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ORIGINAL RESEARCH

Recanalization of the Portal Vein and Transjugular Intrahepatic Portosystemic Shunt (PVR-TIPS) as an Aid for Live Donor Liver Transplantation in Cirrhotic Patients with Portal Vein Thrombosis

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Abstract:

Purpose: Portal vein thrombosis (PVT), is seen in about 25% of patients with cirrhosis. Chronic portal vein thrombosis can significantly alter anatomy, often leading to the diversion of splanchnic blood into expansive and compliant vascular channels. This process generates extensive collateral networks and large varices that function as portosystemic shunts. Portal cavernous transformation represents a critical vascular condition marked by the formation of a network of collateral veins that develops to bypass an obstructed portal vein [PV]. Given these physiological changes, performing liver transplantation is associated with higher morbidity and mortality rates. We present an early, single-center experience for portal vein reconstruction (PVR) and the creation of a transjugular intrahepatic portosystemic shunt (TIPS) to increase transplant candidacy in such patients.

Material and Methods: Retrospectively, data was obtained from the Picture Archiving and Communication System (PACS) and Hospital Information System (HIS) from a single center between January 2016 to January 2024. In total, 15 patients with obliterative main portal vein thrombosis were selected. These patients underwent Percutaneous transhepatic portal vein recanalization with transjugular intrahepatic portosystemic shunt to increase their transplant eligibility after a collaborative imaging examination by transplant surgery and interventional radiology team. Up until liver transplant LT, patients were monitored in the hepatology/transplant clinic, and thereafter in the posttransplant clinic. To confirm portal vein PV patency, serial ultrasound/Dynamic computed tomography/magnetic resonance imaging was done.

Results: Portal vein recanalization with transjugular intrahepatic portosystemic shunt was performed in 15 patients. Technical success, defined as the maintenance of patency in both the portal vein and the transjugular intrahepatic portosystemic shunt at the conclusion of the procedure, was achieved in all 15 cases (100%).

Conclusions: Patients with portal vein thrombosis may significantly benefit from portal vein recanalization with transjugular intrahepatic portosystemic shunt, enhancing transplantation candidacy and facilitating physiologic end-to-end anastomoses.

Keywords:
PVR TIPS, TIPS, portal vein recanalization, portal vein reconstruction, liver transplant

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Introduction

Portal cavernous transformation represents a critical vascular condition marked by the formation of a network of collateral veins that develops to bypass an obstructed portal vein. This complex vascular architecture manifests following a thrombotic event in the portal vein, leading to a regenerative response wherein cavernous channels maintain essential hepatic and splanchnic blood flow [1].

The etiology of portal cavernoma is multifaceted, and frequently associated with underlying conditions such as idiopathic PVT, liver cirrhosis, abdominal malignancies, pancreatitis, intra-abdominal infections, or post-surgical complications. PVT is seen in about 25% of patients with cirrhosis [2, 3]. Chronic PVT can significantly alter anatomy, often leading to the diversion of splanchnic blood into expansive and compliant vascular channels. This process generates extensive collateral networks and large varices that function as portosystemic shunts. Consequently, the original portal vein, which remains thrombosed and hypo-perfused, eventually becomes a thin, fibrotic cord. This phenomenon, termed "venous rescue," which ensures continued flow to the liver byrerouting the blood through these new pathways [4-7]. Given these physiological changes, performing liver transplantation is associated with higher morbidity and mortality rates [8-11]. TIPS can reduce the thrombus load, restore portal vein blood flow, decrease portal pressure, enhance patient eligibility for liver transplantation, and improve prognosis. However, performing TIPS in these patients poses a challenge. Salem et al. [12] reported a novel technique of portal vein recanalization followed by TIPS. More research in this area has garnered fruitful results. Here, we demonstrate the preprocedural workup, the technicality of the procedure, promising outcomes of portal vein recanalization, and placement of TIPS stent in cirrhotic patients having obliterated portal veins who were otherwise candidates for a liver transplant.

Material and Methods

A Retrospective observational study was performed from January 2016 to January 2024. Forty-seven patients were evaluated during this period, of which 15 patients underwent portal vein recanalization and TIPS (PVR-TIPS). A multidisciplinary team, including transplant surgeons, hepatologists, and interventional radiologists, deliberated on the feasibility of liver transplants and the need for recanalization.

Inclusion criteria - All patients with obliterated main portal vein due to PVT secondary to cirrhosis, who are otherwise candidates for liver transplant.

Exclusion criteria - lack of splenic/mesenteric access because of extensive portomesenteric thrombosis, transplantation infeasibility, presence of portal vein tumor thrombus secondary to intrahepatic or extrahepatic malignancy, or any prothrombotic disorders.

Convenience sampling was done to collect data from selected cases from January 2016 to October 2023, who were then followed up after the liver transplant until January 2025. The data were obtained from the PACS and HIS.

Laboratory tests were utilized to evaluate baseline characteristics, including the Child-Turcotte-Pugh classification and the Model for End-Stage Liver Disease (MELD) score.

The extent and grading of PVT were assessed on preprocedural dynamic CT and were defined using the Yerdel classification [10] of PVT.

Primary outcomes (calculated as technical success rate) and secondary outcomes were defined as success/failure of PVR-TIPS, and clean recipient portal vein during transplant surgery with successful end-to-end anastomosis of recipient portal vein with graft portal vein, respectively. Patients were followed by the IR team/Liver transplant unit in post transplant clinics.

This study represents data from a large Hepatobiliary and liver transplant center with a team of experienced interventional radiologists who have experience in >500 TIPS procedures in the last decade. There has been >250 liver transplants per year in the last 5 years.

Pre-operative imaging was performed in all patients, including dynamic triple-phase CT abdomen to assess: (a) anatomy of the portomesenteric access, (b) status and grade of PVT, (c) fibrosed native portal vein (if appreciated), (d) course and target site for transplenic puncture, (e) status of mesenteric veins, (f) thrombus load in the portomesenteric circulation, and (g) ascites. The Yerdel grading system classifies PVT into four grades: Grade 1 (partial thrombosis involving <50%), grade 2 (thrombosis affecting 50%-100% of the main portal vein), grade 3 (complete thrombosis including the proximal superior mesenteric vein), and grade 4 (complete thrombosis with extension into the distal superior mesenteric vein). In patients with ascites, a drain was placed to completely dry the peritoneum before the procedure to reduce bleeding complications.

Procedural technique

Under general anesthesia, access to the internal jugular vein is established (using a 10 Fr sheath) and the hepatic vein is cannulated. Given the fibrosis and replacement of the main portal vein by a cord, an upfront additional transhepatic (**Fig. 1**) or trans-splenic (**Fig. 2**) access is performed using a 22 G needle, under ultrasound guidance to minimize bleeding complications. The choice of access route is determined based on cross-sectional imaging findings. Through the trans-splenic route, once the access is taken into the splenic vein using a Neff set, which is a percutaneous puncture set by Cook Medical, a 3-part system (22 G puncture needle with stellate, a tapered plastic cannula and outermost 4 Fr sheath) a splenic venogram is taken through its 4 Fr sheath to outline the venous anatomy and locate the thrombosed native portal vein. Using a Kumpe catheter (5 Fr/65 cm access and catheterization catheter with short-angled-tip, from Cook Medical) and an angled-tip glidewire (Terumo, Somerset, NJ), the obliterated portal vein is negotiated up to the intrahepatic portion. Venoplasty using a high-pressure balloon is performed in a graded manner up to 10 mm. Fi-

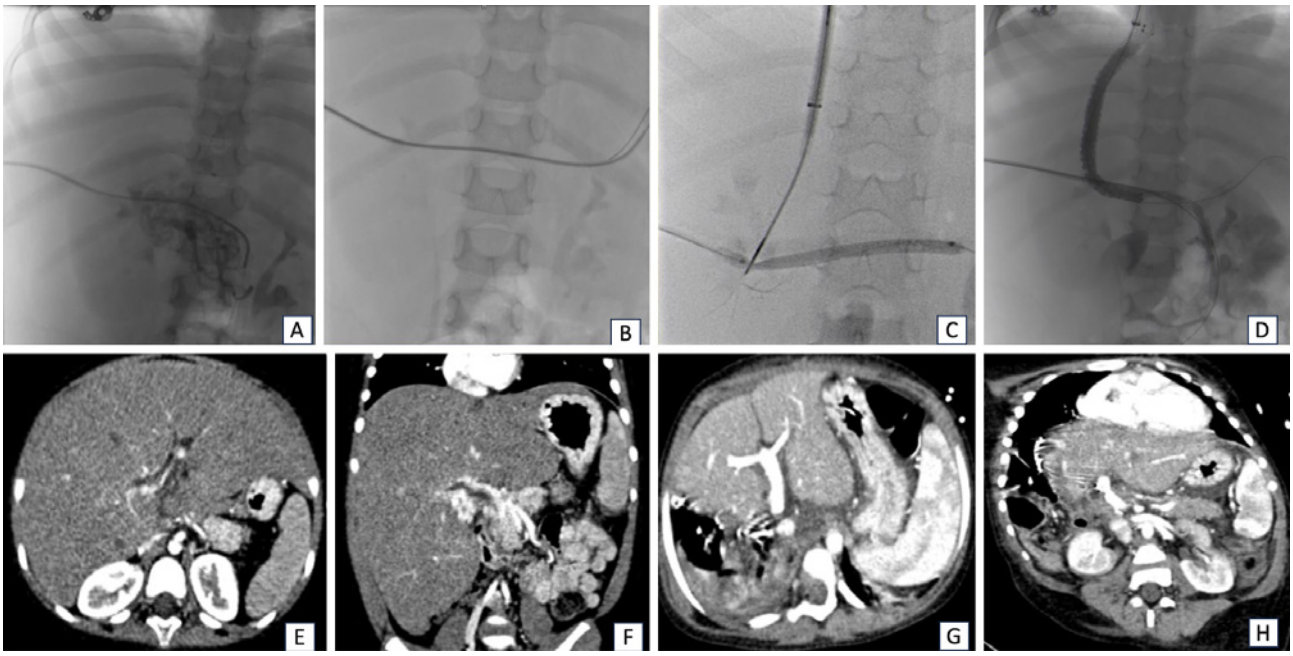

Figure 1. Portal vein recanalization with transjugular intrahepatic porto systemic shunt (PVR-TIPS) using transhepatic access. (A) Direct transhepatic portal venogram showing cavernoma and absence of the main portal vein. (B) The thrombosed portal vein is crossed using a KMP catheter and glidewire. (C) The contrast-inflated balloon is used as a fluoroscopic target and advancing the TIPS needle through the balloon. (D) Patent portal vein and TIPS at the conclusion of the procedure. (E, F) Pre-PVR-TIPS dynamic axial and coronal CT demonstrating chronic portal vein thrombosis and extensive cavernoma. After PVR-TIPS, the patient was transplanted and received an end-to-end anastomosis. (G, H) Dynamic axial and coronal CT during transplant follow-up demonstrates portal vein patency.

nally, a 10 mm balloon is placed in the right portal vein. Using the balloon as a target and under constant needle tracking with transabdominal ultrasound and fluoroscopy guidance, TIPS is performed, and an exchange-length wire is placed into the mesenteric vein. The use of intracardiac echocardiography has been mentioned in the literature for guidance of portal vein puncture during TIPS, to decrease the procedure time and procedural complications [13]. In the present cohort, transabdominal ultrasound was used for the same purpose in all patients. It provides real-time needle tracking within hepatic parenchyma. Following this, standard steps are performed until TIPS stent (Taewoong Niti-S) deployment. This woven metallic stent is a combination of covered and uncovered portions. The stent comes in variable lengths of proximal covered portion (5-10 cm) with constant, uncovered 2 cm, distally (**Fig. 3**). The stent is deployed in such a manner that the covered portion covers the hepatic parenchymal track and the distal uncovered 2 cm gets deployed into the main portal vein.

While using the transhepatic route, the peripheral intrahepatic portal vein (either segment 5 or segment 6) is punctured using a Neff set. A portal venogram is taken through the sheath of the Neff set to delineate the possible path of the native portal vein. The Kumpe catheter and angled-tip glide wire are used in a similar manner to negotiate through the chronically thrombosed portal vein. The rest of the steps are the same as described above. In cases in which an anatomically distinguished portal vein was seen on imaging, a TIPS stent was deployed using conventional steps under ultrasound and fluoro-guidance to puncture the right posterior portal vein. No additional access (trans-hepatic or trans-splenic) was used in such cases.

The transplant surgeons require a 2 cm uncovered portion of therecanalized portal vein for easy anastomosis creation with the graft liver. Hence, the covered stent grafts are deployed within proximal main portal vein, leaving a significant length of the non-stented distal main portal vein, during the PVR-TIPS procedure. During the transplant the diseased liver along with the TIPS stent was removed. The non-stented distal main portal vein of recipient was then anastomosed end-to-end with a graft portal vein at the porta hepatis. The tracks (transhepatic or trans-splenic access) are embolized using a coil (4 mm × 14 cm) as well as glue-lipiodol emulsion under ultrasound and fluoroscopic guidance. Glue + lipiodol (1:1) was injected in such a way, that it created a glue cast over the hepatic/splenic capsule, to embolize the tiny capsular vessels. Post-stenting, patients are initiated on 1,000 IU/hour of intravenous heparin for the first 24 hours followed by newer oral anticoagulants. Patients are reviewed to assess stent flow and patency before listing for surgery. In patients with extensive splenic or mesenteric vein thrombosis, stenting is performed to allow good in flow to the portal circulation, ensuring a 2 cm uncovered portal vein to facilitate surgical anastomosis (**Fig. 4**).

Results

Fifteen patients underwent PVR-TIPS during the study

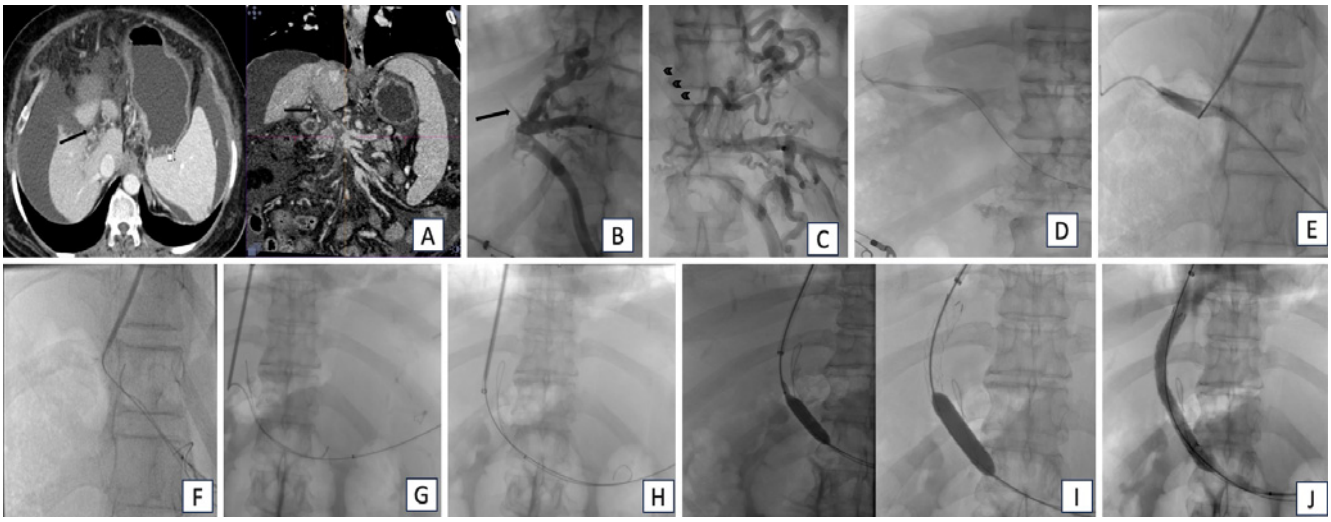

Figure 2. A 65-year-old man with hepatitis C cirrhosis. (A) Axial dynamic CT performed for transplant planning shows the absence of a patent portal vein and extensive cavernoma (black arrow). A completely thrombosed structured portal vein is seen extending up to the hepatic hilum (arrow). (B) Splenic Venography performed through the trans-splenic sheath confirms occlusion of the main portal vein with a thin residual channel in the expected position of the portal vein (black arrow). (C) The contrast tends to hold up within this residual channel of the thrombosed portal vein (arrowheads), which serves as a guide for recanalization. (D) Venography through the recanalized portal vein demonstrates the intrahepatic portal branches. (E) Transabdominal ultrasound and fluoro-guided puncture of a balloon placed in the right portal vein using transjugular intrahepatic portosystemic shunt (TIPS) cannula. (F) The exchange-length stiff glide wire is snared and withdrawn through the splenic sheath. (G) The stiff wire is exchanged with a working wire using a catheter. (H) After exchange for a working wire, the splenic sheath can be advanced into the portal vein over the through-and-through access. (I) Balloon dilation of the hepatic track and main portal vein is performed with a 10- and 12-mm high-pressure balloon respectively. (J) Portal venography after TIPS placement and portal vein recanalization shows a widely patent portal vein and TIPS. Note that the cavernoma is no longer opacified and should not compromise TIPS and recanalized portal vein patency by acting as a competitive outflow for portal flow.

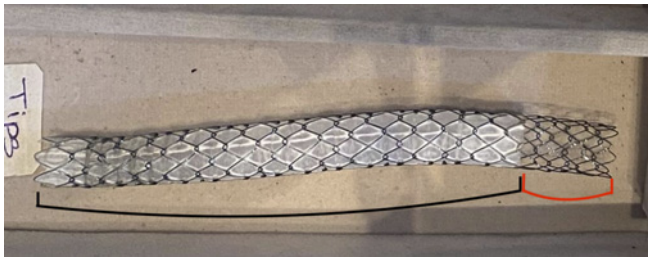

Figure 3. Taewoong Niti-S stent. The black underlined segment is covered, the proximal portion and the red-underlined segment is constant 2 cm, uncovered, the distal portion of the stent.

period. Patient demographic data, laboratory tests, and clinical assessments are listed in **Table 1**. Diverse etiologies contributing to chronic liver disease were identified within the cohort, including cryptogenic origins (5 patients), glycogen storage disease (1 patient), nonalcoholic steatohepatitis (2 patients), chronic liver disease attributed to alcohol consumption (4 patients), autoimmune or hepatitis B virus-related chronic liver disease (2 patients), and Budd-Chiari syndrome (1 patient). The median baseline preprocedural MELD score was 17, ranging from 10 to 22. PVT was complete (with or without extension into the splenic or superior mesenteric veins) in 80% of patients, and partial in the remaining 20%. All grades 2, 3, and 4 patients had complete 100% occlusion. All grade 1 patients had partial occlusion. According to the Yerdel classification, 53% had grade 2 PVT, 13% had grade 3 PVT, and 13% had grade 4 of PVT. Notably, 53% demonstrated the cavernous transformation of the portal vein, and thrombotic disorders were absent across the cohort.

Percutaneous transhepatic PVR-TIPS was performed in 15 patients. Technical success (primary outcome), defined as the maintenance of patency in both the portal vein and the TIPS at the conclusion of the procedure, was achieved in all 15 cases (100%).

Of the 15 patients who underwent successful PVR-TIPS, 14 maintained the patency of both the portal vein and TIPS until the transplanting phase, demonstrating favorable outcomes. However, one patient could not reach the transplant stage. This patient underwent successful PVR-TIPS but died 6 days later due to multiorgan failure.

Of 14 patients, none of them showed any significant clinical or laboratory adverse events. No reported event of TIPS stenosis/thrombosis, encephalopathy, hemoperitoneum (attributed to procedure), arterio-portal fistula, right failure, or radiation skin burn were noted in these 14 patients. Mild increase in MELD was seen in 5 of 15 patients which was clinically not significant.

Imaging follow-up of all 14 patients was done on ultrasound just 1 day before surgery which showed patent main portal vein and flowing TIPS stent.

Among our cohort, 14 individuals (93%) proceeded to re-

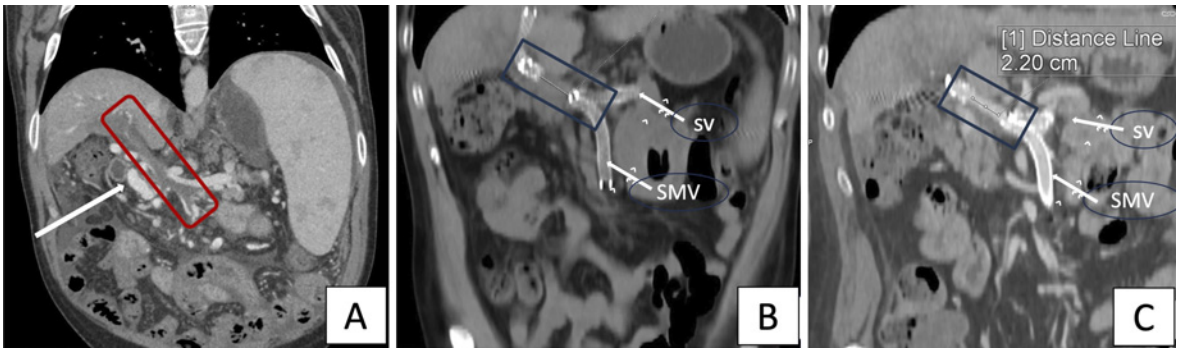

Figure 4. (A) Red box showing extensive thrombosis of main portal vein extending into superior mesenteric vein and splenic vein. Notice a large collateral vessel (white arrow) in the periportal region. (B and C) Status post-portal vein recanalization with transjugular intrahepatic portosystemic shunt (post-PVR-TIPS), pre-transplant patient with plain (B) and contrast (C) coronal reformatted CT images showing >2 cm stent-free, recanalized extrahepatic main portal vein (black box), meeting the needs for clean anastomosis during transplant. Notice the TIPS stent along with recanalization and stenting of the splenic vein (SV) and superior mesenteric vein (SMV).

ceive liver transplants, all undergoing end-to-end anastomoses. The median time to transplant was 20 days.

Consequently, all transplanted patients had physiologically intact portal inflow to the transplanted liver. Transplant surgeons reported that the recanalized portal veins exhibited normal elasticity, devoid of scarring or induration post-procedure. The recipient portal vein was seamlessly connected to the donor vessel without discernible challenges in all 14 patients (secondary outcome). The quality of the portal vein was found excellent with easy, secure suture placement and significant elasticity for growth factor accommodation. There have been no instances of recurrent PVT following liver transplantation in this cohort.

All 14 patients have done well with no reported complications in post-operative follow-up every 8 weeks for the first year.

Discussion

PVT has known peri-operative and post-operative risks after liver transplant and hence is considered a relative contraindication. Anticoagulation is considered therapeutic, for PVT in cirrhotic patients. However, in such patients, gastrointestinal varices are considered a relative contraindication to anticoagulation. Hence, despite the available guidelines for anticoagulation, safety and efficacy in this population is uncertain. Also, there are moderate quality and weaker recommendations regarding the use of anticoagulation in liver transplant candidates with PVT (European Association for the Study of the Liver) [14]. Other studies [15, 16] have demonstrated the effectiveness of anticoagulation in treating partial PVT associated with cirrhosis; however, its role in managing complete or chronic PVT remains significantly less defined. A meta-analysis of 16 studies assessing anticoagulation for PVT [17] reported recanalization rates varying between 37% and 93%, with an overall pooled rate of 67%. However, the analysis did not specify the severity of PVT (e.g., partial versus complete Yerdel stage) or the thrombus's chronicity. In our study, 8 of 15 patients (53%) were diagnosed with gastroesophageal varices before undergoing PVR-TIPS. As a result, in this cohort, anticoagulation was deemed less feasible for consistent recanalization before transplantation.

There are physiological and non-physiological surgical techniques to create portal inflow in a thrombosed portal vein. Physiologic ways include eversion thrombectomy to facilitate end-to-end anastomosis, interposition grafts, and mesoportal jump grafts through transverse mesocolon [18, 19]. Non-physiological techniques are caval hemitransposition, renoportal anastomosis, and portal vein arterialization [20-22]. There is significant morbidity and mortality associated with these non-physiological anastomotic techniques. Hibi et al. [23] in their series of patients with physiological anastomosis in 53% (with complete PVT) and non-physiological reconstructions in 27% (with complete PVT) patients. Their study had shown that establishing a physiological end-to-end portal vein anastomosis in liver transplant is critically important for better outcomes.

Given these considerations, the decision of PVR-TIPS was undertaken in this cohort of patients with chronic PVT to establish a patent portal vein, facilitating an end-to-end anastomosis during transplantation. The technical success rate was 100% in 15 of 15 patients. This was possible with adoption of transhepatic as well as trans-splenic approach. While trans-splenic access for portal venography and intervention has been documented, there are limited reports of its use in combination with TIPS creation and only used when the transhepatic approach failed. In the present cohort, recanalization of the portal vein was done using transhepatic access in two patients, and in three patients the trans-splenic access was considered as the first-line option for PVR.

Thornburg et al. [24] conducted the largest study to date involving 61 patients who underwent PVR-TIPS and were monitored for up to 105.9 months. This study reported an overall survival rate of 82%, with 39% subsequently undergoing liver transplantation [24]. However, in the second phase of their study in 2017, they demonstrated a 100% technical success with the use of the trans-splenic approach.

Table 1. Detailed Information about Our Cohort Group of 15 patients Regarding Demographics, Degree and Extension of PVT, cavernous Transformation, Etiology of CLD, Preprocedural MELD-Na Score, Additional Access during Procedure and Average Time Period between PVR TIPS, and Liver Transplant.

Age (in years)	
Median	59
Range	04-69
Sex	
Male	12
Female	03
PVT degree	
Partial	03
Complete	12
PVT grade	
1	03
2	08
3	02
4	02
Cavernous transformation	
Yes	08
No	07
MELD Na	
Median	17
Range	10-22
Etiology of CLD	
Cryptogenic	05
Alcohol	04
NASH	02
BCS/ALD	01
Glycogen storage disease	01
HBV related	02
Manifestations of liver disease	
Varices	07
Ascites	13
Hepatic encephalopathy	05
Hepatic hydrothorax	02
Mean time period between PVR TIPS and liver transplant	20 days
Median	14 days
Range	11-55 days
Additional access (any access, other than trans-jugular)	
Trans-splenic	03
Trans-hepatic	02

BCS/ALD: Bud Chiari syndrome-related acute liver failure; CLD: chronic liver disease; HBV: hepatitis B-virus; MELD-Na: Model of end-stage liver disease; NASH; non-alcoholic steatohepatitis; PVR TIPS: portal vein recanalization with trans-jugular intrahepatic portosystemic shunt; PVT: portal vein thrombus

In the present study, we demonstrated a 100% technical success rate with 93% undergoing a liver transplant. All patients in our study were kept on anticoagulation which helped in keeping the patency of TIPS until reaching transplant. However, in the study by Thornburg et al. [24], only patients with complete PVT were kept on anticoagulation, also in their second phase of study. In their first phase of study in 44 patients, none of their patients received anticoagulation after PVR-TIPS. In their study, 4 of 5 patients in which re-thrombosis occurred, happened within 30 days. The improvement in our patency rates may be attributed to routine post-procedure anticoagulation protocol in every patient. The median time for PVR-TIPS to Liver transplant was 75 days in the study by Thornburg et al. [24] 09 of their patients got transplanted within 75 days after PVR-TIPS. All 14 patients in the current study also got transplanted within 55 days post-PVR-TIPS. The mixed cohort of these 23 patients got transplanted within 75 days, suggesting that portal vein gets well remodeled within two and a half months (75 days) post PVR-TIPS.

In the present cohort, there was one pediatric (toddler) patient with chronic PVT, with the formation of portal cavernoma and post-splenectomy status, who had undergone successful PVR-TIPS followed by a liver transplant. To the best of our knowledge, no case of pediatric PVR-TIPS for liver transplant is reported.

Several studies have explored the trans-mesenteric approach for PVR-TIPS creation, both via mini-laparotomy [25, 26] and percutaneous routes [27-29]. Steffen et al. [27] reported percutaneous trans-mesenteric access as safe, with no bleeding complications. None of the patients in the present study had to undergo the trans-mesenteric approach.

The patent intrahepatic portal and splenic veins are crucial for planning this procedure to ensure effective access. Transsplenic access is recommended as the primary approach, shown to improve recanalization outcomes. We have learned that identifying a peripheral, intraparenchymal splenic vein that is in line with the main PV is a key step in the transsplenic approach (**Fig. 5**). A meticulously planned transsplenic procedure has always led to a successful recanalization of the portal vein, even in the presence of extensive portal cavernoma.

Our study demonstrates excellent efficacy and safety of PVR-TIPS, however, has limitations being single center with a relatively small cohort size. Long-term data maturation is necessary for comprehensive evaluation.

It is a single-center experience but has a high level of technical expertise. Nevertheless, it represents an aggressive approach to patients in the transplant setting. A comparison to a control population, such as those receiving anticoagulation, was not conducted because patients in this series had cavernomas and GI bleeds, conditions in which anticoagulation is contraindicated. Still, the patency rates and outcomes in this series surpass those reported in studies focusing on anticoagulation alone [16]. From a surgical perspective, while most transplant surgeons agree that they can technically manage PVT, having a patent portal vein during liver transplantation is generally reassuring. Other than simple eversion thrombectomy, surgical interventions such as graft transposition, cavo-portal hemi-transposition, or renoportal anastomosis are typically associated with poor outcomes [22].

Conclusion

Patients with PVT may significantly benefit from PVR-TIPS, enhancing transplantation candidacy and facilitating physiologic end-to-end anastomoses. Such anastomoses are associated with reduced post-operative complications and

Figure 5. Representation of selection of splenic vein (white arrow) on preprocedural dynamic CT, for trans-splenic access for recanalization of chronically thrombosed portal vein. The selected splenic vein branch should be in the direction toward the porta-hepatic and parallel/in-line with the portal vein.

mortality rates, underscoring the pivotal role of PVR-TIPS in optimizing outcomes for individuals with PVT undergoing liver transplantation.

Conflict of Interest: None

Author Contribution: All authors have participated in the procedures. VS has collected all the data from the institutional source and PACS. AM, SJ, RK, AK, GSS, RR, and HR have helped in formulating the master chart. VS, SS, and AHK have contributed to the research analysis and review of reference articles. SSB is our mentor who has guided us through each difficult step through the procedure.

Informed Consent: Written consent was obtained from each patient/their relatives.

Necessary approvals were taken from the Institutional Ethical Committee.

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