Application of transmesenteric vein extrahepatic portosystemic shunt in treatment of symptomatic portal hypertension with cavernous transformation of portal vein

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ABSTRACT

Purpose: To evaluate the feasibility and efficacy of a transmesenteric vein extrahepatic portosystemic shunt (TmEPS) for the treatment of cavernous transformation of the portal vein (CTPV).
Materials and methods: The clinical data of 20 patients with CTPV who underwent TmEPS between December 2020 and January 2022 at Henan Provincial People's Hospital were retrospectively collected. The superior mesenteric vein (SMV) trunk was patent or partially occluded in these patients. An extrahepatic portosystemic shunt between the inferior vena cava and the SMV was established using a stent graft through an infraumbilical median longitudinal mini-laparotomy. The technical success, efficacy, and complication rates were evaluated, and the pre- and postoperative SMV pressures were compared. Patients' clinical outcomes and shunt patency were assessed.
Results: TmEPS was successfully performed in 20 patients. The initial puncture success rate of the balloon-assisted puncture technique is 95%. The mean SMV pressure decreased from 29.1 ± 2.9 mmHg to 15.6 ± 3.3 mmHg (p < 0.001). All symptoms of portal hypertension resolved. No fatal procedural complications occurred. During the follow-up period, hepatic encephalopathy occurred in two patients. The remaining patients remained asymptomatic. All shunts were patent.
Conclusions: TmEPS is a feasible, safe, and effective treatment option for patients with CTPV.

1. Introduction

Acute and chronic portal vein thrombosis (PVT) is a fundamental cause of pre-hepatic portal hypertension. The prevalence of PVT in cirrhosis, reportedly 2–40%, increases with liver disease severity.[1,2] Splenectomy can result in a 10-fold increased risk of developing PVT.[3] In patients with an occluded portal vein caused by PVT, collateral circulation is built around the venous thrombus and cavernous transformation of the portal vein (CTPV) occurs. CTPV has a variety of clinical manifestations ranging from asymptomatic to life-threatening, such as gastroesophageal variceal bleeding, ascites and hypersplenism.[4] Surgical portosystemic shunts and meso-Rex bypass effectively relieve portal hypertension. However, surgical trauma and technical challenge limit the clinical application of these surgical techniques.[5] CTPV was previously considered a contraindication for transjugular intrahepatic portosystemic shunt (TIPS); however, recent studies demonstrated the effectiveness of TIPS for CTPV.[6–8] Chen et al. reported a success rate of 77.8%,[9] while Luo et al. reported that the success rate of percutaneous transhepatic and intrahepatic portosystemic shunts could reach 91.7%.[10] However, CTPV increases the technical difficulty of TIPS. Sun et al. reported that the success rate of TIPS was significantly higher in patients with versus without CTPV (68.0% vs. 92.8%, respectively; p < 0.001).[11]

To improve the success rate and simplify the procedure, we applied the transmesenteric vein extrahepatic portosystemic shunt (TmEPS) to treat patients with CTPV. The present study reports the technical details and short-term results of TmEPS.
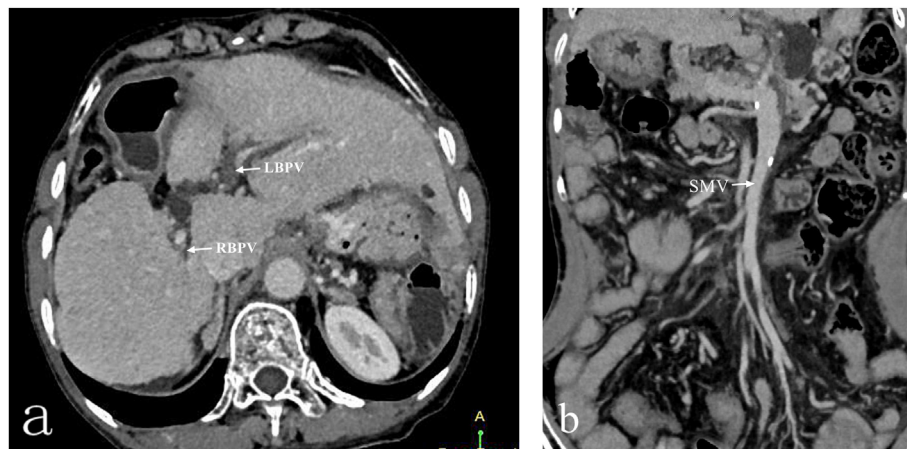
Fig. 1. (a) The left branch of the portal vein (LBPV) and right branch of the portal vein (RBPV) were completely occluded. (b) The curved planar reconstruction showed patency of the superior mesenteric vein (SMV) trunk and its tributaries.

Table 1
Preoperative baseline characteristics.

No.	Gender/age (y)	Etiology	Main symptoms and signs	Child-Pugh	SMVT	SMVB	SV
1	M/51	Cirrhosis, HBV	Variceal rebleeding, ascites	C (10)	Patent	Patent	Patent
2	M/44	Cirrhosis, HBV, splenectomy	Variceal rebleeding	A (6)	Patent	Patent	Occluded
3	F/23	EHPVO	Variceal rebleeding	B (7)	Patent	Patent	Patent
4	M/54	Previous pancreatitis	Variceal rebleeding	B (8)	Patent	Patent	Occluded
5	F/45	Cirrhosis, HBV, splenectomy	Variceal rebleeding	A (5)	Patent	Patent	Patent
6	F/61	IVC obstruction syndrome, JAK2V617F mutation	Variceal rebleeding, Bilateral legs ulcer	A (5)	Partial occluded (70%)	Patent	Occluded
7	M/56	Alcoholic cirrhosis	Variceal rebleeding	B (9)	Patent	Patent	Patent
8	M/49	Cirrhosis, HBV, splenectomy	Variceal rebleeding, ascites	B (9)	Patent	Patent	Patent
9	F/65	Cirrhosis, HCV, splenectomy	Variceal rebleeding	B (7)	Patent	Patent	Patent
10	M/47	Cirrhosis, HBV, splenectomy	Variceal rebleeding	B (8)	Patent	Patent	Occluded
11	M/62	Cirrhosis, HBV, splenectomy	Variceal rebleeding, ascites	C (10)	Patent	Patent	Occluded
12	F/56	Cirrhosis, HBV, splenectomy	Variceal rebleeding	A (5)	Partial occluded (70%)	Patent	Occluded
13	M/64	Cirrhosis, HBV	Variceal rebleeding, ascites	B (9)	Patent	Patent	Patent
14	M/31	EHPVO, splenectomy	Variceal rebleeding	B (7)	Patent	Patent	Occluded
15	F/64	Cirrhosis, HBV	Variceal rebleeding, ascites	B (9)	Patent	Patent	Patent
16	F/63	Cirrhosis, HBV, splenectomy	Variceal rebleeding, ascites	B (8)	Patent	Patent	Patent
17	M/48	Cirrhosis, HBV, splenectomy	Variceal rebleeding	B (8)	Patent	Patent	Occluded
18	M/42	Cirrhosis, HBV, splenectomy	Variceal rebleeding	B (7)	Partial occluded (50%)	Patent	Occluded
19	M/45	Cirrhosis, HBV, splenectomy	Variceal rebleeding, ascites	B (9)	Patent	Patent	Occluded
20	M/56	Previous pancreatitis	Variceal rebleeding	B (7)	Patent	Patent	Occluded

SMVT = superior mesenteric vein trunk. SMVB = superior mesenteric vein branches. SV = splenic vein. HBV = hepatitis B virus. EHPVO = extra-hepatic portal vein obstruction. IVC = inferior vena cava. HCV = hepatitis C virus.

2. Materials and methods

2.1. Study population and protocol

Between December 2020 and January 2022, 20 patients (13 men, seven women) with apparent symptoms of portal hypertension were treated with TmEPS. All patients underwent computed tomographic venography (CTV), which revealed that the trunks and intrahepatic tributaries of the portal vein were occluded and surrounded by collateral circulation and that the superior mesenteric vein (SMV) trunks were patent or partially occluded (Fig. 1). All 20 patients (mean age, 51.3 ± 11.2 years; range, 23–65 years) underwent TmEPS. The mean preoperative Child-Pugh Score was 7.7 ± 1.6. The patients' baseline characteristics are presented in Table 1.

This study was approved by our hospital's ethics committee. All patients provided informed consent prior to the procedure. The inclusion criteria were: (1) age 18–75 years; (2) Child-Pugh Score ≤10; (3) definite symptoms of portal hypertension; and (4) diagnosis of CTPV with a
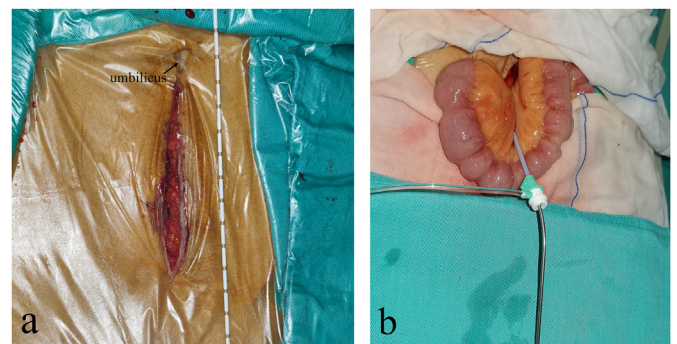

Fig. 2. (a) Infraumbilical midline longitudinal mini-laparotomy. (b) A distal branch of the superior mesenteric vein (SMV) was exposed from the mesenterium. Upon puncture of the branch of the SMV, a 6F sheath was inserted. A 14G stiffening cannula and a 5F RUPS-100 catheter were introduced through the 6F sheath into the SMV.
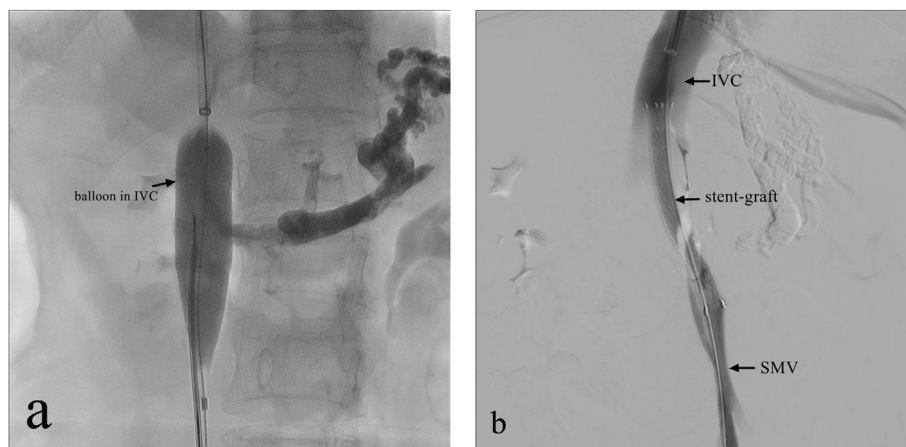
Fig. 3. (a) A balloon was filled with a contrast agent to label the position of the inferior vena cava (IVC). The tip of the stiffening cannula was adjusted toward the balloon in the IVC. The balloon was punctured. (b) Portography showed patency of the superior mesenteric vein (SMV) and the stent graft.

patent or partially occluded SMV trunk. The exclusion criteria were as follows: (1) uncontrolled spontaneous bacterial peritonitis; (2) extensive occlusion of the SMV trunk and its tributaries; (3) severe coagulation disorder; and (4) terminal cancer.

2.2. TmEPS procedures

All procedures were conducted in a hybrid operating room under general anesthesia. An infraumbilical midline longitudinal mini-laparotomy 7–10 cm long was performed (Fig. 2a). A tributary of the SMV was exposed from the mesenterium, and a 6F, 11-cm sheath (Cordis Co., Miami Lakes, FL, USA) was introduced into the SMV (Fig. 2b). The preoperative SMV pressure was measured by connecting a blood pressure sensor (SCW Medicath Ltd., Shenzhen, China) to the 6F sheath. By puncturing the right internal jugular vein (RIJV), a 10F sheath of the Rösch-Uchida Transjugular Liver Access Set (RUPS-100; Cook Co., Bloomington, IN, USA) was introduced into the inferior vena cava (IVC). The balloon-assisted puncture technique was used to improve the success rate of the IVC puncture. A balloon (Atlas; Bard Peripheral Vascular Inc., Tempe, AZ, USA) with a 20-mm diameter was inserted along a stiff guidewire (Cordis Co.) into the IVC. The balloon was filled with a contrast agent to label the IVC position (Fig. 3a). A 14G stiffening cannula and a 5F RUPS-100 catheter were introduced along the stiff guidewire into the SMV (Fig. 2b). The two puncture sites at the SMV were the junction of the SMV and SV, and the proximal end of the SMV trunk.

For patients with a patent or recanalized SV, we chose the junction of the SMV and SV as the puncture site. The distal ends of the stent grafts were located at the SM–SV junction. Blood flow from the SMV and SV was shunted into the IVC using stent grafts. For patients who previously underwent splenectomy, we chose the proximal end of the SMV trunk as the puncture site. The distal ends of the stent grafts are located on the trunk of the SMV.

Under fluoroscopy, the stiffening cannula was rotated to move its tip toward the balloon in the IVC (Fig. 3a). The balloon was directly punctured in the IVC (Video 1). A 260-cm stiff guidewire was inserted through the 5F catheter into the cavity of the balloon, and the guidewire was pulled out of the 10F sheath to establish direct access between the RIJV and SMV. The RUPS-100 was pushed forward to pass through the anterior wall of the IVC and the posterior wall of the SMV into the SMV cavity. Subsequently, a covered stent graft (Viatorr, Gore & Associates Inc. Flagstaff, AZ, USA; or Fluency, Angiomed GmbH & Co., Karlsruhe, Germany) was introduced through the 10F sheath to establish an extrahepatic portosystemic shunt between the IVC and the SMV. The proximal ends of the stent grafts were parallel to the long axis of the IVC, while the distal ends of the stent grafts were parallel to the long axis of the SMV trunk. A balloon (Bard Peripheral Vascular Inc.) was used to expand the
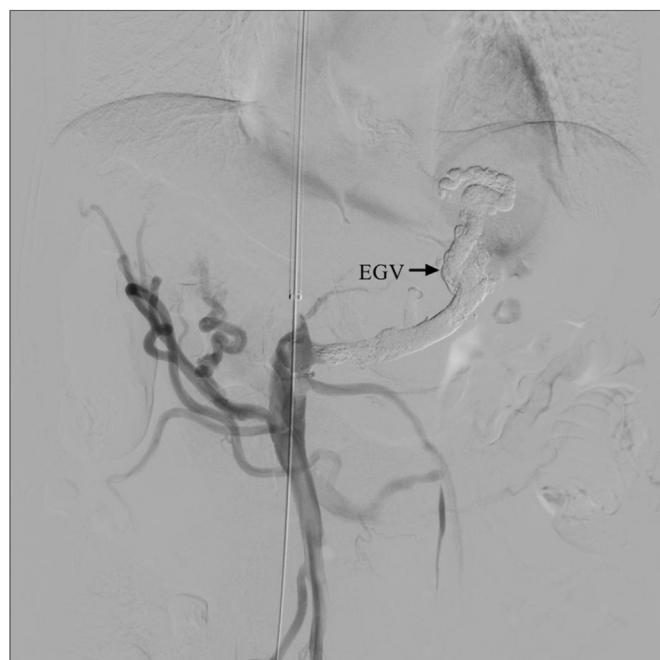

Fig. 4. Venography revealed that esophageal and gastric varices (EGV) were completely embolized with the mixture of glue and iodized oil.

stent graft. Direct portography was repeated to observe the patency of the extrahepatic portosystemic shunt (Fig. 3b). The postoperative SMV pressure was measured, the 6F sheath removed, the puncture point of the SMV sutured, and the abdominal incision closed. The total operation time, contrast agent dosage, and TmEPS alone duration were recorded.

The supplementary video related to this article can be found at http s://doi.org/10.1016/j.jimed.2023.04.001

Video 1. The balloon was filled with a contrast agent to label the position of IVC. The balloon in IVC was punctured.

2.3. Auxiliary procedures

Before TmEPS, the inflow vessels of the esophageal and gastric varices (EGV) were embolized with coils (Cook Co.) and/or a mixture of glue (Compont Medical Instrument Co., Beijing, China) and iodized oil (Guerbet Co., Paris, France) (glue:iodized oil = 1:2) (Fig. 4).

An occluded splenic vein (SV) can be ignored in patients with a

Table 2
Procedure details.

No.	TEPS time (min)	Puncture site	Stent-graft (mm)	Balloon (mm)	Pre-op SMVP (mmHg)	Post-op SMVP (mmHg)	Auxiliary procedures
1	38	SMV-SV	8 × 70 (Viatorr)	8 × 60	28	17	EGV embolization
2	40	SMVT	8 × 70 (Viatorr)	8 × 60	26	13	EGV embolization
3	25	SMV-SV	8 × 60 (Viatorr)	7 × 60	26	11	EGV embolization
4	30	SMVT	8 × 70 (Viatorr)	8 × 60	31	16	EGV embolization, Splenectomy
5	28	SMV-SV	8 × 70 (Viatorr)	8 × 60	29	15	EGV embolization
6	30	SMV-SV	8 × 70 (Viatorr)	7 × 60	33	17	EGV embolization, Splenic vein balloon angioplasty
7	27	SMV-SV	8 × 70 (Viatorr)	8 × 60	27	12	EGV embolization
8	32	SMV-SV	8 × 70 (Viatorr)	8 × 60	26	13	EGV embolization
9	26	SMV-SV	8 × 80 (Viatorr)	7 × 60	24	15	EGV embolization
10	25	SMVT	8 × 70 (Viatorr)	8 × 60	28	14	EGV embolization
11	32	SMV-SV	8 × 70 (Viatorr)	8 × 60	30	12	EGV embolization
12	29	SMVT	8 × 80 (Viatorr)	6 × 80	29	13	EGV embolization
13	32	SMV-SV	8 × 80 (Fluency)	7 × 60	33	12	EGV embolization
14	35	SMVT	8 × 80 (Viatorr)	8 × 60	27	15	EGV embolization
15	28	SMV-SV	8 × 70 (Viatorr)	7 × 60	29	18	EGV embolization
16	35	SMVT	8 × 80 (Viatorr)	7 × 60	34	23	EGV embolization
17	28	SMVT	8 × 80 (Viatorr)	7 × 60	34	21	EGV embolization
18	35	SMV-SV	8 × 80 (Fluency)	8 × 60	28	17	EGV embolization
19	30	SMVT	8 × 80 (Viatorr)	8 × 60	32	20	EGV embolization
20	27	SMV-SV	8 × 80 (Viatorr)	8 × 60	28	18	EGV embolization, Splenic vein balloon angioplasty

TEPS = transmesenteric vein extra-hepatic portosystemic shunt. Pre-op SMVP = preoperative superior mesenteric vein pressure. Post-op SMVP = postoperative superior mesenteric vein pressure. SMV-SV = the junction of superior mesenteric vein and splenic vein. EGV = esophageal and gastric varices. SMVT, superior mesenteric vein trunk.

history of splenectomy. For patients without previous splenectomy, the occluded SV should be recanalized to recover blood flow. If recanalization of the occluded SV fails, a splenectomy or splenic embolization should be performed.

2.4. Postoperative treatment

Postoperatively, enoxaparin was subcutaneously injected at a dose of 1 mg/kg every 12 h. While discharging the patients from the hospital, anticoagulation therapy was sustained with rivaroxaban (Xarelto; Bayer HealthCare AG, Leverkusen, Germany) at a dose of 10 mg/24 h to avoid possible liver injury with a full dose of rivaroxaban.[12,13] Oral lactulose, rifaximin, and acidifying enemas have been suggested as prophylactics for hepatic encephalopathy (HE).[14]

2.5. Follow-up

All patients underwent liver, renal, and coagulation function tests; blood ammonia; full blood picture; and CTV at 3 months postoperative.

2.6. Statistical analysis

Continuous data are expressed as mean ± standard deviation. Student's paired *t*-test was used to assess the differences in data measured before and after the TmEPS procedure. The statistical significance level for all tests was set at $p < 0.05$. All analyses were performed using SPSS version 25 (IBM Corporation, Armonk, NY, USA).

3. Results

TmEPS was successfully performed in all 20 patients (100%). The mean total operation time was 118.8 ± 25 min, while the mean TmEPS alone duration was 30.6 ± 4.2 min. The mean dosage of the contrast agent was 117 ± 22.5 mL. All EGV were embolized. The mean volume of the glue and iodized oil was 11.9 ± 8.3 mL. The first-puncture IVC success rate was 95% (19/20).

All extrahepatic portosystemic shunts were established using 8-mm covered stent grafts (18 Viatorr and two Fluency stent grafts). The SMV pressure significantly decreased from 29.1 ± 2.9 mmHg to 15.6 ± 3.3 mmHg ($p < 0.001$). The technical details are presented in Table 2.

All patients survived the surgery. One patient developed a subcutaneous hematoma. One patient experienced delayed healing of the incision. Two patients developed HE (grade I). No recurrent variceal bleeding or ascites were observed during the follow-up period. CTV revealed that all stent grafts were patent. No thrombi were observed in the IVC (Fig. 5). Comparing the preoperative, 7-day postoperative, and 3-month postoperative laboratory indicators, insignificant differences in the values of alanine transaminase, aspartate transaminase, total bilirubin, basophil counts, prothrombin time, International Normalized Ratio, serum creatinine, and white blood cell counts were noted. During the follow-up period, the mean patient weight increased from 60.62 ± 14.05 kg to 66.32 ± 13.67 kg ($p < 0.05$), the mean albumin level increased from 31.22 ± 4.03 g/L to 35.00 ± 5.92 g/L ($p < 0.05$), and the mean red blood cell count and hemoglobin level significantly increased (Table 3).

4. Discussion

The development of CTPV can increase portal vein pressure and lead to variceal bleeding and ascites.[4] TIPS is a less invasive and reliable treatment modality. TIPS recanalizes the occluded portal vein and decreases the portal vein pressure, effectively preventing recurrent bleeding and relieving refractory ascites.[15] However, successful puncture of an occluded portal vein is technically challenging. Several innovative methods have been developed to improve the TIPS success rate in the treatment of CTPV. In patients with CTPV, establishing an intrahepatic portosystemic shunt through the transjugular route alone is challenging. The success rate was only 5–16%.[16,17] The combined transjugular and transhepatic approaches could improve the success rate to 28–91.7%.[9,10,16,17] The combined transjugular and *trans*-splenic approach could also improve the success rate of surgery by 40–100%.[16–19]
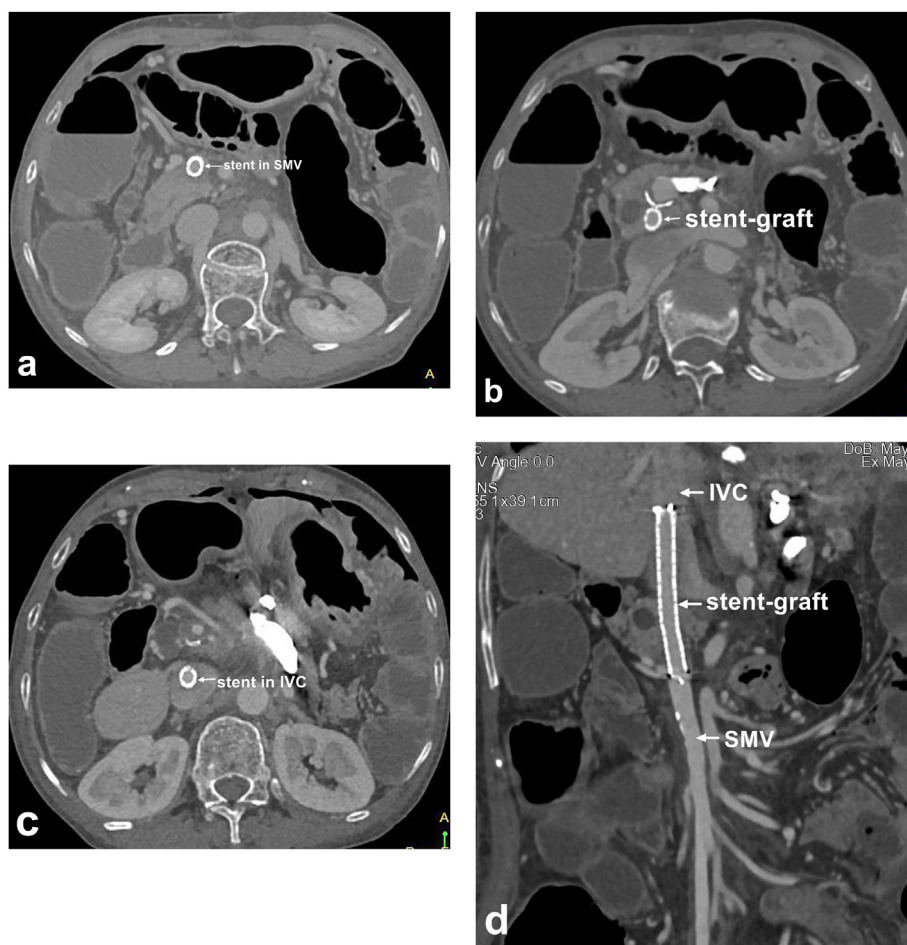
Fig. 5. Postoperative computed tomographic venography. (a) The distal end of the covered stent graft was in the superior mesenteric vein (SMV). (b) The middle segment of the covered stent graft was in the gap between the inferior vena cava (IVC) and superior mesenteric vein (SMV). No hematoma was noted around the stent graft. (c) The proximal end of the stent graft was in the IVC. (d) The SMV and the stent graft were patent.

Table 3
Follow-up outcomes of patients in laboratory indicators.

Items	Pre-operation	Post-operation (7 days)	Post-operation (3 months)
ALT (U/L)	22.47 ± 14.21	39.85 ± 38.18	32.20 ± 19.94
AST (U/L)	32.01 ± 18.22	36.73 ± 18.92	46.81 ± 23.09
TBIL (umol/L)	15.35 ± 9.72	18.15 ± 7.92	23.49 ± 17.02
ALB (g/L)	32.00 ± 3.74	31.22 ± 4.03	35.00 ± 5.92#
PT (s)	16.14 ± 3.62	16.54 ± 3.23	16.25 ± 2.42
INR	1.33 ± 0.32	1.39 ± 0.33	1.33 ± 0.21
RBC (10^9/L)	3.86 ± 1.26	3.54 ± 1.00*	4.01 ± 1.02#
Hb (g/L)	106.62 ± 29.43	97.23 ± 21.26*	109.23 ± 24.75#
PLT (10^9/L)	283.46 ± 234.48	220.92 ± 187.86*	232.69 ± 174.14
WBC (10^9/L)	7.51 ± 4.53	5.89 ± 2.37	5.81 ± 2.90
SCr (umol/L)	49.54 ± 14.31	44.92 ± 12.30	50.85 ± 13.52
BA (umol/L)	81.80 ± 37.11	67.20 ± 23.40	68.80 ± 23.97

ALT = alanine aminotransferase. AST = aspartate aminotransferase. TBIL = Total bilirubin. ALB = Albumin. PT = Prothrombin time. INR = international normalized ratio. RBC = red blood cell. Hb = hemoglobin. PLT = platelet. WBC = white blood cell. SCr = serum creatinine. BA = blood ammonia.
* significant statistical difference between the preoperative and postoperative groups.
# significant statistical difference between the postoperative (7 days) and postoperative (3 months) groups.

An extrahepatic portosystemic shunt was directly established between the patent IVC and portal vein trunk during TmEPS. The mean distance between the IVC and lower third of the portal vein trunk was approximately 1.18 cm. There were no vital organs in the gap between the IVC and lower third of the portal vein trunk. The lower third of the portal vein trunk is the most suitable location for establishing an extrahepatic portosystemic shunt.[20] Intraoperatively, the preloaded balloon in the IVC clearly labeled the position of the IVC and expanded its diameter to 2 cm (Fig. 3a, Video 1). The initial puncture success rate of the balloon-assisted puncture technique was 95%. The TmEPS success rate was 100%.

The portal vein of patients with CTPV is occluded and surrounded by collateral circulation. To successfully puncture the occluded portal vein, repeated punctures are inevitable during TIPS. However, repeated punctures can injure the liver capsule, bile ducts, and hepatic arteries.[10] The incidence of puncture-related complications was 7%.[21] During TmEPS, the IVC was directly punctured through the SMV (Fig. 5). There was no injury to the liver capsule or parenchyma. In addition, direct access between the RIJV and the SMV was established using a 260-cm stiff guidewire. This ensures that the 10F sheath of the RUPS-100 and the stent graft can be safely introduced into the SMV. The covered stent graft successfully sealed the puncture sites in the IVC and SMV. During surgery, postoperative digital subtraction angiography showed no contrast agent extravasation (Fig. 3b). The CTV showed no hematoma around the stent graft between the SMV and the IVC (Fig. 5b).

The combined transjugular and transmesenteric vein approach has also been used to establish an intrahepatic portosystemic shunt.[22,23] In these reports, the occluded portal vein was recanalized and TIPS was

performed to establish a portosystemic shunt. However, the recanalization of an occluded portal vein is complicated and time-consuming. TmEPS simplifies the operative procedure. The occluded portal vein trunk and intrahepatic tributaries were ignored. It was not necessary to combine classical TIPS. The mean TmEPS alone duration was 30.6 ± 4.2 min.

HE is a common complication of portosystemic shunts. The incidence of HE after TIPS in patients with CTPV is 9.32–27.05%.[24] During follow-up, the incidence rate of HE after TmEPS was 10%. Terminal tributaries of the portal vein cannot be recanalized. The blood flow in the portal vein was diverted into IVC through the low-resistance portosystemic shunt after TIPS or TmEPS. Therefore, the incidence of HE was similar in the TIPS and TmEPS groups.

Our study had several limitations. First, mini-laparotomy increases the risk of surgical trauma. This laparoscopic technique can be applied in future studies. Second, a small number of patients was included in this study. Therefore, it is essential to enroll more patients in future studies. Third, this study only reported the technical details and short-term results of TmEPS; thus, its medium- and long-term results require further investigation.

In summary, TmEPS is a feasible, safe, and effective treatment for patients with CTPV. Further studies with larger sample sizes and longer follow-up periods are warranted to confirm our findings.

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Declaration of competing interest

Tianxiao Li is an associate editors-in-chief for Journal of Interventional Medicine and was not involved in the editorial review or the decision to publish this article. All authors declare that there are no competing interests.

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