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ORIGINAL ARTICLE

Retrospective Study

Contrast enhanced computed tomography and reconstruction of hepatic vascular system for transjugular intrahepatic portal systemic shunt puncture path planning

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Abstract

AIM: To describe a method for the transjugular intrahepatic portal systemic shunt (TIPS) placement performed with the aid of contrast-enhanced computed tomography (CECT) and three-dimensional reconstructed vascular images (3D RVIs), and to assess its safety and effectiveness.

METHODS: Four hundred and ninety patients were treated with TIPS between January 2005 and December 2012. All patients underwent liver CECT and reconstruction of 3D RVIs of the right hepatic vein to portal vein (PV) prior to the operation. The 3D RVIs were carefully reviewed to plan the puncture path from the start to target points for needle pass through the PV in the TIPS procedure.

RESULTS: The improved TIPS procedure was successful in 483 (98.6%) of the 490 patients. The number of punctures attempted was one in 294 (60%) patients, 2 to 3 in 147 (30%) patients, 4 to 6 in 25 (5.1%) patients and more than 6 in 17 (3.5%) patients. Seven patients failed. Of the 490 patients, 12 had punctures into the artery, 15 into the bile duct, eight into the gallbladder, and 18 through the liver capsule. Analysis of the portograms from the 483 successful cases indicated that the puncture points were all located distally to the PV bifurcation on anteroposterior images, while the points were located proximally to the bifurcation in the three cases with intraabdominal bleeding. The complications included three cases of bleeding, of whom one died and two needed surgery.

CONCLUSION: Use of CECT and 3D RVIs to plan the puncture path for TIPS procedure is safe, simple and effective for clinical use.

Key words: Transjugular intrahepatic portal systemic shunt; Contrast-enhanced computed tomography; 3D vascular reconstruction; Interventional radiology

Core tip: Precise planning of puncture path is crucial for safe and effective transjugular intrahepatic portal systemic shunt (TIPS) placement. We have developed and applied an approach that combines contrast-enhanced computed tomography and reconstruction of hepatic vascular system in TIPS placement. Our retrospective study with 490 patients over a period of seven years shows that the improved TIPS procedure was successful in 98.6% of the patients, indicating that this method is safe, simple and effective for clinical use.

Qin JP, Tang SH, Jiang MD, He QW, Chen HB, Yao X, Zeng WZ, Gu M. Contrast enhanced computed tomography and reconstruction of hepatic vascular system for transjugular intrahepatic portal systemic shunt puncture path planning. *World J Gastroenterol* 2015; 21(32): 9623-9629 Available from: URL: http://www.wjgnet.com/1007-9327/full/v21/i32/9623.htm DOI: http://dx.doi.org/10.3748/wjg.v21.i32.9623

INTRODUCTION

China has a high prevalence rate of hepatitis B, and chronic hepatitis often results in hepatic cirrhosis, portal hypertension and other related complications. These diseases impose a heavy burden on the patient's family and the country[1,2]. Currently, liver transplantation is still limited in China, and the common therapeutic option is to manage the complications of hepatic cirrhosis, particularly to treat the rupture and bleeding due to esophageal varices resulting from portal hypertension and refractory ascites. Since the late 1980s when Rösch *et al*[3] and Rössle *et al*[4] first reported the clinical use of self-expandable metallic stents, transjugular intrahepatic portosystemic shunt (TIPS) has been increasingly used clinically with satisfactory results to treat cirrhotic portal hypertension and associated complications[4-8]. However, TIPS procedures are operationally complicated with many steps and technical challenges. One of the most important and critical steps is to precisely puncture the portal vein (PV) branch and to ensure that the target site is safe to puncture. Precise puncture into the PV branch is a prerequisite for successful operation, while the safety of the puncture point is critical to the safety of patients. For this reason, a large number of studies have been done to explore various methods that can improve the puncture accuracy. Although those studies have helped improve the TIPS techniques, continued improvement of puncture method is being pursued for better, simpler, and safer TIPS procedures with minimally invasion and reduced radiation exposure. Since 2005, our center has been using preoperative contrast-enhanced computed tomography (CECT) and three-dimensional reconstructed vascular images (3D RVIs) to plan and guide the puncture of the PV branch. The clinical outcomes have been satisfactory[9,10]. In this report, the technical details of the method are described and their safety and efficacy were analyzed retrospectively.

MATERIALS AND METHODS

Subjects

Between January 2005 and December 2012, 490 patients diagnosed with portal hypertension and hepatic cirrhosis underwent TIPS placement in our departments[4]. These patients were analyzed retrospectively. All patients for TIPS were selected according to the criteria of the American Hepatological Association for the clinical application of TIPS[11,12]. The study protocol was approved by the institutional ethics committee, and informed consent was obtained from all patients.

TIPS procedure

Before operation, the patients underwent CECT with an Aquilion One scanner (Toshiba, Japan) and the obtained imaging data were used to reconstruct three-dimensional (3D) right hepatic vein to PV images at the Vitrea workstation. The anatomical relationship between the right vein and PV was carefully reviewed to define the spatial relationship between the two puncture points to plan the PV puncture. In typical TIPS procedure, the point of origin is generally started from the right hepatic vein about 1.5 cm away from the confluence of the right hepatic vein to the inferior vena cava (IVC), while the target point is on the

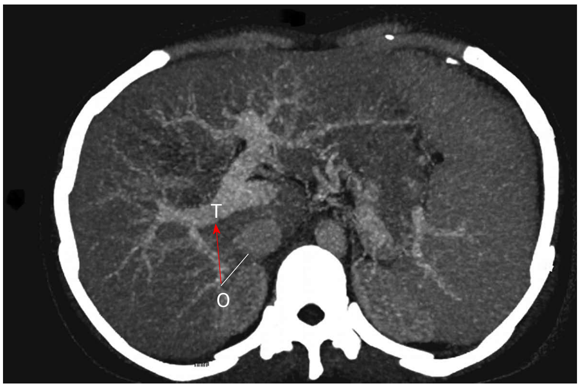

Figure 1 Axial distance between puncture point of origin (o) and target point (t) of the portal vein. Point of origin (o) is located about 1.5 cm (white line) from the confluence of the right hepatic vein to inferior vena cava, and the red arrow between the two points is the anterior-posterior distance of the puncture.

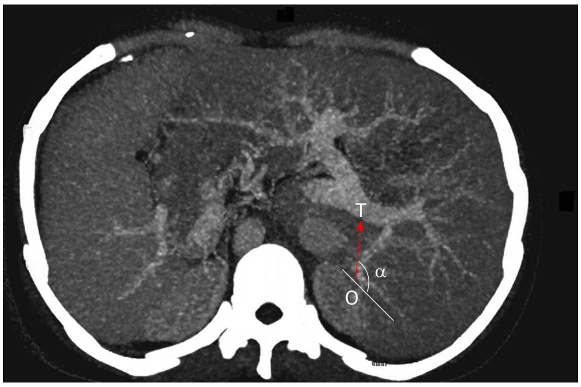

Figure 2 Determination of rotation angle for puncture set. Contrast-enhanced computed tomography image in Figure 1 is rotated 180 degrees, and the angle between the direction given by the extension line that links the two puncture points and direction of the right vein (red arrow) is the rotation angle (α) for the puncture set.

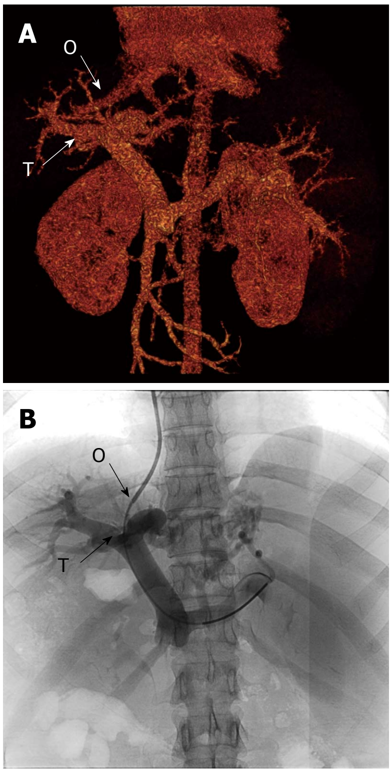

Figure 3 Comparison of preoperative three-dimensional reconstructed image of the portal vein system and direct portogram obtained with non-iodinated contrast medium (Iopamiro 370) after a successful portal vein puncture. A: Preoperative three-dimensional reconstructed vascular image; B: Direct portogram of the portal vein (PV) during a successful puncture. O: Puncture point of the right hepatic vein; T: Target point of the right PV branch.

trunk of the right PV. Thus, once the relationship between the desired start point and target point is adequately defined, the puncture can be achieved precisely. Therefore, the cephalad-caudal and anterior-posterior distances between the two puncture points and left or right position need to be determined. In our TIPS procedure, these distances were adequately determined based on the CECT and 3D RVIs. For the cephalad-caudal distance, we first located the slices of the axial CECT image with the intended puncture start and target points, and then calculated the distance by multiplying the number of slices between the two points and the thickness of the slice. For the anterior-posterior distance, a line was drawn between the desired point of origin and target point on the axial CECT image, and its length was measured (Figure 1). In addition to these distances, the rotation angle (α) of the puncture set was determined as follows: On the axial slice of the desired puncture point, a line was drawn between the point of origin and target point of the right PV trunk, and the direction of the line extending toward the abdomen was the direction of puncture (Figure 2). The image in Figure 1 was flipped horizontally by 180 degrees, and the angle between the direction given by the extension line that links the two puncture points and direction of the right hepatic vein was measured as rotation angle (α). Once these distances were determined, additional information regarding the spatial relationship between the two puncture points was obtained from the reconstructed venograms from coronal CECT (Figure 3A). We used all these parameters and the angle at which the right hepatic vein joins the IVC to adjust the tip angle of the puncture set and to set the counterclockwise rotation angle, as well as to plan puncture path for individual patients. Generally, the directions of the punctures were from left to right, anterior to posterior and cephalad to caudal. All angiographic studies and punctures were performed with the aid of an image-guided system (Innova 3100-IQ, GE, United States). To create the stunt, the Rösch-Uchida set (RUPS-100, COOK Company, United States) *via* the transjugular approach was inserted into IVC with the aid of a guidewire and advanced to the right hepatic vein. The puncture start point selected based on the above parameters was visualized by hand venography and the catheter was advanced to the target point of the PV branch. After entering the hepatic parenchyma, the

Table 1 Clinical data for 490 patients who underwent transjugular intrahepatic portal systemic shunt placement

Clinical factor	Number of patient
Gender	
Male/female	388/102
Age (mean ± SD)	48.2 ± 13.7
TIPS indication	
Upper gastrointestinal bleeding	440
Refractory ascites	22
Hepatorenal syndrome	20
Intractable pleural effusion	8
Cause of disease	
Hepatitis B virus associated cirrhosis	307
Hepatitis C virus associated cirrhosis	22
Alcoholic hepatic disease	52
Autoimmune hepatic disease	17
Hepatitis B virus infection combined with other factors[1]	78
Cirrhosis of unknown cause	14

[1]Other factors include alcohol consumption and schistosome infection.

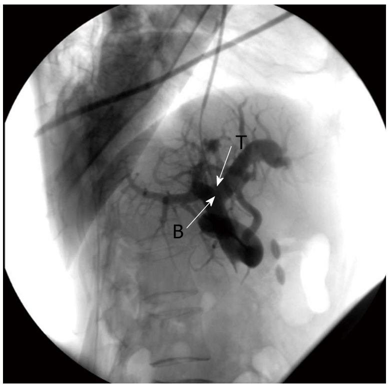

Figure 4 Portogram showing target point in transjugular intrahepatic portal systemic shunt puncture. The points were distal to the image bifurcation (T: Target point of the portal vein; B: The bifurcation).

needle was retrieved, leaving the 5F cannula in place. The cannula was then connected to a 5 mL syringe with 2 mL of heparin saline to aspire the blood. The color and pressure of the blood were used to judge if it was from the portal vein. Five milliliters of non-iodinated contrast medium (Iopamiro 370) was then slowly injected to visualize the PVs distal to the target point. If only one branch was seen, it indicated that the target point would be in the PV branch. If both right and left branches or/and the main trunk were seen, the puncture target point was expected to be near the PV bifurcation or in the PV trunk. Once the safety of the puncture target point was confirmed, the catheter was advanced to the trunk with the aid of the super tiff guidewire, leaving the 10F sheath in the trunk. Pressure measurements were then preformed and direct portography was made at lateral and anteroposterior positions to further confirm the safety. The collateral vessels that cause esophageal varices could be identified by direct PV angiography and embolized with steel spring and gelatin sponge. A balloon (measuring 8 mm in diameter) was inserted into the puncture tract to place a self-expandable metallic stent (measuring 8 mm in diameter). The patient was again measured for pressure and imaged at lateral and axial positions (Figure 3B).

RESULTS

Clinical data

A total of 490 patients with hepatic cirrhosis and portal hypertension underwent TIPS placement in our departments between January 2005 and December 2012[9]. All patients underwent preoperative CECT of the liver and the imaging data were used to reconstruct the 3D right hepatic to portal venograms. Their clinical data are shown in Table 1.

Outcomes of TIPS procedure

Out of the 490 patients, 483 (98.6%) had successful portosystemic shunt creation. The TIPS procedure failed in seven patients. In the seven patients, the punctures caused hepatic subcapsular hematoma, as revealed by intraoperative angiography, and stopping of the TIPS procedure in two patients, portal vein thrombosis blocked the guidewire to enter the PV trunk in two patients, and abdominal bleeding developed in three patients (one died, and two survived after surgical repair or placement of covered stent to stop bleeding). With regards to the number of punctures attempted, the number was one in 294 (60%) patients, 2 to 3 in 147 (30%) patients, 4 to 6 in 25 (5.1%), and more than 6 in 17 (3.5%) patients. During the procedure, all collateral vessels that caused esophageal varices were embolized.

Puncture safety

In 455 (92.8%) patients, the points of origin were selected near the confluence of the right hepatic vein where it joins the IVC and the target points were the right hepatic vein trunk. In the remaining 35 (7.2%) patients, the target points were the left branch of PV; some of these patients had very small right portal vein branches that were not suitable for puncture and the other had thrombus in the right portal veins. In all 490 patients, the target points were all distal to the imaged bifurcation of the right veins. For the three patients with intraabdominal bleeding, their target points were in the left vein branches, and were all near the bifurcation of the PV (Figure 4). When the tracts were dilated with a balloon, they bled.

Puncture-related complications

Three patients had intraoperative intraabdominal bleeding and two had hepatic subcapsular hematoma. Other complications included puncture into the hepatic artery, biliary tract, gallbladder, and through liver capsule, as revealed by leaking of contrast agents (Table 2). The patients were asymptomatic following

Table 2 Incidence of complications related to the transjugular intrahepatic portal systemic shunt procedure *n* (%)

Complication	Number
Intraabdominal bleeding	3 (0.6)
Hepatic subcapsular hematoma	2 (0.4)
Puncture into	
biliary tract	15 (3.1)
gallbladder	8 (1.6)
hepatic artery	12 (2.4)
Puncture through liver capsule	18 (3.7)

rapid needle removal.

DISCUSSION

In TIPS procedures, various methods have been attempted to improve the accuracy and safety of PV puncture. Warner *et al*[13] used a radiopaque marker in the hepatic artery to localize the PV during TIPS for better needle guidance. Yamagami *et al*[14] and Matsui *et al*[15] reported the use of artery-targeting guidewires to increase safety and efficacy of TIPS. The fluoroscopic landmarks in the hepatic artery or vein can be beneficial for the catheterization, guidance of the guidewire, tract balloon dilation, and stent placement. However, the blind passage of puncture needle from the hepatic vein to portal venous system can be difficult, especially for hepatic cirrhosis patients with disordered hepatic anatomy. In addition, ultrasound- and intravascular ultrasound-guided punctures have been reported[16-20]. These methods are noninvasive, real-time, readily available, relatively fast, and have less expense, and less radiation exposure. However, sonographic imaging might be obscured by the ascites and bowel gas in the peritoneal cavity. Magnetic resonance imaging (MRI) is believed to be a relatively ideal method for hepatic and portal vascular imaging, with the advantages of cross-sectional nature, no radioactivity, high sensitivity to vascular flow, and soft-tissue visualization, especially for complex interventions[21]. However, MRI imaging needs relatively long acquisition and display time, which can be influenced by the respiratory motion and surgical metallic devices in patients. The hepatic wedged venography is one of the most frequently used methods for portography, with CO_2 used as the contrast medium[22-24]. This method, without additional invasive access, can produce low-cost, real-time, fast and good images with minimal extra equipment. However, the imaging resolution of CO_2 is lower compared with those obtained with iodinated agents. Due to the low viscosity, CO_2 mainly diffuses to the hepatic veins and branches of the PV, not to the portal vein trunks, resulting in poor ability to image the PV and trunks. The guided methods reported so far have significantly contributed to the improvement of accuracy of TIPS puncture. However, in some of the methods, extra equipment is needed, such as ultrasound, and magnetic resonance imaging machine, while others are invasive, such as placement of intravascular markers and indirect portal venography, and may lead to complications such as bleeding, local and abdominal hematoma, femoral artery pseudoaneurysm, femoral arterial to venous fistula and high vagal reflex, or even death caused by retroperitoneal hematoma[25-27]. Indirect angiography *via* the superior mesenteric artery increases the amount of contrast medium used in the surgery. This not only increases the risk of traumatic injury to organs, particularly the kidney, but also radiation exposure. Patients need to stay supine after angiography, which is inconvenient for patients. As an effort to improve the effectiveness and safety of TIPS procedure, we started to use CECT imaging to plan and guide the puncture path in 2005, and have since been satisfactory with this method[9]. Between 2005 and 2012, the method has been applied to 490 patients. In 98.6% of the patients the stunts were satisfactorily created between the hepatic vein and portal vein. Among the seven who failed, three developed intraabdominal bleeding and two had subcapsular hematoma. The two patients completed the surgery in later times. The remaining two had portal vein thrombosis that prevented the guidewire from entering the PV trunk. Although the reported success rates of indirect portography-, CT- and ultrasound-guided TIPS are nearly 100%[13,24], the number of cases in those studies is much less than that of our study. Furthermore, there are also differences in the case selection in those studies. On the other hand, the seven patients who failed in our study were highly difficult patients with significantly reduced sized liver and shortened cephalad-caudal distance. Therefore the failure is not due to the puncture planning method. In 3D ultrasound-guided needle puncture, the single-passage success rate was shown to be 40% and the rate of over 10 passages was 10%[28]. Using our method, the successful rates for single, 2 to 3, 4 to 6 and more than six needle passages were 60.0%, 29.2% 4.9% and 3.5%, respectively. Therefore, compared with earlier methods, our method has certain advantages and is able to reduce the risk of related complications. In our operation, a few of patients were attempted for more than three needle passages before success. This is partially because some of these patients had relatively large cephalad-caudal and anterior-posterior distances between the right veins and PV branches. This resulted in a puncture distance that is too large for the puncture set (the Rösch-Uchida set RUPS-100) used in the procedure, whose maximal puncture distance is 5.2 cm. For patients with a significantly reduced sized liver, the cephalad-caudal distance between the right vein and PV branch is very short. This would require a greater needle rotating angle, making the puncture more difficult. Our experience also shows that when the left to right distance between the start and intended target point is too large, it will also make the puncture difficult. Since the spatial relationships between the right vein and PV branch in individual patients with different degrees of hepatic cirrhosis are highly variable, careful review of the CECT images and 3D RVIs can effectively help improve the puncture accuracy. As shown in an earlier study[9], the spatial relationship between the right hepatic vein and the PV branch is not affected by sex, age, ascites and the Child score. Therefore, the PV puncture can be planned with a full understanding of the patient's anatomic structures between the right hepatic and PV. The tip curve and rotating angle can be adjusted based on the spatial parameters that measure the cephalad-caudal and anterior-posterior distances between the start point and intended target point. Our clinical data show that CECT and 3D RVIs can provide accurate 3D relationship between the two puncture points and can be used to successfully plan the puncture path. In fact, the direct portogram in successful TIPS patients and preoperatively reconstructed 3D right hepatic vein to PV image are fully consistent (Figure 3), indicating that the CECT and 3D RVIs can be used effectively to plan the puncture. Using this method, fewer equipment is needed during the procedure for the needle guidance and the use of indirect portography is reduced. Therefore, TIPS procedure can be performed *via* the jugular vein approach with fewer steps, thus reducing complications and patient costs. Access to the PV is important for portosystemic shunt creation. The safety of the target point is the key to the success of operation. If wrongly placed, the puncture would result in intraabdominal bleeding, which often endangers the patient's life. So far, the data used to determine the anatomical bifurcation of the PV and puncture point safety are based on autopsy studies[29] and the puncture point that is 2 cm above the bifurcation is considered safe. Our retrospective analysis of 490 TIPS patients based on their direct portograms showed that all successful puncture points were distal to the bifurcation on the portograms (Figure 3). For the three patients with intraabdominal bleeding after the balloon inflation, their livers were remarkably atrophied with increased hepatic fissure and the target points were located on the left branch of the PV, close to the bifurcation[30]. Due to liver atrophy, the target points were in hepatic fissure. Once the balloon was inflated, it resulted in bleeding. In TIPS procedures, no matter which guiding method is used, it is not possible to completely avoid misplaced puncture into the bile duct, gallbladder, liver and hepatic artery. This is because the guidance technique is still not precise enough, and because of the anatomical concomitance of PV branches with the bile duct and hepatic artery. Furthermore, most of the TIPS patients in China have hepatitis B virus associated cirrhosis. They often have remarkable parenchymal atrophy with increased liver hardness. Therefore, the puncture is more difficult to preform by using the most commonly used Rösch-Uchida transjugular liver access set RUPS-100, which uses a 5-Fr catheter, a trocar stylet (diameter 0.038 inch) and a spring tip. In puncture operation, the front part of the stylet assembly is inserted into the hepatic parenchyma toward the portal system, the stylet is then removed from the catheter and the cannula is retrieved to the PV branch. If puncture is misplaced, the catheter can be removed immediately without traumatic injury to the patient. However, if the stylet is advanced too deep into the right hepatic vein, it is more likely to puncture the gallbladder or puncture through the liver capsule. Of course, these complications can be reduced with improvement of the operator's skill.

In summary, we describe here a method for puncture planning and guidance in TIPS procedure using CECT and 3D reconstruction of the hepatic vascular system. Our analysis is based on the stunt creation in a large sample of patients and shows that this method is effective, safe, simple, and conducive to clinical use.

COMMENTS

Background

The transjugular intrahepatic portosystemic shunt (TIPS) has been increasingly used clinically with satisfactory results to treat cirrhotic portal hypertension and associated complications. However, TIPS procedures are operationally complicated with many steps and technical challenges. One of the most important and critical steps is to precisely puncture the portal vein (PV) branch and to ensure that the target site is safe to puncture. Precise puncture into the PV branch is a prerequisite for successful operation.

Research frontiers

The center has been using preoperative contrast-enhanced computed tomography (CECT) and three-dimensional reconstructed vascular images (3D RVIs) to plan and guide the puncture of PV branch.

Innovations and breakthroughs

Compared with earlier methods, our method has certain advantages and is able to reduce the risk of related complications. Careful review of the CECT images and 3D RVIs can effectively help improve the puncture accuracy. Using this method, fewer equipment is needed during the procedure for the needle guidance and the use of indirect portography is reduced.

Applications

The authors describe here a method for puncture planning and guidance which can be used in TIPS procedures using CECT and three-dimensional reconstruction of the hepatic vascular system.

Peer-review

In this manuscript, the authors report the results of their work in which the authors have developed and applied an approach that combines CECT and reconstructed vascular systems in the TIPS placement. The authors report that the application of the technique over a period of seven years was safe, simple and effective for clinical use. Obviously, the results would be of interest to medical researchers and physicians conducting TIPS placements.

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