MR Evaluation of Portal Hypertensive Collateral Shunting Vessels for Predicting Outcome after Transjugular Intrahepatic Portosystemic Shunt

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Purpose: We assessed whether magnetic resonance (MR) imaging evaluation of portosystemic collateral shunts can aid prediction of therapeutic effectiveness and complications after creation of a transjugular portosystemic shunt (TIPS), and technical difficulty during the TIPS procedure.

Materials and Methods: We retrospectively reviewed 32 patients (27 men, 5 women; mean age, 56.4 years) who underwent TIPS creation following gadolinium-enhanced MR examination. We measured the diameters of pre-existing portosystemic collateral shunting vessels, added the measurements together to generate a shunting collateral score for each patient, and divided patients into 2 groups by score of 4 or greater or less than 4. We then compared therapeutic effectiveness, technical difficulty and complications of the TIPS procedure, and portal venous (PV) pressure, PV-inferior vena cava (IVC) pressure gradient, and PV diameter between the groups.

Results: The patients with a pre-existing large portosystemic shunt showed insignificant trends toward higher technical difficulty of the shunt procedure and rate of shunt dysfunction. The 2 groups showed no significant difference in early mortality rate, onset or worsening rate of hepatic encephalopathy after TIPS creation, PV pressure, PV-IVC pressure gradient, or PV diameter.

Conclusion: Gadolinium-enhanced MR imaging may help in predicting technical difficulty and complications of TIPS.

Keywords: abdomen, cirrhosis, magnetic resonance imaging, portal hypertension, transjugular portosystemic shunt

Introduction

The transjugular intrahepatic portosystemic shunt (TIPS) was developed in the 1980s to treat complications of cirrhotic portal hypertension, such as variceal bleeding, refractory ascites, and hepatic hydrothorax. This percutaneous technique decompresses the portal vessel using minimally invasive interventional radiologic procedures to create a communication between a central hepatic vein and an intrahepatic branch of the portal vein.

However, selection of patients remains controversial. Recent reports indicate one-year mortality rates between 10% to 54%1-4 and 30-day mortality as high as 55%5; various complications after TIPS creation, such as shunt dysfunction and onset or worsening of hepatic encephalopathy,1-4 can worsen patient quality of life (QOL); and technical difficulties in the TIPS procedure differ from patient to patient.

Many parameters and criteria, such as the Child-Pugh classification and others, have been considered for patient selection.1,2,6-8 However, these parameters are used mainly to predict long-term survival rather than the therapeutic effectiveness of TIPS and complications of the procedure, such as onset or worsening of hepatic encephalopathy, technical difficulty, or shunt dysfunction.

The usefulness of magnetic resonance (MR) imag-
ing for evaluating cirrhosis and its complications, including MR detailing of the portal venous system, such as portal occlusion, thrombosis, or portosystemic shunting collaterals, has been described.9–14 We aimed to assess whether MR imaging evaluation of portosystemic collateral shunts can be used to predict therapeutic effectiveness of, complications after, and technical difficulty during TIPS creation.

Materials and Methods

Patients

Our institutional review board approved this retrospective patient study and waived the requirement for informed patient consent. We retrospectively reviewed records of 32 patients (27 men, 5 women; aged 27 to 84 years; mean, 56.4 years) admitted to our institution for treatment with TIPS preceded by gadolinium-enhanced MR examination. The patients were treated by TIPS for esophageal varices refractory to endoscopic therapy (n = 11), gastric varices (n = 4), gastroesophageal varices (n = 1), mesenteric varices (n = 1), portal hypertensive gastropathy (n = 2), stomal bleeding (n = 1), refractory ascites (n = 11), and hepatic hydrothorax (n = 1), all of which resulted from portal hypertension. Seven of the 32 were in unstable hemodynamic state and underwent emergent TIPS. Cause of portal hypertension was alcohol-related cirrhosis in 22 patients, chronic hepatitis C in ten, primary biliary cirrhosis in two, chronic hepatitis B in one, autoimmune hepatitis in one, cystinosis in one, and cryptogenic in four. Eight patients had 2 causes. Histological diagnosis of cirrhosis was obtained in 7 patients and of cystinosis in one. Of all patients, five were classified as Child-Pugh Class A, 13 were B, and 13 were C. One patient could not be classified because of lack of record. Twenty-three patients were treated with vasoactive drugs and/or diuretics prior to TIPS creation.

TIPS

TIPS creation was performed in all patients as previously described1–4,15 and included transjugular catheterization of the portal vein. The portal vein was punctured, pressures measured in its main stem and the inferior vena cava above the hepatic veins, the needle track dilated using a balloon catheter, and one to 3 stents (Wallstent; Boston Scientific, Natick, MA, USA) placed. Balloon catheter dilation was employed to adjust the tract to achieve a post-procedural portal venous (PV)-inferior vena cava (IVC) pressure gradient equal to 12 mmHg or less and expanded to approximately 10 mm in most patients. Four patients also underwent embolization of gastric or mesenteric veins using metallic coils.

Outcomes were reviewed on patient charts; technical difficulty was recorded when TIPS creation could not be completed during one procedural session; and major complications15 during TIPS procedures were recorded. Hemodynamic success was defined as a portosystemic pressure gradient equal to 12 mmHg or less after TIPS.15 Therapeutic success was defined as immediate homeostasis for variceal or gastrointestinal mucosal bleeding or reduced frequency of paracentesis for ascites or hydrothorax. Early mortality was evaluated by patient death within 30 days after TIPS and recorded on TIPS procedures, body coils for signal transmission, and phased-array multicoils for the body for reception. Gadolinium-enhanced biphasic MR images were obtained in the axial plane using 5-mm section thickness with 50% overlap via zero fill interpolation, 320-mm field of view, 256 × 192 matrix size, and 190- to 240-mm slab thickness (coverage in Z axis direction) to cover the entire upper abdomen. Three-dimensional enhanced fast-gradient-echo (3D-EFGRE) sequence parameters were repetition time (TR), 4 to 7 ms; echo time (TE), 1.4 to 1.8 ms; flip angle, 12°; signal acquired, 0.6 with half-Fourier technique; and 23-s breath-hold acquisition time in each phase. A frequency selective fat inversion nulling technique, spectral inversion at lipids (SPECIAL), was used.

Prior to imaging, patients received antecubital intravenous bolus injection of 0.1 mmol/kg of gadopentetate dimeglumine (Magnevist; Berlex Laboratories, Wayne, NJ, USA) delivered at 2 mL/s and flushed by 20 mL of sterile saline solution. The delay between injection and first scan, which represented the hepatic arterial phase, was determined by injecting a 2-mL test bolus followed by 20-mL saline flush. The delay between the first and second scan, which represented the portal venous phase, was determined by a brief rest period between suspended respirations of about 15 s. In most cases, contrast material and saline solution flush were administered using a power injector. In each
patient, all images were obtained in relaxed end-expiratory phase with breath-hold technique. Mean time between MR imaging and TIPS was 74.4 days (range, one to 330 days).

Image analysis

Two experienced abdominal radiologists blinded to the results of the TIPS procedure reviewed the images at a picture archiving and communication system (PACS) workstation (Canon, Los Angeles, CA, USA) and evaluated PV and pre-existing portosystemic shunting collaterals caused by portal hypertension, such as left gastric vein, paraumbilical vein, gastrorenal shunt, splenorenal shunt, or mesenteric varices. The same radiologists measured the short-axis diameters of the main stem of the PV and portosystemic shunting collaterals on the axial MR images. The PV was measured along the hepatoduodenal ligament approximately halfway between the venous confluence and portal bifurcation. The shunting collaterals were measured at the sites of maximum diameter.

The 2 radiologists graded each portosystemic shunting collateral by consensus using a system shown in Table 1; severity was evaluated using a sum of the scores, referred to as shunting collateral score. The grading system was created considering total area of shunting collaterals. Left gastric and paraumbilical veins, gastrorenal and splenorenal shunts, and mesenteric varices were selected for measurement to avoid overestimation of the same shunting vessels, such as the left gastric vein and esophageal varices or posterior or short gastric veins and gastrorenal shunt (Fig. 1). Figure 2 shows an example of grading.

Finally, we divided the patients into 2 groups according to their shunting collateral scores. Those

| Diameter | Grade |
|----------|-------|
| < 2 mm   | 0     |
| ≥ 2 mm, ≤ 7 mm | 1     |
| ≥ 8 mm, ≤ 10 mm | 2     |
| ≥ 11 mm, ≤ 12 mm | 3     |
| ≥ 13 mm, ≤ 14 mm | 4     |
| 15 mm    | 5     |
| ≥ 16 mm, ≤ 17 mm | 6     |
| 18 mm    | 7     |
| ≥ 19 mm, ≤ 20 mm | 8     |

Fig. 1. Schema of dominant portosystemic shunting vessels and measurement sites. Bars indicate the measurement sites. EV, esophageal varices; GR, gastrorenal; GV, gastric varices; PV, portal vein; SR, splenorenal.
Fig. 2. A 53-year-old man with bleeding esophageal varices refractory to endoscopic therapies. Paraumbilical (A) and left gastric (B) veins and gastrorenal shunt (C) were detected as pre-existing portosystemic shunting collateral vessels. The diameters were measured. Shunting collateral scores for each vessel were one for paraumbilical vein, 2 for left gastric vein, and 4 for gastrorenal shunt. The sum of the scores (shunting collateral score) for this patient was seven. He was assigned to the “pre-existing large portosystemic shunting collateral group.” The diameter of the portal vein was also measured (D).

with a score of 4 or greater were assigned to the group with pre-existing large portosystemic shunting collateral, and the others were assigned to the group with small or no pre-existing portosystemic shunt (Table 2). This cut-off value was set based on results of previous reports.16–20

Statistical analysis
We performed statistical analysis using statistical analysis software (StatView version 5.0, SAS, Cary, NC, USA); compared mean age, Child-Pugh score, PV pressure, PV-IVC pressure gradient, post-TIPS pressure gradient, or PV diameter between the 2 groups using unpaired t test; and compared sex, emergent case number, or therapeutic success, early mortality, onset or worsening of hepatic encephalopathy, technical difficulty, or shunt dysfunction rates after TIPS using Fisher’s exact probability test. Quantitative variables were expressed as mean ± standard deviation (SD), and statistical significance was established as $P<0.05$.

Results
The TIPS procedure was completed successfully in all patients. In 7 patients, TIPS was performed emergently because of bleeding refractory to medication or endoscopic therapies. Hemodynamic success was obtained in 31 patients. In one patient, post-TIPS pressure gradient was 13 mmHg. Major complications during TIPS procedures were not recorded. PV pressure was not recorded in 15 patients, and PV-IVC pressure gradients were not recorded in 11 patients. Therapy was successful in 12 patients. Follow-up ranged from one day to 84 months (mean, 10.2 months). Two patients subsequently underwent liver transplant. Nine patients died after TIPS. Three died from rebleeding and in-
Table 2. Patient characteristics, image findings, measurement results during TIPS and outcomes after TIPS in each group

|                          | With large pre-existing portosystemic shunt (n = 10) | None or with small pre-existing portosystemic shunt (n = 22) | P value |
|--------------------------|-----------------------------------------------------|----------------------------------------------------------|---------|
| Age                      | 53.7 ± 10.0                                         | 57.6 ± 12.3                                              | 0.39    |
| Sex                      | 10 men                                              | 17 men, 5 women                                          | 0.16    |
| Cause of portal hypertension | alcoholic, 9; cryptogenic, 1; hepatitis B, 1; hepatitis C, 4 | alcoholic, 13; AIH, 1; cystinosis, 1; hepatitis C, 6; PBC, 2; cryptogenic, 3 | 0.64    |
| Child-Pugh score         | 8.7 ± 2.5 (n = 10)                                  | 9.0 ± 1.6 (n = 21)                                       |         |
| Reason for TIPS          | AS, 1; EV, 6; GV, 2; PHG, 1                         | AS, 10; EV, 6; GV, 2; GEV, 1; MV, 1; HH, 1; PHG, 1; SB, 1 |         |
| Emergent cases           | 4/10 (40.0%)                                        | 3/22 (13.6%)                                             | 0.17    |
| PV pressure (mmHg)       | 36.0 ± 11.5 (n = 5)                                 | 33.9 ± 8.9 (n = 12)                                      | 0.69    |
| PV-IVC pressure gradients (mmHg) | 23.8 ± 8.0 (n = 5)                           | 21.6 ± 9.4 (n = 16)                                      | 0.72    |
| Post TIPS pressure gradients (mmHg) | 6.4 ± 2.3 (n = 10)                        | 8.0 ± 2.4 (n = 22)                                       | 0.10    |
| PV diameter (mm)         | 13.7 ± 3.4                                          | 14.8 ± 3.1                                               | 0.35    |
| Therapeutic success      | 7/10 (70.0%)                                         | 13/22 (59.1%)                                            | 0.70    |
| Early mortality          | 2/10 (20.0%)                                         | 5/22 (22.7%)                                             | >0.99   |
| Onset or worsening of hepatic encephalopathy after TIPS | 4/10 (40.0%)                               | 7/22 (31.8%)                                             | 0.70    |
| Technical difficulty     | 4/10 (40.0%)                                         | 2/22 (9.1%)                                              | 0.06    |
| TIPS dysfunction         | 6/10 (60.0%)                                         | 7/22 (31.8%)                                             | 0.24    |

AIH, autoimmune hepatitis; AS, ascites; EV, esophageal varices; GEV: gastroesophageal varices, GV, gastric varices; HH, hepatic hydrothorax; IVC, inferior vena cava; MV, mesenteric varices; PBC, primary biliary cirrhosis; PHG, portal hypertensive gastropathy; PV, portal vein; SB, stomal bleeding; TIPS, transjugular portosystemic shunt

Infection, two from liver and renal failure, two from liver failure and infection, one from rebleeding, and one from renal failure (range, one day to 20 months; mean, 3.6 months). Seven patients died soon after TIPS. Onset or worsening of hepatic encephalopathy was recorded in 11 patients. Technical difficulty was recorded in 6 patients. Hepatic veins could not be selected in 2 patients, and PV could not be cannulated in four. TIPS dysfunction was recorded in 13 patients. Mean time between TIPS and occurrence of shunt dysfunction was 124.9 days (range, 7 to 401 days).

The mean shunting collateral score was 2.8 (range, 0 to 9). The patients classified with pre-existing large portosystemic shunt showed non-significant trends toward higher technical difficulty and rate of shunt dysfunction. The 2 groups showed no significant difference in early mortality rate, onset or worsening rate of hepatic encephalopathy after TIPS, PV pressure, PV-IVC pressure gradient, or PV diameter.

Discussion

Suboptimal patient selection affected early high mortality following TIPS creation. Death following TIPS usually results from the progression of liver disease, probably by decreased hepatopetal portal blood flow, rather than from a complication of the TIPS procedure itself. Many parameters and criteria, such as the Child-Pugh and other classifications, have been considered for patient selection but without consensus. Shunt dysfunction occurs in 10% to 78% and onset or worsening of hepatic encephalopathy, in 10% to 44%. Technical difficulty in the TIPS procedure differs from patient to patient and may be caused by narrowing of the access or target vessels, i.e., hepatic or portal veins, or distortion of the liver due to cirrhosis. Prediction of complications during or after TIPS could reduce medical costs and improve patients' QOL. Preprocedural cross-sectional imaging of the liver and portal system can detect important contraindications to TIPS placement, such as multiple or huge hepatic cysts or hepatocellular carcinomas or obstruction or thrombosis of the portal or hepatic veins.
Many researchers have investigated the relationships between diameter of the portal vein and portal pressure, flow direction, development of the shunting vessels, diameter of the shunting vessels and gastroesophageal bleeding, or onset of encephalopathy. Ito and associates recently reported decreased diameter and hepatopetal flow of the left gastric vein and the presence of non-variceal portosystemic shunt as predictive factors for variceal relapse after endoscopic therapies. These findings suggest that measurements of portal system and portosystemic shunting collateral diameters may be useful to guide management of patients with portal hypertension.

We found that patients with a pre-existing large portosystemic shunt showed non-significant trends toward higher technical difficulty and rate of shunt dysfunction, possibly caused by decreased hepatopetal portal blood flow. Although we did not evaluate the diameters of the portal branches or hepatic veins, their smaller diameters resulting from decreased portal blood flow in patients with large shunts may complicate the TIPS procedure and jeopardize shunt patency. In such a patient, preoperative assessments of related vasculatures should be performed precisely as far as possible, and image guidance using computed tomography or ultrasonography should be considered in addition to routine fluoroscopy guidance during procedures. Shunt patency should also be carefully observed after procedures.

The 2 groups in our study were not significantly different in PV pressure, PV-IVC pressure gradient, PV diameter, or therapeutic success rate. Our results suggested that development of collateral shunts cannot be used to predict PV pressure, PV-IVC pressure gradient, or the rate of therapeutic success of TIPS. Our results concerning PV diameter are similar to those of Lafortune’s conventional angiographic study but contrary to those of Brancatelli and colleagues, who evaluated only spleno-renal shunt and patients with portal complications, such as thrombosis or sclerosis. This discrepancy may be explained by the differences in study design and population.

The portal veins and portosystemic shunts can be evaluated using other cross-sectional imaging modalities and by CT, with its higher spatial resolution and larger craniocaudal coverage. However, the toxicity of contrast media to renal function remains an issue for both CT and MR imaging. Recently developed non-contrast-enhanced MR imaging sequences, such as true-fast imaging steady-state precession (FISP) technique, permit visualization of abdominal vessels with short acquisition time and high signal-to-noise ratio. These new techniques can make MR examinations more suitable for patients with renal dysfunction, which is often associated with portal hypertension. Ultrasonography (US) can also be used to evaluate the portal system. However, its attenuation of ultrasound waves, especially in patients with severely atrophic liver or massive ascites, makes evaluation of deep or small portosystemic shunts difficult; US cannot indicate accurate maximum or minimum diameters of the portal vessels; and the examination depends greatly on the operator’s skill.

Our study has several limitations. Our small sample size precluded our finding statistical significance. We evaluated patients with various diseases and various symptoms caused by portal hypertension, but further studies are needed that are restricted to one disease or symptom, such as ascites or bleeding esophageal varices. As well, we evaluated only initial results and did not compare MR findings with long-term results, but TIPS is one of several conservative treatments whose long-term outcome might be affected by various factors, such as the patient’s systemic conditions and other coexisting diseases, so the predictive effectiveness of TIPS should take into consideration both initial and long-term results. MR imaging and TIPS creation were also not immediately contemporaneous in some cases. In addition, we analyzed only collateral shunting vessels in the upper abdominal area, and lack of information in the lower abdomen may lead to underestimation of blood flow in shunting vessels. Finally, we used only bare stents in our patients, but improved patency and clinical success rates have been reported recently using stents with polytetrafluoroethylene.

Conclusion

Gadolinium-enhanced MR imaging may help predict technical difficulty and complications of TIPS, but a larger series with more refined patient selection is required to confirm this.

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