Portacaval Shunting for Portal Hypertension

58

Francis G. Celii, Jayesh M. Soni, and Anil K. Pillai

Key Concepts

- Overview of Portal Hypertension
- Current Treatment Options
  - Surgical Shunts, TIPS Shunt, DIPS Shunt, Transjugular Mesocaval Shunts
  - Description of shunts anatomy, clinical indication/contraindications, technical considerations, and complications
  - Potential complications and long-term outcomes of different portocaval shunt procedures,
  - Future Directions

58.1 Overview of Portal Hypertension

Portal hypertension is a clinical condition characterized by a portosystemic gradient exceeding 5 mmHg. Cirrhosis contributes to the majority of cases with less than 10% arising from noncirrhotic etiology. Pathophysiological mechanisms for the development of portal hypertension are categorized into two broad theories, forward and backward flow theories. In the latter, cirrhosis causes fibrosis and architectural distortion of the liver, leading to increased intrahepatic vascular resistance. Elevated pressure in the portal system eventually leading to reversal of flow within the portal vein, known as hepatofugal flow ensues. In the former, hyperdynamic mesenteric circulation mediated by vasoactive compounds such as Nitrous Oxide (NO), Vascular Endothelial Growth Factor (VEGF), and Tumor Necrosis Factor (TNF) α results in hyper dynamic circulation and increased forward flow [1, 2].

The downstream clinical effects of elevated portal pressure are mainly threefold and include variceal bleeding, ascites and hepatic encephalopathy [3]. When these complications occur, cirrhosis is said to be decompensated with a life expectancy that now plummets to only 2 years from a 12-year life expectancy seen in a compensated cirrhotic patient. Variceal bleeding is a medical emergency with a 7–12% mortality. The onset of ascites portends a poor prognosis with a 1-year and 5-year mortality rate of 15% and 44% respectively. Hepatic encephalopathy is seen in half the patients with portal hypertension.

Other less common clinical manifestations of portal hypertension include hepatorenal syndrome, hepatopulmonary syndrome, hypersplenism, bacterial peritonitis, hepatic hydrothorax, and portal hypertensive biliopathy.

F. G. Celii
University of Texas Health Science Center, Houston, TX, USA
e-mail: Francis.G.Celii@uth.tmc.edu

J. M. Soni · A. K. Pillai (✉)
Diagnostic and Interventional Imaging, University of Texas Health Science Center, Houston, TX, USA
e-mail: Jayesh.Soni@uth.tmc.edu; Anil.K.Pillai@uth.tmc.edu

F. Radu-Ionita et al. (eds.), *Liver Diseases*, https://doi.org/10.1007/978-3-030-24432-3_58

Definition

Portal hypertension condition in which the portosystemic blood pressure gradient is above 5 mmHg.

Hepatofugal or Non-forward portal flow (NFPF) is defined as an abnormal flow pattern where portal venous flow is retrograde from the periphery of the liver towards the porta hepatis.

Hepatic Venous Pressure Gradient (HVPG) is defined as the gradient in pressure between the portal vein and the inferior vena cava (IVC).

- Normal portal pressure is defined as HVPG of ≤5 mmHg.
- Subclinical portal hypertension is defined as HVPG 6–9 mmHg.
- Clinically significant portal hypertension (CSPH) is defined as HVPG of ≥10 mmHg, at which point varices may develop [4].
- Measurement of HVPG provides independent prognostic information on survival.
- HPVG helps assess the risk of decompensation after resection in patients with compensated cirrhosis and hepatocellular cancer

The diagnosis of portal hypertension is made on a clinical basis when a patient with cirrhosis presents with complications of portal hypertension. Direct portal vein measurement via a transhepatic, transjugular or umbilical vein approach is the gold standard but is invasive with a risk of bleeding. The wedged hepatic venous pressure (WHVP) can be measured using a balloon catheter which is wedged in the hepatic vein. Subsequently, the balloon is deflated to measure the free hepatic venous pressure (FHVP). The corrected sinusoidal HVPG is calculated by subtracting the free hepatic venous pressure (FHVP, which reflects intra-abdominal pressure) from the wedged hepatic venous pressure (WHVP, which reflects hepatic sinusoidal portal venous pressure and intra-abdominal pressure). The technique is accurate in the majority of patients with cirrhosis that involves sinusoidal scarring. Other methods to diagnose portal hypertension include ultrasound and elastography; however, ultrasound lacks the sensitivity, and elastography, though it has good correlation with liver fibrosis, is an indirect measure of portal hypertension and is susceptible to confounding factors; additionally, it does not account for extrahepatic causes of portal hypertension [5].

Cirrhosis can remain compensated for many years before the development of a decompensating event. Decompensation includes the development of any of the abovementioned complications of portal hypertension. Managing portal hypertension revolves around preventing or treating its complications. The former (preventing complications) is applicable in patients with compensated cirrhosis (Child-Pugh A) while the later (treating complications) is applicable in decompensated cirrhosis (Child-Pugh B or C). Preventing complications of portal hypertension involves regular screening of patients with Child-Pugh A cirrhosis with endoscopy and managing the portal blood pressure medically. The goal of preventative measures is to avoid the first variceal bleed, which is termed primary prophylaxis. Discussion of preventative measures is beyond the scope of this chapter and discussed elsewhere in this book.

Variceal bleeding is the most dreaded complication of portal hypertension with a 1-year mortality of 50% [6]. Endoscopic therapy (either variceal ligation or sclerotherapy) is the first line treatment for acute variceal hemorrhage. However, when rebleeding occurs, more definite therapy is required. This definitive treatment to reduce portal hypertension, outside of liver transplant, is by creation of a portacaval shunt to decompress the system. Historically, surgical shunts, whereby a connection between the portal vein and vena cava provides a low resistance outlet, and consequently lowers variceal pressures, preventing bleeds. Today, surgical shunts are not commonly used for the treatment of portal hypertension as percutaneous options have largely replaced them, but they should still be understood as they do have potential clinical scenarios of utility (Fig. 58.1).

58.2 Current Treatment Options

58.2.1 Surgical Shunts

Three categories of surgical shunts including total, selective and partial shunts have been described. Portacaval and mesocaval shunts are examples of total Portacaval shunts (TPCS). End-to-side portacaval shunt is created by ligating the portal vein and connecting the proximal stump of the ligated portal vein to the side of the inferior vena cava (Fig. 58.2). Mesocaval shunt are created between the superior mesenteric vein and the inferior vena cava. Although total shunts were remarkably effective in preventing variceal bleeding, operative mortality was high and the incidence of hepatic encephalopathy and liver failure were not acceptable [7–9]. To reduce the risks, selective shunts including the proximal and distal splenorenal shunts were described. Splenorenal shunts maintain forward flow to the liver while decompressing the gastro-esophageal varices (Fig. 58.2).

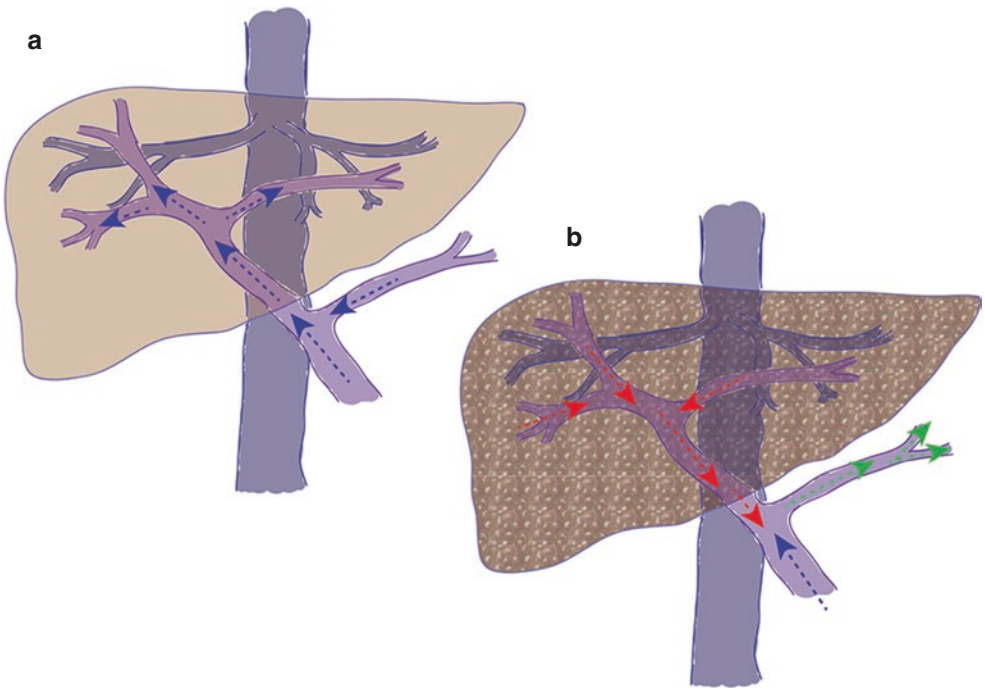

Fig. 58.1 Illustration depicting the normal flow (**a**) and hepatofugal flow seen in portal hypertensive pathology (**b**)

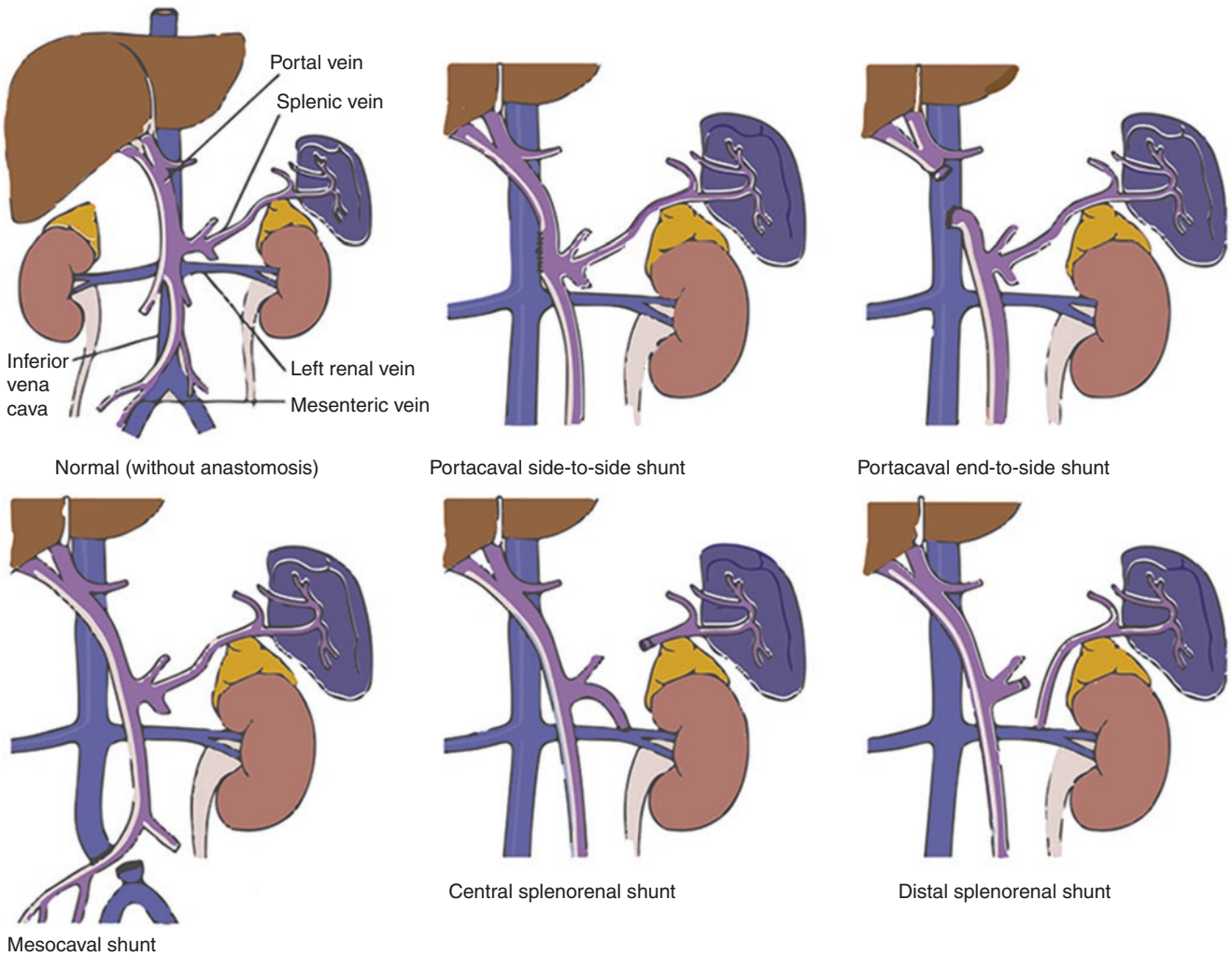

Fig. 58.2 Diagrams of common surgical shunts compared to normal vascular anatomy

Definition
Distal Splenorenal Shunts (DSRS) are created by ligating the distal splenic vein and connecting the proximal arm of the ligated splenic vein to the left renal vein in order to decompress the gastro-esophageal varices.

Definition
Proximal Splenorenal Shunts (PSRS) are created by ligating the proximal splenic vein and the distal arm is connected into the left renal vein, taking portal pressure away from the site of confluence with the superior mesenteric vein.

Clinical trials comparing TPCS to DSRS did not show significant differences in rebleeding, encephalopathy, or mortality. In addition, trials comparing DSRS with sclerotherapy found that patients had worse survival after DSRS even though that arm had better bleeding control [10]. As a result, prophylactic shunt surgery was rapidly abandoned and became only indicated as a salvage therapy.

Partial shunts including calibrated small-diameter portocaval H-graft shunts were eventually designed with the same end goal as DSRS. If the volume of shunted portal blood could be regulated, suppression of variceal bleeding without incurring hepatic encephalopathy or liver dysfunction could be achieved. There have been few RCTs to date evaluating the efficacy of this shunt. Partial shunts were shown to have better encephalopathy-free survival compared to total surgical shunts, and are easier to handle in subsequent transplants, but more data is needed [11, 12].

Ideal surgical shunt candidates in which PCS may be attempted are those who have well-preserved liver function but fail emergent endoscopic therapy or those who are not excellent surgical candidates, but have a contraindication to TIPS placement.

58.2.2 Percutaneous Shunts

58.2.2.1 Transjugular Intrahepatic Portosystemic Shunt (TIPS)

Creation of a transjugular intrahepatic portosystemic shunt (TIPS) is a well-established procedure recommended for patients suffering from sequelae of portal hypertension that is refractory to medical management. An effective end-to-end portacaval shunt between a branch of the portal vein and usually the right hepatic vein, which flows into the inferior vena cava, is created to decompress the portal system

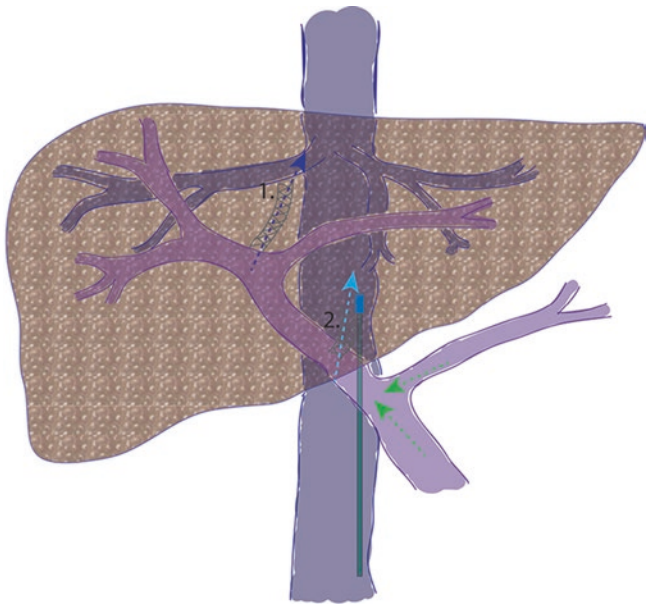

Fig. 58.3 Illustration demonstrating placement and flow of TIPS procedure (1) and DIPS procedure (2) using IVUS and improved portal flow (blue arrows)

(Fig. 58.3). TIPS is performed in the interventional radiology lab with moderate sedation or general anesthesia. Creation of a TIPS shunts is preferred over surgical shunts in patients who are transplant candidates as the extra-hepatic anatomy is not altered.

The most widely supported indications for TIPS include secondary prevention of variceal bleeding and refractory ascites. Multiple randomized controlled studies and several meta-analyses have proven the utility of TIPS creation in both these conditions. It has been shown to be superior in long-term prevention of rebleeding compared to endoscopic therapy [13]. In the treatment of refractory ascites, TIPS has been shown not only to control ascites in 70% of cases [14], it has also been shown to increase transplant-free survival as compared to large volume paracentesis (LVP) [14–16]. The meta-analysis summarizing five of the six RCTs found a 7.1-fold reduction in the risk of recurrent tense ascites after TIPS [11, 17, 18]. The first line treatment for acute variceal bleeding includes vasoactive pharmacotherapy and endoscopic sclerotherapy or banding. Failure to achieve hemostasis occurs in 20% of patients undergoing the first line treatment [3]. TIPS is considered the second line treatment due to higher incidence of hepatic encephalopathy but achieves hemostasis in 95% of acute variceal bleeding [19].

The utility of TIPS shunt creation in the treatment of Budd-Chiari Syndrome (BCS) is highly dependent on etiology. In primary BCS the patency and long-term survival is promising [20]. It has been postulated that using TIPS to return intravascular volume from the splanchnic circulation to the systemic circulation should improve renal status in

cirrhotic patients with hepatorenal syndrome. Currently, there is 2B evidence [21] for using TIPS in the treatment of hepatorenal syndrome. One study even screened patients likely to benefit by verifying response to combination therapy of midodrine, octreotide, and albumin. They then saw further normalization of kidney function with the implementation of TIPS [22, 23]. Portal Hypertensive gastropathy has only level 4 evidence to support the use of TIPS for primary treatment [22, 24]. It has been shown to improve endoscopic endpoints and clinically stop hemorrhage in a case study.

Contraindications to TIPS placement a mostly related to the hemodynamic changes that take place after TIPS placement. Severe congestive heart failure, tricuspid regurgitation, and severe pulmonary hypertension (mean pulmonary pressure >45 mmHg) are all absolute contraindications due to the massive increase in preload that results after blood is shunted from the portal vein to the IVC. If there is evidence that the patient's cardiopulmonary system cannot handle the increased load from the shunt, it should not be placed. Other absolute contraindications are multiple hepatic cysts, bacteremia or sepsis, and unrelieved biliary obstruction. Relative contraindications include portal venous thrombosis, hepatocellular cancer, moderate pulmonary hypertension, obstruction of all hepatic veins, uncorrectable coagulopathy or thrombocytopenia, and existing hepatic encephalopathy [25].

The overall goal is the placement of a stent allowing for portal flow from the portal vein to the Inferior vena cava through the hepatic veins, thus creating a low resistance shunt to relieve elevated portal pressures. This reduction of the portosystemic gradient is successful in over 90% of cases [21]. This is accomplished by obtaining vascular access to the right jugular vein, traversing the superior vena cava through the right atrium, and into the inferior vena cava. From this point, the right or middle hepatic vein is cannulated and hepatic pressures are recorded. Next, a needle assembly is advanced over the wire through a sheath and used to traverse the liver parenchyma and enter the portal vein. After establishing access to the portal vein, portal pressures are obtained. Subsequently, the parenchymal tract is dilated with a balloon catheter and the stent graft is deployed. It is vital to ensure that the appropriate size endograft is selected so that it completely covers the tract, decreasing chances of stent stenosis from fibrous tissue overgrowth at the hepatic venous end. Furthermore, angiographic evidence of reversal of hepatofugal flow and decreased varices, as well as treatment to HVPG of less than 12 mmHg significantly decreases the likelihood of variceal rebleeding (seen in Fig. 58.4).

Complication rates continue to decrease as technique improves. Currently, only 3% of patients experience major complications and the likelihood of minor complications is

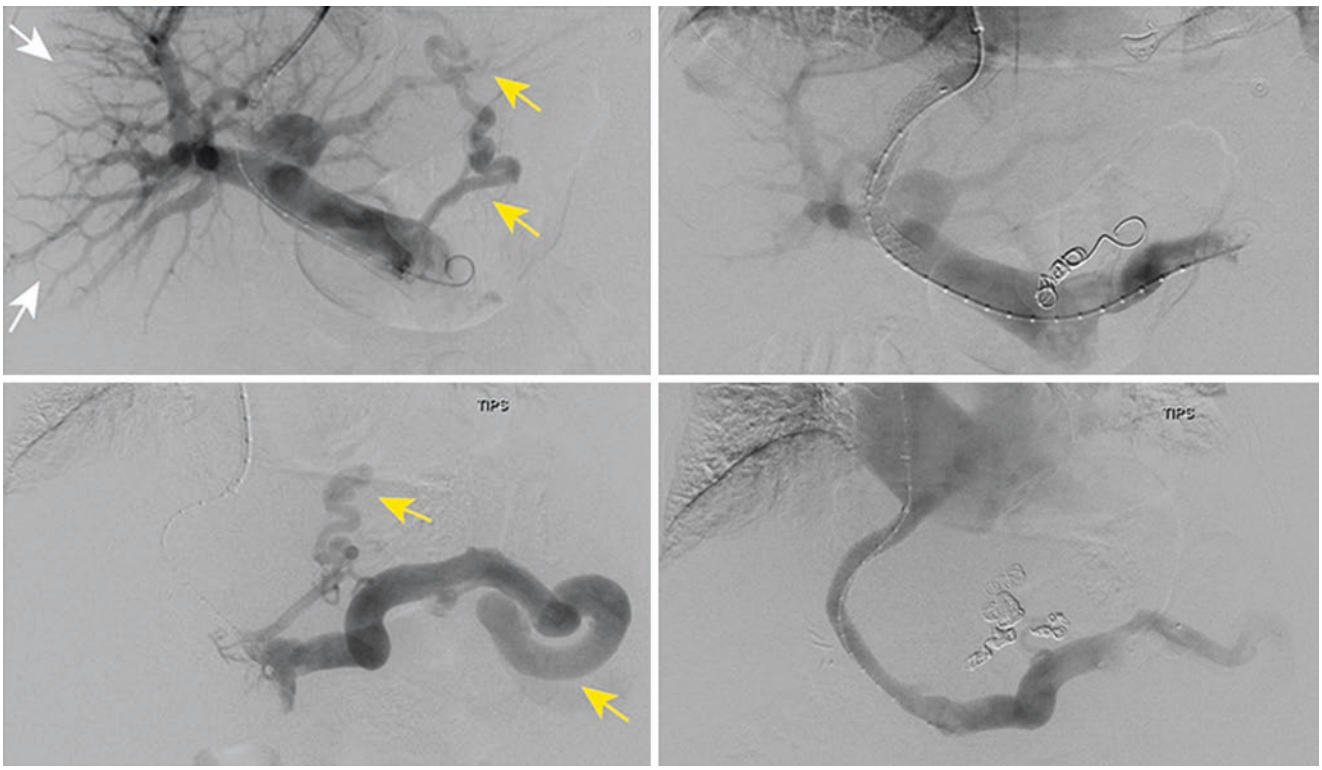

Fig. 58.4 TIPS Procedure showing resolution portal hepatic congestion (white arrow) and gastro-esophageal varices (yellow arrows) before (left) and after (right) shunt placement

reported at 4% [26]. In addition, procedural mortality is only 1.7% [26]. Of the complications that patients may experience, the most commonly encountered are hepatic encephalopathy, variceal hemorrhage, and stent dysfunction. TIPS stent dysfunction can happen due to technical failure (e.g. stent shortening that leads to thrombosis, or biliary stent fistula), parenchymal stenosis due to excessive fibrotic healing response, or late "Pseudo-intimal" hyperplasia of the hepatic vein [27].

In response to the relatively high rates of stent dysfunction, bare metal stents (BMS) were presumed to be more susceptible to the pseudo-intimal hyperplasia and polytetrafluoroethylene (PTFE)-covered stents were introduced to prevent this stenosis. At this point, the evidence is robust enough to deem PTFE-covered stents as superior to bare metal stents [28–30] as a strong meta-analysis that includes four RCTs demonstrated that covered stents are almost 5 times more likely to retain primary patency, two-thirds less likely to have rebleeding as a complication, and survival is superior with an odds ratio of 1.85 [31]. It appears that covered stents are less predisposed to pseudo-intimal hyperplasia and this is thought to be the reason for better patency rates. It has been demonstrated that stent to inferior vena cava distance (SIVCD) has no negative effect on primary patency of TIPS when performed with covered stents as opposed to BMS [27]. In terms of sizing, 10-mm PTFE-covered stent have been shown to better control refractory ascites in patients with cirrhosis, compared with an 8-mm stent, and importantly, without increasing the incidence of hepatic encephalopathy [17]. As a result, the American Association for the Study of Liver Diseases (AASLD) now recommends the use of PTFE covered stents over bare metal stents.

As an important way to manage patients with uncontrollable variceal bleeding and recurrent variceal bleeding, studies on the outcomes of early TIPS placement have shown that risk stratification is vital. Those patients with a persistent HPVG at 20 mmHg or above were at higher risk for recurrent bleeding despite best medical therapy and were shown to benefits from early TIPS intervention. Early TIPS intervention has been shown to have improved 1-year survival of 86% over 76% in the drug + Endoscopic Therapy (ET) group for acute variceal bleeding [32–35].

58.2.2.2 Direct Intrahepatic Portacaval Shunt (DIPS)

The Direct Intrahepatic Portacaval Shunt (DIPS) was first described by Petersen et al. [36] as a response to common failures observed when performing the more established TIPS procedure. The goal was to address parenchymal tract overgrowth at the hepatic venous end and prevent the most common cause of TIPS failure by means of bypassing it completely. In addition, exclusion of the hepatic vein allows for the DIPS procedure to treat those with hepatic veno-occlusive disease (i.e. Budd-Chiari Syndrome). Direct Intrahepatic Portacaval Shunt (DIPS) is a modification to the original TIPS procedure where an artificial communication between the IVC and portal vein is created through the caudate lobe. DIPS also allows for decreased radiation exposure due to real-time image guidance as intravascular ultrasound (IVUS). IVUS is used to navigate from the IVC to the portal vein (See Figs. 58.3 and 58.5). The other described benefit of this modification is that the much shorter liver tract decreases susceptibility to stent stenosis from fibrous tissue overgrowth [37, 38].

Indications for the DIPS procedure are identical to that of the TIPS; however, the evidence backing these indications is not as robust at this point as DIPS is still a relatively new procedure. However, it seems to have good indication for portal hypertension secondary to hepatic veno-occlusive disease, patients with difficult vascular anatomy, those with unsuitable parenchymal tract [39], and DIPS may be considered in patients needing secondary intervention after an occluded TIPS [40].

Contraindications to DIPS mirror those of TIPS, with absolute contraindications being severe congestive heart failure, tricuspid regurgitation, severe pulmonary hypertension, multiple hepatic cysts, bacteremia or sepsis, and unrelieved biliary obstruction. Relative contraindications are fewer without obstruction of hepatic or portal veins being as much a concern. Moderate pulmonary hypertension, uncorrectable coagulopathy or thrombocytopenia, and existing hepatic encephalopathy are still relative contraindications [25].

The DIPS procedure begins with femoral venous access for introduction of the IVUS catheter which is placed in the retrohepatic IVC. Next, an echo tip trocar needle is advanced from a jugular access point to the same level of the IVC. Portal access is then created by advancement of the echo tip trocar needle under real-time ultrasound guidance through the liver and into the portal vein. This can be confirmed with aspiration or contrast-injection. Rest of the procedure is similar to a conventional TIPS procedure.

Complications of DIPS placement are identical to those of TIPS placement and include hepatic encephalopathy, variceal hemorrhage, and stent dysfunction. Although the theoretical risk of stent occlusion by parenchymal tract hypertrophy is reduced, more evidence is needed to substantiate this conclusion. Additionally, in patients with extrahepatic portal vein anatomy, there have been minor complications due to hemoperitoneum.

58.2.2.3 Percutaneous Mesocaval Shunt

One of the main benefits of using a mesenteric vessel as a connection to the systemic vasculature is the preservation of native portal venous anatomy in order for subsequent liver transplantation. This was the concept behind surgical mesocaval shunts, and has now been adapted as a percutaneous procedure. The percutaneous mesocaval shunt also allows

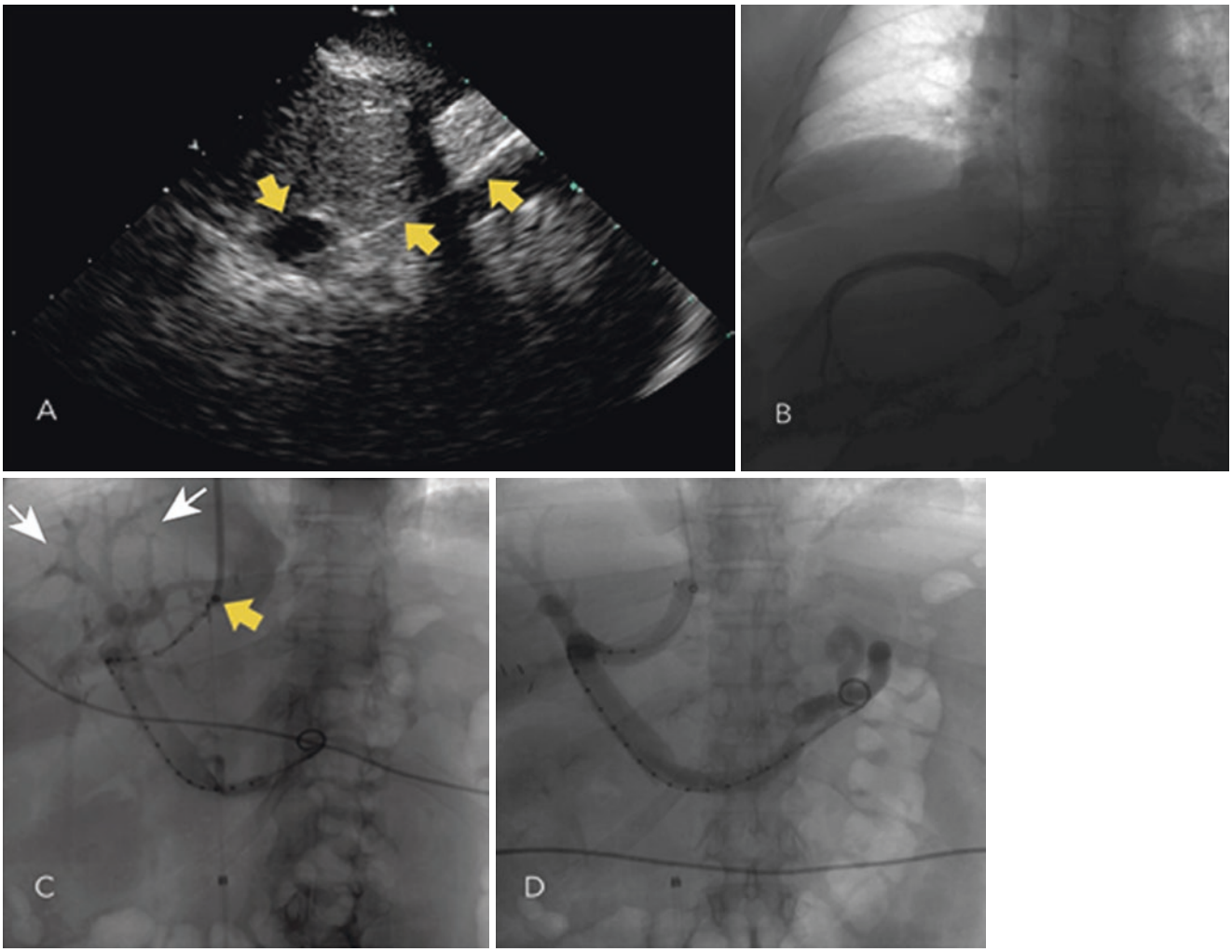

Fig. 58.5 DIPS Procedure showing echogenic needle (yellow arrows) traversing the IVC through the caudate lobe and into the portal vein (**a**), measuring catheter before stent placement (**b**) and after (**c**) demonstrating resolution of portal hepatic congestion (white arrows), (**d**) Completion venography after placement of a DIPS from the IVC to left portal vein

for patients with chronically occluded portal veins, who are not good candidates for TIPS, to have their portal hypertension treated [37].

Indications are again identical to the TIPS procedure; however, percutaneous mesocaval shunts (PMCS) allow for the circumvention of absolute and relative contraindications based on hepatic anatomy that can make TIPS difficult (Hepato-occlusive venous disease, severe hepatic cysts, etc.).

Absolute contraindications are still severe congestive heart failure, tricuspid regurgitation, severe pulmonary hypertension, multiple hepatic cysts, bacteremia or sepsis, and unrelieved biliary obstruction. Moderate pulmonary hypertension, uncorrectable coagulopathy or thrombocytopenia, and existing hepatic encephalopathy are still relative contraindications.

A transjugular or percutaneous mesocaval shunt procedure beings with a retrieval device, usually a snare basket, being placed through the internal jugular vein down to the IVC near the level of the desired shunt. After bowel preparation and prophylactic antibiotics, a 20-gauge Chiba needle is directed through the anterior abdominal wall under CT-guidance. It is advanced through-and-through the SMV and into the IVC. A wire is advanced through the chiba needle and introduced into the previously place snare. The wire is snared and pulled out through the jugular sheath, effectively leaving a wire percutaneously that travels from SMV to IVC and out the jugular sheath. Then a catheter is advanced over the wire, keeping a second wire as the safety wire. Using the working wire, access is obtained further into the SMV. At this point, the percutaneous safety wire is removed, and the stent can be advanced over the working wire. After dilation, pressures and venogram can be taken to confirm appropriate placement and function of the shunt [41] (Fig. 58.6).

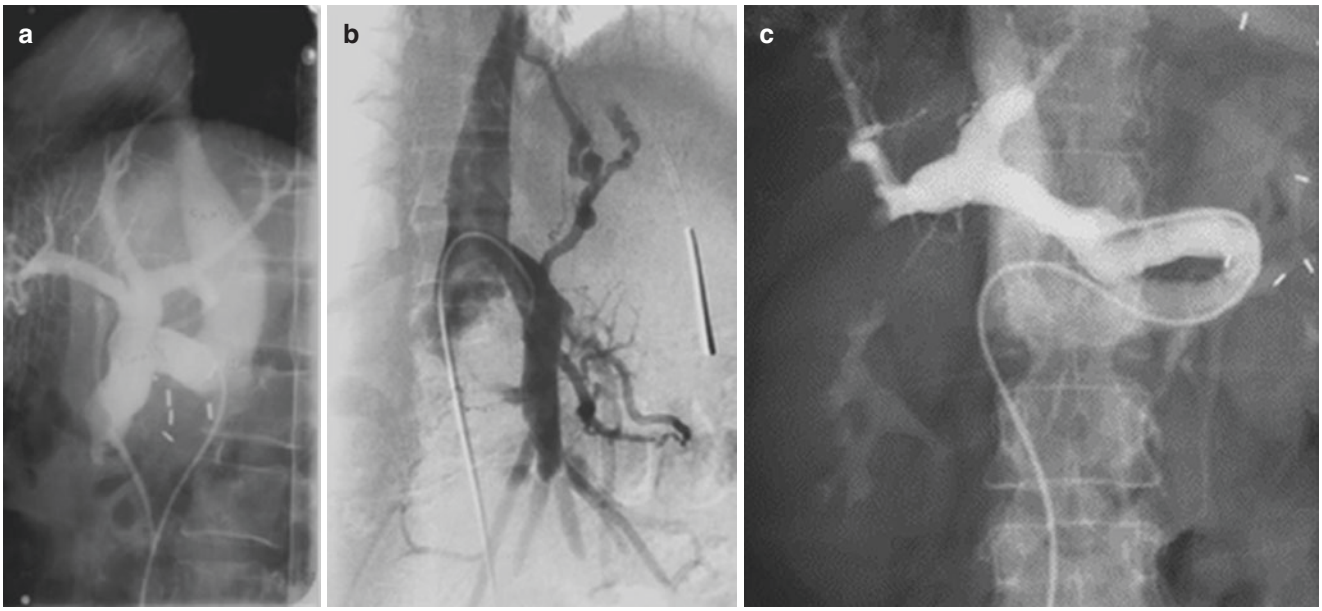

Fig. 58.6 Surgical Shunts visualized via angiography: Portacaval shunt (**a**), Mesocaval shunt (**b**), and Distal splenorenal shunt (**c**)

58.3 Comparison of Available Portocaval Shunting Procedures (Table 58.1)

Table 58.1 Comparison of relative complications across portacaval shunt types

Complications	Surgical shunt	TIPS	DIPS	Mesocaval
Operative mortality	+++	+	+	++
Cont. variceal bleeding	–	+	+	+
Hepatic encephalopathy	+++	+++	+++	?
Stent dysfunction	+	++	–	?
Acute liver failure	+	+	+	–
Hemoperitoneum	–	–	+	++
Bile Leaks	–	+	–	–

58.4 Future Directions

The DIPS procedure appears to be an excellent alternative to the standard TIPS treatment. The main advantages over a TIPS placement are that common failures due to bile leaks, tract hyperplasia, and hepatic vein occlusion are either excluded or much less likely (e.g. tract hyperplasia). Additionally, intravascular US used in DIPS placement allows for visualization portal vein puncture, the most technically challenging and dangerous aspect of TIPS creation. Finally, the widened indications for patients with altered intrahepatic anatomy and portal veno-occlusive disease of the hepatic or portal vein are more easily circumvented [36]. Further studies are currently needed to better quantify the complication rates for DIPS as well as randomized clinical trials to compare TIPS against DIPS on a broader level with stratification based on indication.

Self Study

Questions

1. Which is not an absolute contraindication to TIPS placement?
   (a) Severe Pulmonary Hypertension
   (b) Hepatocellular Carcinoma
   (c) Severe Congestive Heart Failure
   (d) Multiple Hepatic Cysts
2. Which statement is true?
   (a) Early TIPS treatment improves outcome in patients with persistently high HVPG
   (b) DIPS significantly increases patency rates compared to TIPS
   (c) Covered (PTFE) stent grafts have similar patency to Bare metal stents
   (d) TIPS placement for the treatment of refractory ascites is effective is 90% of patients

Answers

1. Which is not an absolute contraindication to TIPS placement?
   (a) Severe pulmonary hypertension is an absolute contraindication TIPS placement as shunt creation will rapidly increase portal venous return to the right side of the heart, leading to exacerbation of pulmonary hypertension, which can lead to right heart failure and circulatory collapse.

(b) CORRECT ANSWER. Hepatocellular carcinoma is a not an absolute contraindication to TIPS. HCC most commonly arises in a background of cirrhosis and as such will likely have sequelae of portal hypertension that may benefit from TIPS. Unless the HCC is directly occluding the majority of the hepatic veins, portal vein, or their is a large degree portal venous thrombosis (PVT), HCC does not present issues with shunt placement.

(c) Severe congestive heart failure is also an absolute contraindication to TIPS, for similar reasons as severe pulmonary hypertension. The rapid increase blood volume returning to the right side of the heart is likely to overload the already failing heart and lead to circulatory collapse and death.

(d) A multitude of hepatic cysts can lead to compression of venous structures, obstruction of parenchymal tracts, and increased risk of hemorrhage.

2. Which statement is true?

(a) CORRECT ANSWER. Studies have shown that patients who fail to respond to Endoscopic therapy and medical management with a decrease in HVPG below 20 mmHg are at significantly increased risk of rebleed and benefit from early intervention with TIPS placement.

(b) Although theoretically performing DIPS increases the patency rates compare to TIPS as the hepatic venous stenosis from TIPS creation is avoided, not enough studies have been conducted to evaluate the potential benefit of increased patency.

(c) Many RCTs have demonstrated improved patency, survival and decreased rates of bleeding with use of PTFE covered stents compared to bare metal stents. In fact, the AASLD now officially recommends the use of PTFE covered stents over bare metal stents.

(d) TIPS placement in the setting of refractory ascites results in 70% resolution of ascites in addition to a significant improvement in transplant free survival

References

1. Benoit JN, Womack WA, Hernandez L, Neil Granger D. "Forward" and "backward" flow mechanisms of portal hypertension: relative contributions in the rat model of portal vein stenosis. Gastroenterology. 1985;89:1092–6.
2. Iwakiri Y. Pathophysiology of portal hypertension. Clin Liver Dis. 2014;18:281–91.
3. Garcia-Tsao G. Current management of the complications of cirrhosis and portal hypertension: variceal hemorrhage, ascites, and spontaneous bacterial peritonitis. Gastroenterology. 2001;120:726–48.
4. Reiberger T, Püspök A, Schoder M, et al. Austrian consensus guidelines on the management and treatment of portal hypertension (Billroth III). Wien Klin Wochenschr. 2017;129:135–58.
5. Roccarina D, Rosselli M, Genesca J, Tsochatzis EA. Elastography methods for the non-invasive assessment of portal hypertension. Expert Rev Gastroenterol Hepatol. 2018;12:155–64.
6. Graham DY, Smith JL. The course of patients after variceal hemorrhage. Gastroenterology. 1981;80:800–9.
7. Jackson FC, Perrin EB, Felix WR, Smith AG. A clinical investigation of the portacaval shunt. V. Survival analysis of the therapeutic operation. Ann Surg. 1971;174:672–701.
8. Rueff B, Prandi D, Degos F, Sicot J, Degos JD, Sicot C, Maillard JN, Fauvert R, Benhamou JP. A controlled study of therapeutic portacaval shunt in alcoholic cirrhosis. Lancet. 1976;1:655–9.
9. Resnick RH, Iber FL, Ishihara AM, Chalmers TC, Zimmerman H. A controlled study of the therapeutic portacaval shunt. Gastroenterology. 1974;67:843–57.
10. Henderson JM, Kutner MH, Millikan WJ Jr, Galambos JT, Riepe SP, Brooks WS, Bryan FC, Warren WD. Endoscopic variceal sclerosis compared with distal splenorenal shunt to prevent recurrent variceal bleeding in cirrhosis. A prospective, randomized trial. Ann Intern Med. 1990;112:262–9.
11. D'amico G, Pagliaro L, Bosch J. The treatment of portal hypertension: a meta-analytic review. Hepatology. 1995;22:332–54.
12. Sarfeh IJ, Rypins EB. Partial versus total portacaval shunt in alcoholic cirrhosis. Results of a prospective, randomized clinical trial. Ann Surg. 1994;219:353–61.
13. Papatheodoridis GV, Goulis J, Leandro G, Patch D, Burroughs AK. Transjugular intrahepatic portosystemic shunt compared with endoscopic treatment for prevention of variceal rebleeding: a meta-analysis. Hepatology. 1999;30:612–22.
14. Salerno F, Cammà C, Enea M, Rössle M, Wong F. Transjugular intrahepatic portosystemic shunt for refractory ascites: a meta-analysis of individual patient data. Gastroenterology. 2007;133:825–34.
15. Bureau C, Thabut D, Oberti F, et al. Transjugular intrahepatic portosystemic shunts with covered stents increase transplant-free survival of patients with cirrhosis and recurrent ascites. Gastroenterology. 2017;152:157–63.
16. Bai M, Qi X-S, Yang Z-P, Yang M, Fan D-M, Han G-H. TIPS improves liver transplantation-free survival in cirrhotic patients with refractory ascites: an updated meta-analysis. World J Gastroenterol. 2014;20:2704–14.
17. Miraglia R, Maruzzelli L, Tuzzolino F, Petridis I, D'Amico M, Luca A. Transjugular intrahepatic portosystemic shunts in patients with cirrhosis with refractory ascites: comparison of clinical outcomes by using 8- and 10-mm PTFE-covered stents. Radiology. 2017;284:281–8.
18. D'Amico G, Luca A. TIPS is a cost effective alternative to surgical shunt as a rescue therapy for prevention of recurrent bleeding from esophageal varices. J Hepatol. 2008;48:387–90.
19. Boyer TD, Haskal ZJ. AASLD practice guidelines the role of transjugular intrahepatic portosystemic shunt (TIPS) in the management of portal hypertension update 2009. Hepatology. 2010;51:306.
20. Hayek G, Ronot M, Plessier A, Sibert A, Abdel-Rehim M, Zappa M, Rautou P-E, Valla D, Vilgrain V. Long-term outcome and analysis of dysfunction of transjugular intrahepatic portosystemic shunt placement in chronic primary Budd-Chiari syndrome. Radiology. 2017;283:280–92.
21. Fidelman N, Kwan SW, LaBerge JM, Gordon RL, Ring EJ, Kerlan RK Jr. The transjugular intrahepatic portosystemic shunt: an update. AJR Am J Roentgenol. 2012;199:746–55.
22. Siramolpiwat S. Transjugular intrahepatic portosystemic shunts and portal hypertension-related complications. World J Gastroenterol. 2014;20:16996–7010.
23. Wong F, Pantea L, Sniderman K. Midodrine, octreotide, albumin, and TIPS in selected patients with cirrhosis and type 1 hepatorenal syndrome. Hepatology. 2004;40:55–64.
24. Mezawa S, Homma H, Ohta H, Masuko E, Doi T, Miyanishi K, Takada K, Kukitsu T, Sato T, Niitsu Y. Effect of transjugular intrahepatic portosystemic shunt formation on portal hyperten-

sive gastropathy and gastric circulation. Am J Gastroenterol. 2001;96:1155–9.
25. Patidar KR, Sanyal AJ. Transjugular intrahepatic portosystemic shunt for refractory ascites in patients with high model for end-stage liver disease scores. Clin Liver Dis. 2016;7:84–7.
26. Franklin VR, Simmons LQ, Baker AL. Transjugular intrahepatic portosystemic shunt: a literature review. J Diagn Med Sonogr. 2018;34:114–22.
27. Andring B, Kalva SP, Sutphin P, Srinivasa R, Anene A, Burrell M, Xi Y, Pillai AK. Effect of technical parameters on transjugular intrahepatic portosystemic shunts utilizing stent grafts. World J Gastroenterol. 2015;21:8110–7.
28. Bureau C, Garcia-Pagan JC, Otal P, et al. Improved clinical outcome using polytetrafluoroethylene-coated stents for TIPS: results of a randomized study. Gastroenterology. 2004;126:469–75.
29. Bureau C, Pagan JCG, Layrargues GP, et al. Patency of stents covered with polytetrafluoroethylene in patients treated by transjugular intrahepatic portosystemic shunts: long-term results of a randomized multicentre study. Liver Int. 2007;27:742–7.
30. Perarnau JM, Le Gouge A, Nicolas C, et al. Covered vs. uncovered stents for transjugular intrahepatic portosystemic shunt: a randomized controlled trial. J Hepatol. 2014;60:962–8.
31. Triantafyllou T, Aggarwal P, Gupta E, Svetanoff WJ, Bhirud DP, Singhal S. Polytetrafluoroethylene-covered stent graft versus bare stent in transjugular intrahepatic portosystemic shunt: systematic review and meta-analysis. J Laparoendosc Adv Surg Tech A. 2018;28:867–79.
32. Garcia-Pagán JC, Di Pascoli M, Caca K, et al. Use of early-TIPS for high-risk variceal bleeding: results of a post-RCT surveillance study. J Hepatol. 2013;58:45–50.
33. Deltenre P, Trépo E, Rudler M, et al. Early transjugular intrahepatic portosystemic shunt in cirrhotic patients with acute variceal bleeding: a systematic review and meta-analysis of controlled trials. Eur J Gastroenterol Hepatol. 2015;27:e1–9.
34. Monescillo A, Martínez-Lagares F, Ruiz-del-Arbol L, et al. Influence of portal hypertension and its early decompression by TIPS placement on the outcome of variceal bleeding. Hepatology. 2004;40:793–801.
35. Garcia-Tsao G, Bosch J. Management of varices and variceal hemorrhage in cirrhosis. N Engl J Med. 2010;362:823–32.
36. Petersen B, Uchida BT, Timmermans H, Keller FS, Rosch J. Intravascular US-guided direct intrahepatic portacaval shunt with a PTFE-covered stent-graft: feasibility study in swine and initial clinical results. J Vasc Interv Radiol. 2001;12:475–86.
37. Casadaban LC, Gaba RC. Percutaneous portosystemic shunts: TIPS and beyond. Semin Intervent Radiol. 2014;31:227–34.
38. Petersen BD, Clark TWI. Direct intrahepatic portocaval shunt. Tech Vasc Interv Radiol. 2008;11:230–4.
39. Kawahara Y, Tanaka Y, Isoi N, et al. Direct intrahepatic portocaval shunt for refractory hepatic hydrothorax: a case report. Acute Med Surg. 2017;4:306–10.
40. Kirby JM, Cho KJ, Midia M. Image-guided intervention in management of complications of portal hypertension: more than TIPS for success. Radiographics. 2013;33:1473–96.
41. Nyman UR, Semba CP, Chang H, Hoffman C, Dake MD. Percutaneous creation of a mesocaval shunt. J Vasc Interv Radiol. 1996;7:769–73.