liver volume was decreased by 12.9% at 2±1 months post TIPS and rebounded at 9±3 months post TIPS, but did not recover to its pre-TIPS level completely. Most patients (78.6%) had decreased liver volume at 2±1 months post TIPS, and in multivariable logistic regression, a lower albumin (ALB) level, a lower subcutaneous fat area at L3 (L3-SFA), and a higher degree of ascites were identified as independent factors predicting increased liver volume. The risk score model for predicting increased liver volume was Logit(P)=1.683-0.078 (ALB) -0.01 (pre TIPS L3-SFA) +0.996 (grade 3 ascites =1; non-grade 3 ascites =0). The area under the curve of the receiver operating characteristic curve was 0.729, and the cut-off value was 0.375. The rate of liver volume change at 2±1 months post TIPS was significantly correlated with that of spleen volume change (R^2=0.378, P<0.001). The rate of subcutaneous fat change at 9±3 months post TIPS was significantly correlated with that of liver volume change (R^2=0.782, P<0.001). In patients with a liver volume increase, the mean computed tomography value (Hounsfield units) decreased significantly after TIPS placement (65.9±17.7 *vs.* 57.8±18.2, P=0.009).

Conclusions: Liver volume was decreased at 2±1 months post TIPS and slightly increased at 9±3 months post TIPS; however, it did not recover to its pre-TIPS level completely. A lower ALB level, a lower L3-SFA, and a higher degree of ascites were all predictors for increased liver volume post TIPS.

Keywords: Transjugular intrahepatic portosystemic shunt (TIPS); liver volume; change trend; fat; ascites

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Introduction

Transjugular intrahepatic portosystemic shunt (TIPS) is well established to be an effective treatment tool for portal hypertension (1-5). With the establishment of a direct channel between the hepatic vein and the portal vein, part of the portal vein blood flows directly into the inferior vena cava through the shunt, reducing the portal vein pressure. Refractory ascites occurs in about 10% of patients with cirrhosis (6). Although the insertion of a TIPS can effectively improve ascites by reducing portal vein pressure, a decrease in hepatic blood perfusion may reduce the liver volume and damage liver function (7), thus affecting the prognosis of patients.

There have been many reports about the prognostic value of liver volume. Liver volume is significantly correlated with liver function, and decreased liver volume is a risk factor for a poor prognosis after TIPS (8,9). Furthermore, the combination of liver volume and spleen volume can be used to evaluate the severity of liver fibrosis (10), predict the hepatic venous pressure gradient of patients with hepatitis B cirrhosis (11), and predict the survival of primary cholangitis (12,13). Liver volume therefore plays an important role in patient prognosis.

Volume measurement by computed tomography (CT) is increasingly becoming widely used in clinical studies, with high accuracy (14,15). Although imaging-based liver volume assessments are increasingly being conducted before hepatectomy or transplantation, studies of how the liver volume changes after TIPS are not sufficient. One study noted that there was no difference in liver volume before and after TIPS insertion (16). However, another study found that pre-TIPS liver volume affects post-TIPS liver volume changes (17). To address this lack of a unified conclusion, the purpose of the present study was to investigate the variation regularity of liver volume after TIPS and the related factors. We present the following article in accordance with the STROBE reporting checklist (available at https://qims.amegroups.com/article/view/10.21037/qims-22-482/rc).

Methods

Patients

This retrospective cohort study retrospectively collected 439 patients from Wuhan Union Hospital from February 2016 to December 2021. After the inclusion and exclusion criteria had been applied, 168 participants were finally included in the study (*Figure 1*). Patients with confirmed cirrhosis who successfully underwent TIPS procedures were considered eligible for the study. The diagnosis of cirrhosis was based on history, imaging, and/or liver biopsy. Patients with missing CT data, liver tumors, or no follow-up data were excluded (*Table 1*). After TIPS insertion, the included patients were followed up by telephone once every 3 months, and regular imaging reviews were performed. Ascites was categorized into three degrees according to the EASL (European Association for the Study of the Liver) and other relevant guidelines (18,19): grade 1: mild ascites, only detectable by ultrasound examination; grade 2: moderate ascites, manifested by moderate symmetrical distension of the abdomen; and grade 3: large or gross ascites with marked abdominal distension (10,11). The study was conducted in accordance with the Declaration of Helsinki (as revised in 2013) (20) and was approved by the Ethics Committee of Wuhan Union Hospital, Tongji Medical College, Huazhong University of Science and Technology (No. 202201043). The requirement to obtain individual consent for this retrospective analysis was waived.

Imaging-based volumetry of the liver and skeletal muscle mass measurements

For liver volume measurement, the volume software (Slice-Omatic version 4.3; TomoVision, Magog, Quebec, Canada) in the CT workstation was used, with the measurement threshold set to 30–300 Hounsfield units (Hu). The stratifying method was used to outline the liver region of interest (ROI) in the axial venous phase image. Non-liver tissues such as the gallbladder, fat, and blood vessels

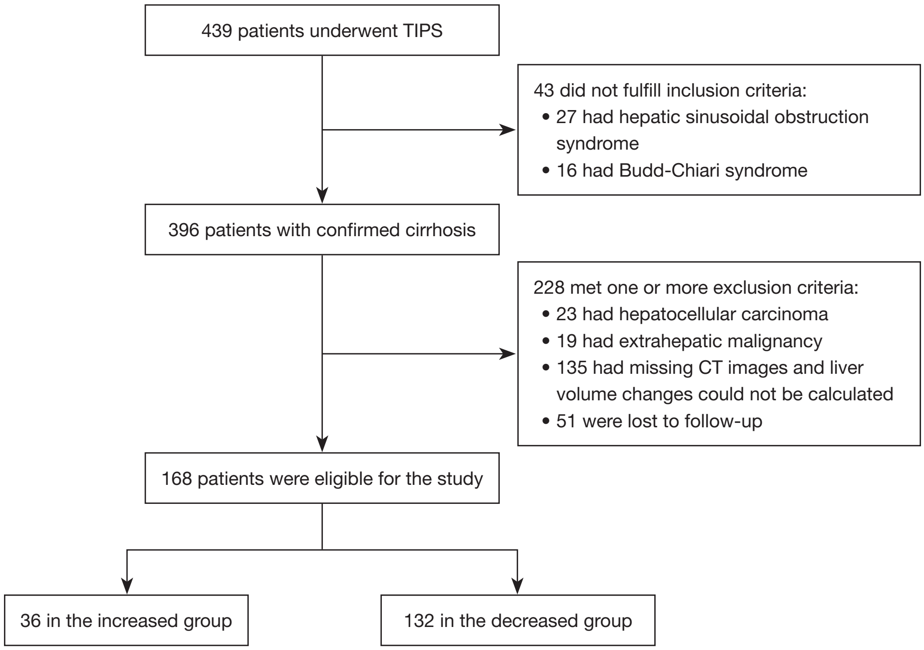

Figure 1 Flowchart of retrospective selection of study patients. CT, computed tomography; TIPS, transjugular intrahepatic portosystemic shunt.

Table 1 Criteria for inclusion and exclusion of patients

Inclusion criteria	Exclusion criteria
Confirmed cirrhosis of the liver	Hepatocellular carcinoma
Complete follow-up	Extrahepatic tumors
	Missing CT data

CT, computed tomography.

were avoided in the drawing process. The volume data was automatically calculated by the software, and all the measurements were performed in three repetitions by each surveyor. We drew the ROI along the skeletal muscle at the level of L3 near the endplate, set the threshold of CT value as −29 to 150 Hu, and obtained the total cross-sectional skeletal muscle area (L3-SMA), including the psoas quadratus, psoas major, internal oblique, external oblique, transverse abdominal, and vertical spinal muscles. We took the mean value of the results measured by three doctors as the final result and calculated skeletal muscle index (SMI), which was the total cross-sectional area of skeletal muscle at L3 divided by the square of the height. We used the diagnostic criteria recommended by Carey *et al.* (21), whose study suggested that SMI <50 cm^2/m^2 in males and SMI <39 cm^2/m^2 in females should be used to define sarcopenia in patients with end-stage liver disease who are waiting for liver transplantation. The measurement of the subcutaneous fat area (L3-SFA) was done in the same manner as that of the L3-SMA. We drew the ROI along the abdominal skin contour and the outer edge of the muscle at the level of L3 near the endplate. The measurements of liver volume, L3-SMA, L3-SFA, and other imaging data were repeated by three radiologists, each with more than 5 years of radiology experience. All the radiologists had carried out standardized training.

Measurement of CT value of liver

The CT value of the liver under plain scan was measured using CT workstation measurement software. Each surveyor selected three ROIs at the level with the largest liver cross section for measurement. Elliptical ROIs were selected in the cross section, avoiding blood vessels and bile ducts. For each patient, the measurements were repeated by three radiologists, each with more than 5 years of experience, and the final results were averaged.

TIPS procedure

TIPS implantation was performed as described previously (22). The procedure was performed by the same team of experienced physicians for all patients. The right internal jugular vein was punctured with a RUPS-100 puncture device (Cook Inc., Castleroy, Limerick, Ireland) and intubated to the hepatic vein through the vena cava. The portal vein was then punctured under fluoroscopy to establish the direct channel between the hepatic and portal veins. The portosystemic shunt was established by balloon expansion (6–8 mm) and stents were placed. All patients in this study were treated with membrane-covered stents to maintain long-term stent patency (23). A bare stent (Bard E-LUMINEXX Vascular Stent, Karlsruhe, Germany) was placed first, followed by a coated stent (Fluency; Bard Inc., Franklin Lakes, NJ, USA or Viabahn; Gore, Flagstaff, AZ, USA). The portal vein pressure gradient (PPG) was measured before and after the shunt was established.

Statistical analysis

The statistical software programs SPSS 26.0 (IBM Corp., Armonk, NY, USA) and R (version 4.0.3; R Foundation for Statistical Computing, Vienna, Austria) were used for statistical analysis. Measurement data were presented as mean ± standard deviation ($\bar{x}$ ± s), and count data were presented as number of cases and percentage [n (%)]. The paired sample *t*-test was used to compare changes in liver volume. Correlations were analyzed through Pearson's correlation analysis. A line chart of the liver volume change was drawn. Univariate and multivariate binary logistic regression analyses were performed for the increased and decreased liver volume groups. The forward Ward method was adopted, and confounding factors were corrected. Then, variables with P<0.1 in the univariate analysis were included in multivariate analysis to get the risk score Logit(P) for predicting increased liver volume. Receiver operating characteristic (ROC) analysis was performed on Logit(P) to calculate the Youden index. A two-sided P value <0.05 was considered significant, and P<0.001 was considered highly statistically significant.

Results

Changes in liver volume after TIPS

A total of 168 patients were included in the study; among them, 49 patients had pre-TIPS, 2±1 months post-TIPS, and 9±3 months post-TIPS follow-up CT scans. As shown by the line chart in *Figure 2A*, the mean liver volume at 2±1 months post TIPS was decreased by 12.9% compared to the baseline liver volume (992.8±322.6 *vs.* 1,140.1±326.6 cm^3, P<0.001). The mean liver volume at 9±3 months post TIPS was 1,018.6±345.1 cm^3, which was not significantly different from that at 2±1 months post TIPS (P=0.27). At 9±3 months post TIPS, the liver volume had still not returned to its pre-TIPS level. The overall liver volume change at 9±3 months post TIPS was still lower than that before TIPS insertion.

At 2±1 months post TIPS, there were 36 patients with increased liver volume and 132 patients with decreased liver volume. On this basis, the patients were divided into two groups: the increased liver volume group and the decreased liver volume group. In the increased liver volume group (*Figure 2B*), the mean liver volume was increased at 2±1 months post TIPS compared to pre-TIPS insertion (1,321.6±377.0 *vs.* 1,160.0±307.8 cm^3, P=0.01) and was decreased at 9±3 months post TIPS compared to at 2±1 months post TIPS (1,238.0±387.4 *vs.* 1,321.6±377.0 cm^3, P=0.45). In the decreased liver volume group (*Figure 2C*), the liver volume was decreased at 2±1 months post TIPS compared to pre-TIPS insertion (936.2±285.2 *vs.* 1,140.8±336.2 cm^3, P<0.001) and was increased at 9±3 months post TIPS compared to at 2±1 months post TIPS (981.1±327.9 *vs.* 936.2±285.2 cm^3, P=0.04).

Additionally, patients were divided into two groups according to whether or not they had a history of splenectomy or partial splenic embolization (*Figure 2D,2E*). In both groups, the liver volume was decreased at 2±1 months post TIPS compared to before TIPS insertion and was increased at 9±3 months post TIPS compared to at 2±1 months post TIPS.

Patient characteristics

The pre-TIPS albumin (ALB) level of the decreased liver volume group was higher than that of the increased liver volume group (32.1±5.5 *vs.* 28.9±5.9 g/L, P=0.003). The baseline prothrombin time was lower in the decreased liver volume group than in the increased liver volume group (16.3±2.3 *vs.* 17.5±3.6 seconds, P=0.02). The baseline Child-Pugh score in the decreased liver volume group was lower than that in the increased liver volume group (7.3±1.4 *vs.* 8.3±1.7, P<0.001). The L3-SMA in the decreased liver volume group was higher than that in the increased liver volume group (120.5±26.0 *vs.* 109.9±26.9, P=0.04). Twenty-five patients (18.9%) in the decreased liver volume group had grade 3 ascites before TIPS insertion, compared to 17 patients (47.2%) in the increased liver volume group,

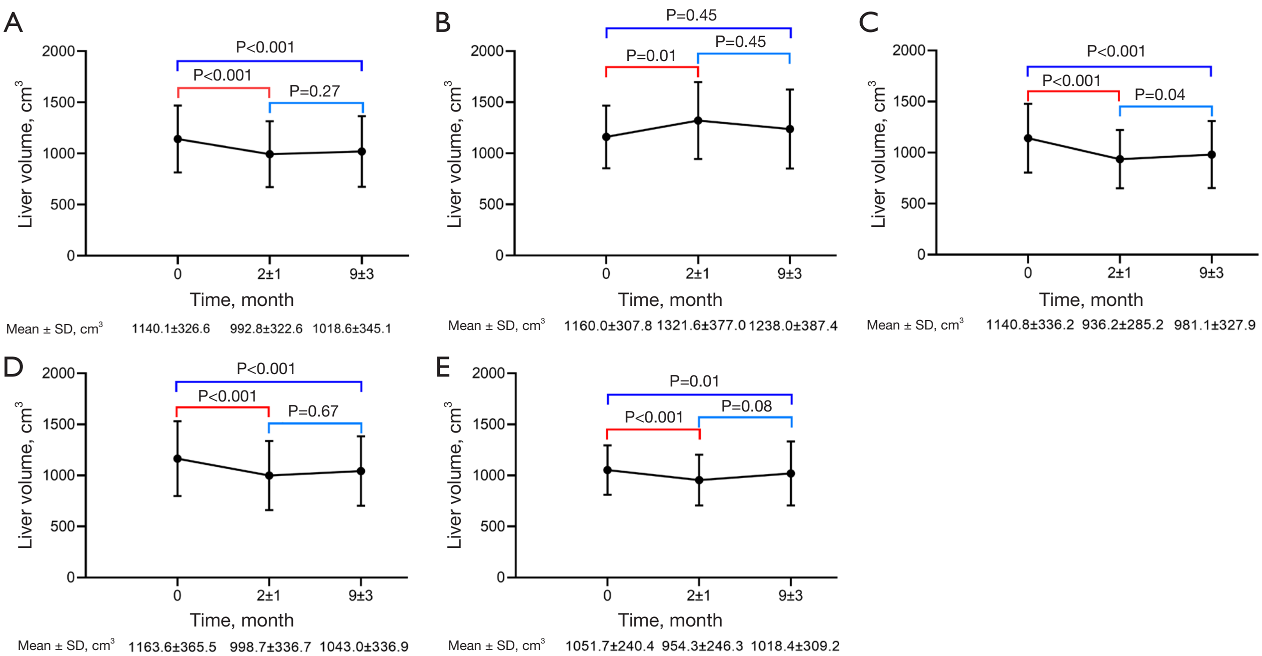

Figure 2 Changes in liver volume in different groups. (A) Liver volume changes before, 2±1 months after TIPS insertion, and 9±3 months after TIPS insertion in 49 patients. (B) Liver volume changes in the increased liver volume group. (C) Liver volume changes in the decreased liver volume group. (D) Liver volume changes in patients without a history of splenectomy or splenic embolization. (E) Liver volume changes in patients with a history of splenectomy or embolization. TIPS, transjugular intrahepatic portosystemic shunt; SD, standard deviation.

representing a significant difference between the two groups (P=0.001). There were no significant differences in other characteristics between the two groups. Details are available in *Table 2*.

We also analyzed changes in post-TIPS liver function in patients with increased and decreased liver volume, and the results showed no significant difference between the two groups (Figure S1). Also, Cox survival analysis revealed no significant difference in cumulative survival between the two groups (Figure S2).

Univariate and multivariate analysis based on binary logistic regression

Binary logistic regression was performed with the outcome of increased liver volume at 2±1 months after TIPS insertion. Univariate analysis showed that the P values of ALB, prothrombin time, International Normalized Ratio, platelets, grade 3 ascites, pre-TIPS L3-SMI, sarcopenia, pre-TIPS L3-SMA, and pre-TIPS L3-SFA were all less than 0.1. After adjustment for confounders, the results of multivariate analysis showed that ALB [P=0.04, odds ratio (OR) =0.925, 95% confidence interval (CI): 0.857–0.998], grade 3 ascites (P=0.03, OR =2.708, 95% CI: 1.128–6.502), and pre-TIPS L3-SFA (P=0.03, OR =0.990, 95% CI: 0.982–0.999) were statistically significant. As shown in *Table 3*, a lower ALB level, a lower pre-TIPS L3-SFA, and a higher degree of ascites were independent factors predicting an increase in liver volume at 2±1 months after TIPS insertion.

Each patient was given a Logit(P) risk score for predicting increased liver volume based on grade 3 ascites, ALB, and pre-TIPS L3-SFA, which was shown as Logit(P)=1.683-0.078 (ALB) -0.01 (pre-TIPS L3-SFA) +0.996 (grade 3 ascites =1; non-grade 3 ascites =0). A ROC curve analysis was performed (*Figure 3*), which produced an AUC of 0.729 and a Youden index of 0.375.

Parameters associated with liver volume enlargement

In the increased liver volume group, the average CT value before TIPS insertion was higher than that after TIPS insertion (65.9±17.7 *vs.* 57.8±18.2, P=0.009) (*Figure 4A*). In the decreased liver volume group, the average CT value before TIPS insertion was not significantly different from

Table 2 Baseline characteristics of patients

Variables	All patients (N=168)	Decreased group (N=132)	Increased group (N=36)	P values
Demographic Characteristics				
Age, years	53.6±11.5	52.8±11.7	56.4±10.3	0.10
Sex, male	107 (63.7)	86 (65.2)	21 (58.3)	0.56
Body weight, kg	60.4±10.6	60.7±10.2	59.3±12.2	0.54
Height, cm	166.3±7.2	166.3±7.2	166.5±7.3	0.88
BMI, kg/m^2	21.8±3.2	22.0±3.1	21.1±3.2	0.28
Indications for TIPS				0.74*
Variceal bleeding	154 (91.7)	120 (90.9)	34 (94.4)	
Refractory ascites	14 (8.3)	12 (9.1)	2 (5.6)	
Etiology				0.96*
HBV	102 (60.7)	82 (62.1)	20 (55.6)	
HCV	20 (11.9)	16 (12.1)	4 (11.1)	
Alcohol	12 (7.1)	9 (6.8)	3 (8.3)	
Schistosoma	10 (6.0)	8 (6.1)	2 (5.6)	
Others	–	–	–	
Laboratory parameters				
TBIL, μmol/L	27.8±30.0	26.7±30.6	31.8±27.5	0.37
ALB, g/L	31.4±5.7	32.1±5.5	28.9±5.9	0.003
ALT, U/L	37.9±74.9	32.6±29.6	56.9±150.7	0.09
AST, U/L	43.5±46.0	42.3±43.3	47.8±55.3	0.53
Creatinine, μmol/L	67.8±25.2	69.1±25.8	63.2±22.4	0.21
BUN, mmol/L	6.1±2.9	6.0±2.9	6.4±3.1	0.55
PT, seconds	16.6±2.7	16.3±2.3	17.5±3.6	0.02
INR	1.4±0.3	1.4±0.2	1.5±0.4	0.02
Platelet count, 10^9/L	84.5±66.0	79.4±60.0	102.9±82.3	0.06
Sodium, mmol/L	138.3±4.8	138.2±4.9	138.8±4.6	0.52
Child-Pugh score	7.5±1.5	7.3±1.4	8.3±1.7	<0.001
MELD score	11.5±3.4	11.3±3.2	12.3±3.8	0.10
MELD-Na score	12.6±4.9	12.5±5.1	12.9±4.2	0.69
Radiographic analysis				
Grade 3 ascites	42 (25.0)	25 (18.9)	17 (47.2)	0.001
L3-SMA, cm^2	118.2±26.5	120.5±26.0	109.9±26.9	0.04
L3-SMI, cm^2/m^2	101.6±65.7	43.6±8.0	39.0±8.8	0.10
Pre-TIPS PPG, mmHg	27.1±6.3	27.0±5.6	28.7±6.5	0.64
Post-TIPS PPG, mmHg	11.8±4.3	11.5±3.7	12.9±6.0	0.13
Sarcopenia	84 (50.0)	62 (47.0)	22 (61.1)	0.20
Liver volume (cm^3)	1,118.0±330.7	1,139.8±343.5	1,038.3±268.4	0.10
Spleen volume (cm^3)	828.3±419.5	830.5±428.1	818.4±387.4	0.90

Continuous variables are expressed as mean and standard deviation. Categorical variables are presented as frequency and percentage. *, calculated by Fisher's exact test. BMI, body mass index; HBV, hepatitis B virus; HCV, hepatitis C virus; TBIL, total bilirubin; ALB, albumin; ALT, alanine aminotransferase; AST, aspartate aminotransferase; PT, prothrombin time; INR, international normalized ratio; MELD, model for end-stage liver disease; PVT, portal vein thrombosis; TIPS, transjugular intrahepatic portosystemic shunt; PPG, portal pressure gradient; SMA, skeletal muscle area; SMI, skeletal muscle index; SFA, subcutaneous fat area.

Table 3 Multivariable logistic regression model for independent predictors of increased liver volume after transjugular intrahepatic portosystemic shunt insertion

Variables	Univariate		Multivariate	
	P value	OR (95%CI)	P value	OR (95% CI)
Sex, male	0.452	0.749 (0.353–1.590)		
Weight, kg	0.534	0.988 (0.949–1.027)		
Height, cm	0.882	1.004 (0.949–1.063)		
TBIL, µmol/L	0.382	1.005 (0.994–1.016)		
ALB, g/L	0.004	0.902 (0.841–0.967)	0.043	0.925 (0.857–0.998)
ALT, U/L	0.22	1.004 (0.998–1.010)		
AST, U/L	0.535	1.002 (0.995–1.009)		
Creatinine, µmol/L	0.208	0.988 (0.970–1.007)		
BUN, mmol/L	0.549	1.038 (0.919–1.173)		
PT, seconds	0.026	1.177 (1.020–1.358)		
INR	0.029	4.564 (1.171–17.782)		
Platelet count, 10^9/L	0.069	1.005 (1.000–1.010)		
Sodium, mmol/L	0.517	1.028 (0.946–1.117)		
Grade 3 ascites	0.001	3.758 (1.712–8.250)	0.026	2.708 (1.128–6.502)
Liver volume (cm^3)	0.104	0.999 (0.998–1.000)		
Spleen volume (cm^3)	0.107	1.000 (1.001–1.002)		
Pre-TIPS PPG, mmHg	0.636	1.012 (0.963–1.063)		
Post-TIPS PPG, mmHg	0.135	1.054 (0.984–1.129)		
Pre-TIPS L3-SMI	0.012	0.930 (0.879–0.984)		
Sarcopenia	0.097	0.434 (0.161–1.164)		
Pre-TIPS L3-SMA	0.042	0.984 (0.969–0.999)		
Pre-TIPS L3-SFA	0.035	0.991 (0.983–0.999)	0.031	0.990 (0.982–0.999)

BMI, body mass index; HBV, hepatitis B virus; HCV, hepatitis C virus; TBIL, total bilirubin; ALB, albumin; ALT, alanine aminotransferase; AST, aspartate aminotransferase; PT, prothrombin time; INR, international normalized ratio; MELD, model for end-stage liver disease; PVT, portal vein thrombosis; TIPS, transjugular intrahepatic portosystemic shunt; PPG, portal pressure gradient; SMA, skeletal muscle area; SMI, skeletal muscle index; SFA, subcutaneous fat area; OR, odds ratio; CI, confidence interval.

that after TIPS insertion (57.4±11.0 *vs.* 60.3±8.3, P=0.31) (*Figure 4B*).

We next analyzed the correlation between the change rate of liver volume and the change rate of CT value at 3 months after TIPS insertion in the increased liver volume group (*Figure 5A*). The results showed that there was a strong correlation between the change rates (R^2=0.551, P<0.001). Correlation analysis further showed that the change rate of liver volume at 2±1 months post TIPS was significantly correlated with that of spleen volume (*Figure 5B*), R^2=0.378, P<0.001. Also, at 9±3 months post TIPS, the change rate of liver volume was significantly correlated with the change rate of the L3-SFA (*Figure 5C*), R^2=0.782, P<0.001.

Discussion

Liver volume plays an important role in patient prognosis. In a single-center study, Cohen *et al.* (24) described 68 patients who underwent cross-sectional imaging (CT/

MRI) to measure the pre-TIPS liver volume, and their linear measurement of liver volume proved to be less accurate than our method (25). Lopera *et al.* (26) conducted a retrospective study of 80 patients and analyzed the influence of liver volume on morbidity and mortality after TIPS; however, they did not describe changes in the liver after TIPS. In the present study, we analyzed changes in liver volume after TIPS and the influencing factors using an accurate volume measurement method. We found that the liver volume of most patients was decreased significantly at 2±1 months post TIPS and, despite a partial rebound at 9±3 months post TIPS, did not recover to the pre-TIPS volume. In a small number of patients, the liver volume was increased at 2±1 months, which was found to be predicted by a lower ALB level, a lower L3-SFA, and a higher degree of ascites by logistic regression. In addition, we measured the plain CT value of the liver in patients with increased liver volume after TIPS insertion and found that it was decreased significantly.

Portal vein embolization is clinically applied in patients with insufficient residual liver volume after major hepatectomy. Preoperative embolization of one portal vein can increase the blood perfusion and pressure of the contralateral portal vein to increase the residual liver volume (22,27,28). With the establishment of a direct channel

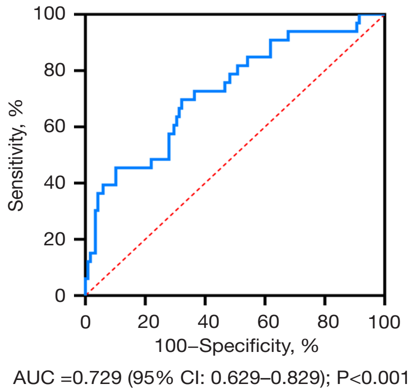

Figure 3 Receiver operating characteristic curve of the Logit(p). AUC, area under the curve; CI, confidence interval.

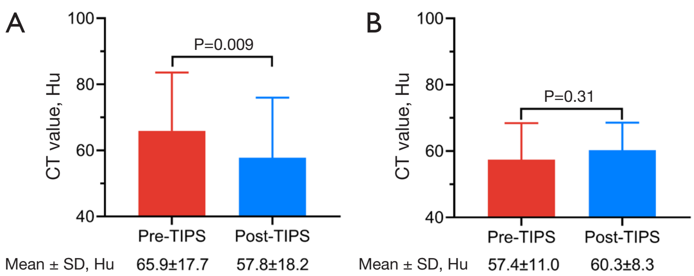

Figure 4 Changes in computed tomography value before and after transjugular intrahepatic portosystemic shunt insertion. (A) Changes in CT value before and after TIPS insertion in the increased liver volume group. (B) Changes in CT value before and after TIPS insertion in patients of the decreased liver volume group. TIPS, transjugular intrahepatic portosystemic shunt; CT, computed tomography; Hu, Hounsfield units.

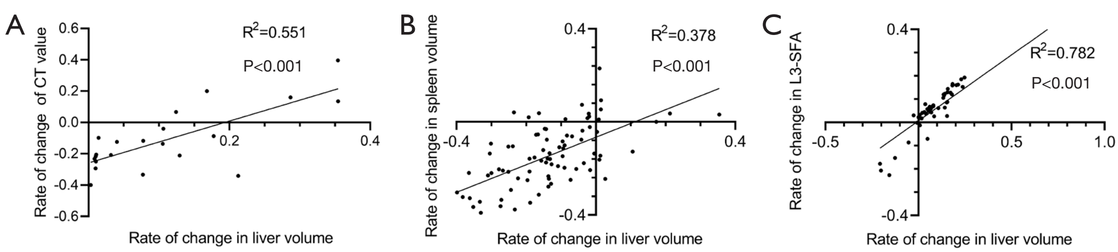

Figure 5 Correlation of liver volume change with other factors. (A) Correlation between liver volume change rate and CT value change rate at 2±1 months post TIPS. (B) Correlation between liver volume change rate and spleen volume change rate at 2±1 months post TIPS. (C) Correlation between liver volume change rate and L3-SFA change rate at 9±3 months post TIPS. TIPS, transjugular intrahepatic portosystemic shunt; CT, computed tomography; L3-SFA, lower subcutaneous fat area at L3.

between the hepatic vein and the portal vein, however, liver hemodynamics change and liver blood perfusion and portal venous pressure decrease, leading to a reduction in liver volume. Therefore, theoretically, liver volume should decrease after TIPS insertion. At the same time, a decrease in portal vein pressure leads to a decrease in spleen volume, which was confirmed by our observation from correlation analysis that the change rate of liver volume at 2±1 months post TIPS was significantly correlated with that of spleen volume. Of the patients enrolled in our study, 78.6% showed a decrease in liver volume after TIPS, but this decrease did not last for a long time. At 9±3 months post TIPS, the liver volume had rebounded to some degree, although it did not recover to its pre-TIPS level completely. The increase in liver volume observed in 21.4% of patients at 2±1 months post TIPS was found to be related to a lower ALB level, a lower L3-SFA, and a higher ascites degree. A previous study reported that the volume of small livers (<1,500 mL) continued to decrease over time after TIPS insertion (17). However, clinically, we found that the volume of the liver did not always decrease after TIPS, which deviates from the conclusion of that study. In actuality, the liver volume may decrease at first before recovering slightly.

Logistic regression showed that a lower ALB level, a lower L3-SFA, and a higher degree of ascites were all predictive factors for increased liver volume post TIPS. The level of ALB reflects the synthesis function of the liver; the L3-SFA reflects body fat, which can indirectly reflect the body's physical condition; and patients with grade 3 ascites tend to have a worse physical condition (29). Patients who have undergone TIPS often experience poor liver synthesis function, emaciation, and even sarcopenia due to long-term portal hypertension of cirrhosis (30). Cohen *et al.* (24) reported that the liver volume after TIPS had a certain compensatory capacity. In the subgroup of patients who had an increase in liver volume post TIPS, the baseline pre-TIPS liver volume was smaller and the synthetic function of the liver was poorer than that in the rest of the cohort. We therefore hypothesize that the post-TIPS increase in liver volume in this subgroup was compensatory, with the insertion of a TIPS permitting hemodynamic changes in response to poor synthetic function. Furthermore, in the increased liver volume subgroup, the removal of refractory ascites after TIPS may have reduced the pressure from ascites on the liver, which may have also led to the increase in liver volume. Besides, the liver volume in the increased liver volume group was smaller than that in the decreased liver volume group before TIPS insertion (1,038.3±268.4 *vs.* 1,139.8±343.5 cm^3).

We found that the CT value of the liver in the increased liver volume group was generally lower after TIPS than it was before TIPS insertion (57.8±18.2 *vs.* 65.9±17.7 Hu, P=0.009). This result suggested a decrease in liver density, which may be caused by an increase in fat components; however, there was no statistically significant change in CT value in the decreased group. Except for visceral fat, the rate of change in subcutaneous fat at 9±3 months post TIPS was significantly correlated with that in liver volume (R^2=0.782, P<0.001). There is a certain correlation between fat accumulation and an improvement in physical condition. Studies have confirmed that TIPS can reverse sarcopenia in patients with cirrhosis (31,32) and improve the physical condition of patients. Furthermore, L3-SMI, L3-SMA, and sarcopenia were shown to be significant in our univariate analysis. Therefore, the resolution of ascites and increase in fat might lead to liver enlargement.

There are some limitations to our study. Firstly, since it was a retrospective study, the results are inevitably biased. Secondly, the insufficient number of patients with complete follow-up records may have had a minor impact on the results. Moreover, no long-term clinical outcomes, such as patient morbidity and mortality, were analyzed in our study, and related research should be conducted in the future.

Conclusions

Liver volume was decreased at 2±1 months after TIPS and slightly increased at 9±3 months after TIPS, but did not recover to its pre-TIPS level completely. Baseline ALB, L3-SFA, and grade 3 ascites were associated with liver volume change after TIPS. A lower ALB level, a lower L3-SFA, and a higher degree of ascites were all predictors forincreased liver volume post TIPS.

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Footnote

Reporting Checklist: The authors have completed the STROBE reporting checklist. Available at https://qims.amegroups.com/article/view/10.21037/qims-22-482/rc

Conflicts of Interest: All authors have completed the ICMJE uniform disclosure form (available at https://qims.amegroups.com/article/view/10.21037/qims-22-482/coif). The authors have no conflicts of interest to declare.

Ethical Statement: The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. The study was conducted in accordance with the Declaration of Helsinki (as revised in 2013). The study was approved by the Ethics Committee of Wuhan Union Hospital, Tongji Medical College, Huazhong University of Science and Technology, and the requirement to obtain individual consent for this retrospective analysis was waived (No. 202201043).

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Supplementary

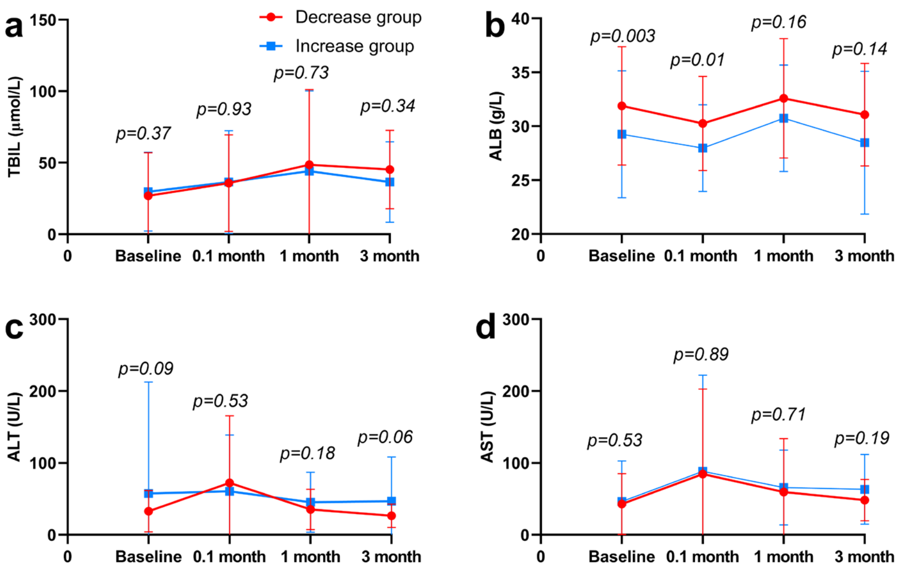

Figure S1 Changes in liver function after transjugular intrahepatic portosystemic shunt insertion. a, TBIL; b, ALB; c, ALT; d, AST. There was no significant difference in liver function between the increased liver volume and decreased liver volume groups before and after TIPS insertion. TIPS, transjugular intrahepatic portosystemic shunt; TBIL, total bilirubin; ALB, albumin; ALT, alanine aminotransferase; AST, aspartate aminotransferase.

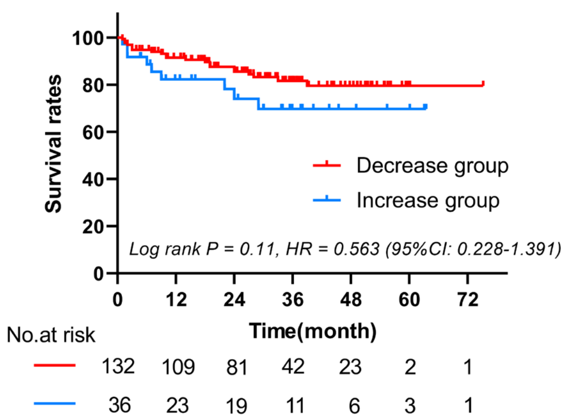

Figure S2 Cox survival analysis of the increased and decreased liver volume groups. Survival analysis showing a trend toward higher mortality in the increased liver volume group, but the difference between the two groups is without statistical significance due to the limited sample size. HR, hazard ratio; CI, confidence interval.

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