Intravascular Ultrasound for Transjugular Intrahepatic Portosystemic Shunt Creation: "TIPS" and Tricks

Josi L. Herren, DO[1] Ketan Y. Shah, MD[2] Meet Patel, MS[1] Matthew M. Niemeyer, MD[1]

[1] Division of Interventional Radiology, Department of Radiology, University of Illinois Hospital and Health Sciences System, Chicago, Illinois
[2] Department of Radiology, MD Anderson Cancer Center, Houston, Texas

Address for correspondence Matthew Niemeyer, MD, Division of Interventional Radiology, Department of Radiology, University of Illinois Hospital and Health Sciences System, 1740 West Taylor Street, MC 931, Chicago, IL 60612 (e-mail: mniemeye@uic.edu).

Semin Intervent Radiol 2023;40:212–220

This document was downloaded for personal use only. Unauthorized distribution is strictly prohibited.

Cirrhosis affects 4.5 million people in the United States.[1] Sequela of cirrhosis and portal hypertension include varices, which occur in up to 60 to 80% of cirrhotic patients and pose a bleeding risk of 25 to 35%[2]; refractory ascites, which occurs in 5 to 10% of patients[3]; recurrent hepatic hydrothorax, which occurs in 5 to 10% of cirrhotic patients[4]; and hepatic encephalopathy, which occurs in up to 45% of patients with cirrhosis.[5] Transjugular intrahepatic portosystemic shunt (TIPS) creation results in portal venous decompression and reduces mortality and morbidity associated with these portal hypertensive sequelae. There is a clear survival benefit with TIPS creation in patients at risk of variceal hemorrhage, including those who fail endoscopic banding, who are at high risk of pharmacologic or endoscopic treatment failure,[6] and who undergo early TIPS creation for secondary prophylaxis against bleeding.[7,8] For those with refractory ascites and hepatic hydrothorax, resolution of fluid accumulation can be expected in 85%[9] and 82%, respectively.[10]

First developed by Josef Rosch in 1969, TIPS has undergone multiple iterations that have improved the technical and clinical success rates, including incorporation of the bare metal stent and introduction of the Viatorr (GORE, Flagstaff, AZ) stent graft.[11] Despite such improvements, traditional fluoroscopic-guided TIPS still has limitations. Most notable are the operator's dependence on a two-dimensional (2D) understanding of the relationship between hepatic veins (HVs) and portal veins (PVs) as visualized by wedged hepatic venography, and the lack of real-time PV visualization during PV puncture. This fluoroscopic technique potentiates risks associated with multiple errant punctures, including hepatic artery pseudoaneurysm and thrombosis, biliary injury, and transcapsular perforation. Although rare, wedge venography also carries the risk of capsular rupture, which can lead to fatal bleeding and the need for additional interventions.[8] Multiple modifications have been explored to address this specific issue of PV access, including transhepatic or transsplenic access with placement of a marker wire and use of transabdominal ultrasound guidance.[12] Because all these techniques have their own risks and shortcomings, their attempts to address the remaining challenges with fluoroscopic TIPS have led to the innovative use of intravascular ultrasound (IVUS). IVUS guidance during TIPS creation allows direct, real-time visualization of PV puncture. Additionally, it facilitates accurate determination of stent size and precise stent deployment. Finally, IVUS aids in more challenging cases, such as in the setting of challenging venous anatomy (accessory right HV or small PV branches), liver masses, Budd-Chiari, and PV thrombosis.[13,14]

The application of IVUS was first reported in 1967 for intracardiac imaging. The original IVUS probe was a 5.5-Fr, over-the-wire catheter with a high frequency (20 MHz), which was a rotational transducer that provided high-resolution 360-degree cross-sectional images of the coronary arteries.[15] Subsequently, a lower frequency, phased array intracardiac echocardiography (ICE) catheter was developed to provide high resolution, real-time visualization of cardiac structures during guidance of percutaneous cardiac interventions and electrophysiology procedures. The creation of this side firing catheter opened the door for use in TIPS. When positioned in the IVC at the level of caudate lobe, the ICE catheter generates high-resolution 90-degree longitudinal sector images of the hepatic parenchyma, bile ducts, arteries, and veins, thus allowing real-time visualization of the entire needle trajectory as it traverses the hepatic parenchyma from HV to PV. This review aims to provide an evidence-based overview of the benefits of IVUS guidance during TIPS, to highlight the rotational IVUS atlas through correlation with computed tomographic (CT) and

Issue Theme Peripheral Arterial Disease; Guest Editors, Parag J. Patel, MD, MS, FSIR and Matthew J. Scheidt, MD, FSIR

© 2023. Thieme. All rights reserved.
Thieme Medical Publishers, Inc., 333 Seventh Avenue, 18th Floor, New York, NY 10001, USA

DOI https://doi.org/10.1055/s-0043-1768609.
ISSN 0739-9529.

fluoroscopic anatomy, and to provide a case-based tutorial on the techniques and benefits of IVUS guidance.

Current Intracardiac Echocardiography Catheters and Consoles

Currently, there are five side firing IVUS catheters available for use on the market. Abbott Vascular offers the ViewFlex Xtra ICE Catheter, which is compatible with the ViewMate Z and ViewMate II ultrasound consoles. Philips ICE catheters can also be used with the Philips CX50 xMatrix ultrasound system. GE Healthcare also offers portable ultrasound systems with ICE imaging capability on its Vivid S70N v204, Vivid iq 4D v204, and Vivid iq Premium v204 ultrasound systems. However, GE does not make its own ICE imaging catheters. The GE systems are compatible with the Biosense Webster CartoSound ICE Module. Siemens AcuNav ICE catheter (Siemens Healthineers) is compatible with the Acuson Siemens console. Cross-compatibility of the probes with the consoles is proprietary.

ICE Catheter Access and Basic Rotational Anatomy

It is initially disorienting to interpret IVUS images during TIPS, so an understanding of basic rotational anatomy is paramount to procedural success. The first factor affecting image orientation is the selection of venous access site for ICE catheter placement. At the author's institution, tandem right (or left) internal jugular venous access is obtained cephalad to the TIPS access. The 8-Fr ICE catheter passes easily through a 9-Fr 35 cm Bright-Tip sheath (Cordis, Hialeah, FL). The ICE catheter is not an over-the-wire catheter, so positioning the 9 Fr sheath tip in the IVC will allow for easy advancement of the catheter through the right atrium into the intrahepatic IVC. Tandem internal jugular access allows for a single operator to perform the procedure from the usual position at the patient's head, simultaneously maneuvering the TIPS needle and the IVUS probe. Alternatively, the right or left femoral vein can also be used for ICE catheter insertion. This access requires two operators, one at the head and one at the femoral vein/groin access site.[16,17]

Next, adjustments to the frequency, depth, and focal zone of the probe should be optimized for visualization of portal and HVs, which will be visualized sequentially with rotational movement of the ICE catheter. It is important to recognize that rotational anatomy is reversed when access is changed from the jugular and femoral veins. For the remainder of this review, the implied access site will be the right internal jugular vein. For further orientation, the pericaval deep liver is in the near field while the superficial liver is in the far field. Cephalad liver (segments II, IVa, VII, and VIII) is seen on screen left while caudal liver (segments III, IVb, V, VI) is seen on screen right. Cranial-caudal orientation will also reverse when access site is changed. It is worth noting that this orientation can be flipped by reversing the right-to-left orientation of the projected image on the imaging console.

Once the ICE catheter is positioned in the intrahepatic IVC, the probe should be rotated in either direction until the aorta is identified. This will be the starting point for future probe rotations and is a good reference to return to if one becomes disoriented. Rotating in a counterclockwise manner, starting once the aorta is identified, the right posterior hepatic segments will be the first to come into view. Continuing in a counterclockwise rotation, the first relevant structure to be visualized will be the right HV, seen in long axis (►**Fig. 1a**). Next, the transverse anterior and posterior branch right PVs come into view in the far and near fields, respectively (►**Fig. 1b**). Note the relationship between right hepatic and right PV, as the right HV (long) and posterior branch right PV (transverse) are often seen in the same ultrasound plane. Continue rotating counterclockwise, and the middle HV in long axis is seen. This often coincides with the bifurcation of anterior and posterior branches of the right PV to form the right PV (►**Fig. 1c**). Rotate counterclockwise to visualize the left PV as it divides and heads cephalad while the main PV dives caudally (►**Fig. 1d**). Compared with right and middle HVs, the left HV can be challenging to locate, but when cannulated with a wire and catheter, the bright reflectors from the wire make it readily apparent. Finally, by advancing the catheter caudally, the PVs will become more easily visualized and withdrawing the catheter cranially will allow visualization of the HVs and their confluence with the IVC. In the authors' experience, positioning the ultrasound catheter within the sheath does not detract significantly from imaging quality of the hepatic vasculature, allowing for easy advancement and retraction of the probe within the sheath without risk of probe buckling in the right atrium or renal veins.

Selection of Hepatic and Portal Vein Shunt Pathways

During rotational anatomical surveillance of the hepatic and PVs, it is important to note the relationships between the potential creation sites. Important considerations include length of the parenchymal tract between HV and target PV, the ability to visualize both HV and target PV in the same ultrasound plane, and the access angle required to puncture the target PV. For the third, if the target PV is too deep (in the very near field) or too superficial (in the very far field), the likelihood of successful puncture is reduced. Common shunt pathways will be described in the following paragraphs. However, it is worth emphasizing that IVUS allows for greater flexibility and predictability in selecting shunt pathways, and is particularly beneficial with variant, distorted, or complex anatomy.[17]

Right Hepatic Vein to Posterior Right Portal Vein TIPS Creation

As previously described, the right HV in its long axis is often seen in the same plane with the posterior branch right PV in transverse axis, making an easy trajectory for a right hepatic to posterior branch right portal venous TIPS creation (►**Fig. 2**). If the posterior branch right PV is not too deep,

This document was downloaded for personal use only. Unauthorized distribution is strictly prohibited.

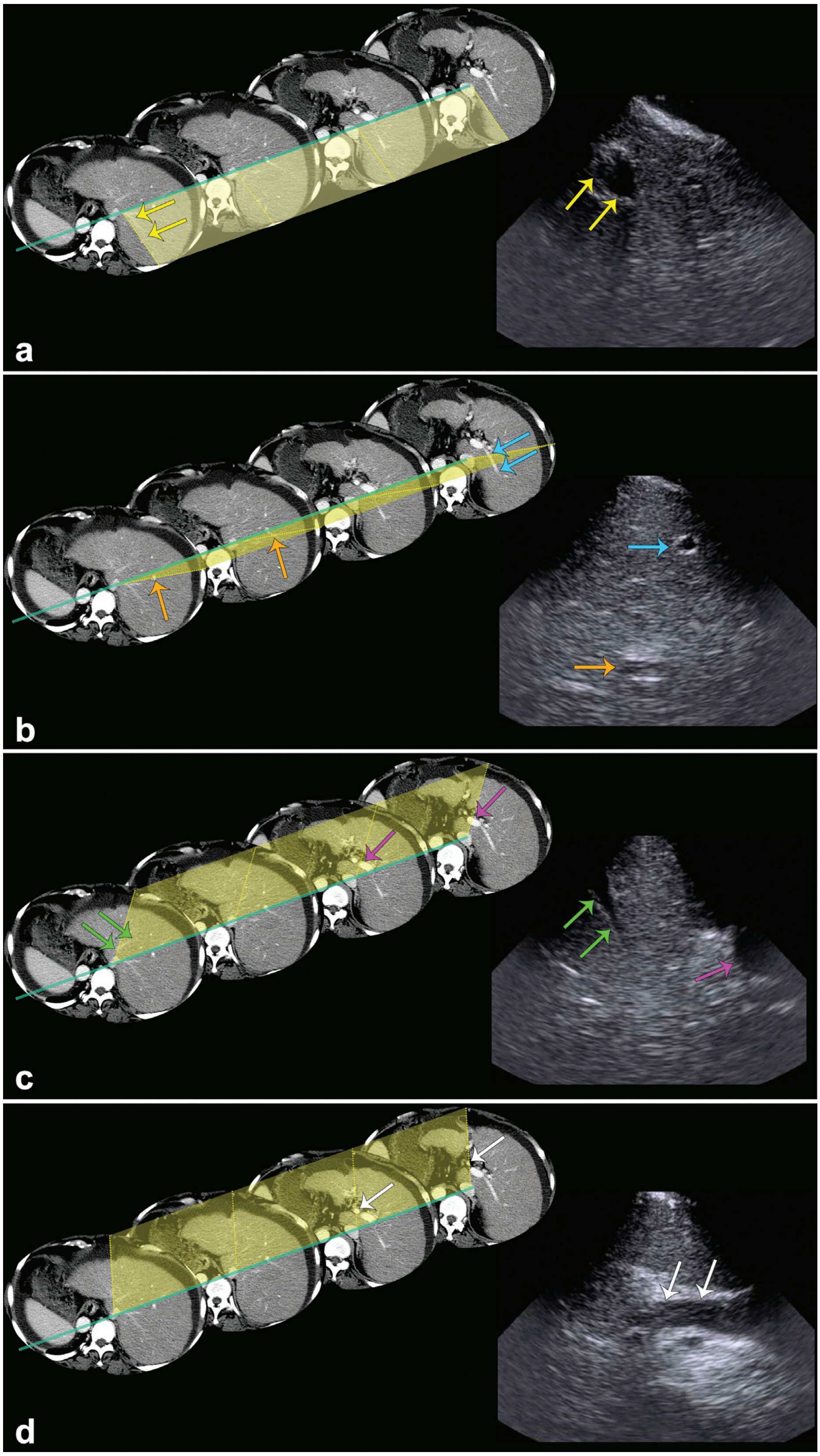

Fig. 1 Transaxial CT images have been flipped in right-to-left orientation to simulate the positioning of the patient on the angiography table, with the IVUS probe positioned in the IVC, as represented by the turquoise line. The shaded yellow trapezoid represents the ultrasound plane visualized by the probe in each image as it is rotated sequentially in a counterclockwise fashion. (**a**)The first significant anatomical landmark, the right hepatic vein, is visualized (yellow arrows). With further counterclockwise rotation, (**b**) reveals the anterior (orange arrow) and posterior (blue arrow) branches of the right portal vein. As counterclockwise rotation continues, (**c**) shows the middle hepatic vein (green arrow), which is often seen in the same plane as the right portal vein (magenta arrow). Finally, (**d**) reveals the left portal vein (white arrows).

 © 2023. Thieme. All rights reserved.

This document was downloaded for personal use only. Unauthorized distribution is strictly prohibited.

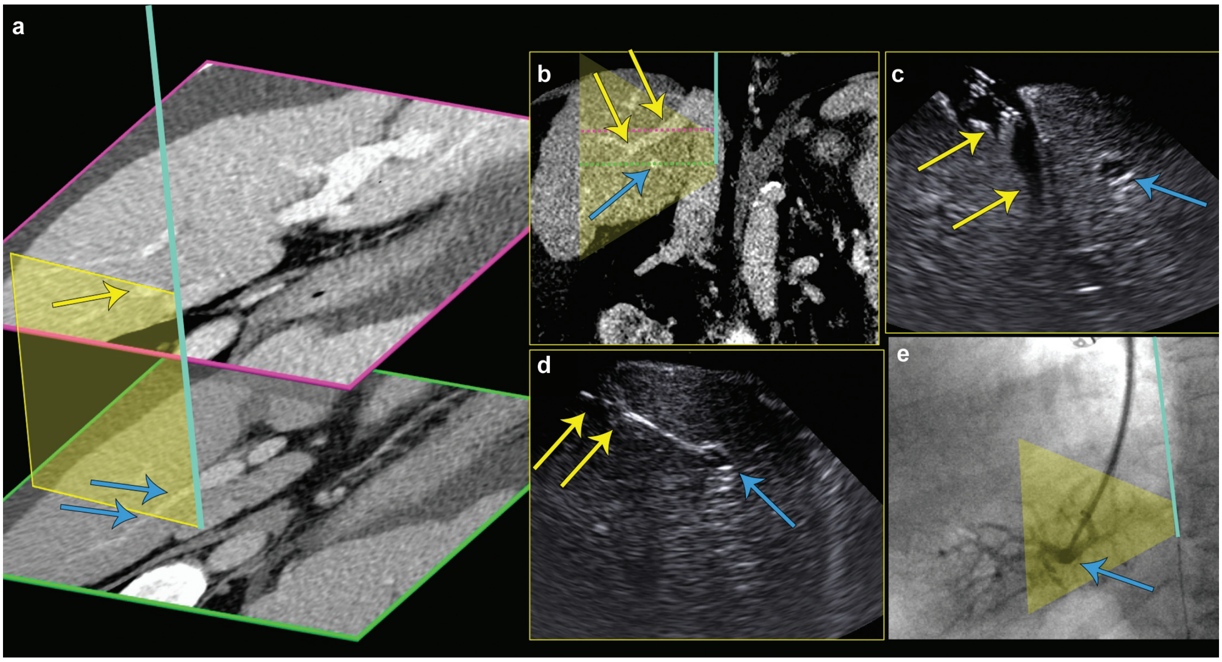

Fig. 2 Contrast-enhanced CT was obtained prior to TIPS placement, and representative transaxial (**a**) and coronal (**b**) images are shown. Magenta and green dotted lines on sagittal CT image (**b**) indicate the level of the transaxial CT images with the matching border color. The yellow-shaded trapezoid represents the plane of the IVUS ultrasound obtained in the same patient at the time of TIPS placement. IVUS images at the time of TIPS placement (**c**) reveal the catheter positioned in the right hepatic vein (yellow arrows). The target portal vein is the posterior branch right portal vein (blue arrows). Note that the right hepatic vein and posterior branch right portal vein are in the same IVUS plane. This allows for real-time visualization of the entire needle trajectory in a single plane without rotation of the IVUS probe. Subsequent IVUS image (**d**) reveals the tip of the Colapinto needle (Cook Medical, Bloomington, IN) within the posterior branch right portal vein. Contrast injection under fluoroscopy (**e**) confirms intravascular location of the needle in the posterior branch right portal vein.

it is an easy target for puncture, as the needle can be visualized throughout the entire pass without the need for any rotational adjustment of the ICE catheter. Under traditional fluoroscopic guidance, access of the posterior branch right PV poses a challenge because the wire naturally selects the peripheral PV, and therefore requires redirection centrally with an angled or reverse curve catheter. Such a maneuver requires a tenuous exchange of the TIPS needle for the catheter, and blind withdrawal of both wire and catheter near the site of PV entry for central redirection, both of which risk loss of PV access. With the presence of IVUS, the catheter and wire can be visualized within the posterior branch right PV in real time, thus ensuring that PV access is not sacrificed during central redirection of the catheter and wire into the main PV (►**Fig. 3**).

Right Hepatic Vein to Proper Right Portal Vein TIPS Creation

Conventional TIPS creation from right HV to right PV allows for easy wire advancement into the main PV, and a less acute angle between HV and PV, making deployment of the stent graft relatively straightforward. When using IVUS guidance, the right HV and right PV are not commonly visualized in the same plane. Just as the TIPS needle requires counterclockwise rotation to access the right PV, the ICE catheter must also be rotated in a counterclockwise rotation during the pass to maintain needle visualization during access (►**Fig. 4**).

Middle Hepatic Vein to Right and Left Portal Vein TIPS Creation

Like a right hepatic to posterior branch right PV pathway, the middle HV in long axis is often visualized in the same plane as the target right (and sometimes left) PV in transverse axis (►**Fig. 1c**). Thus, a middle HV to right (or left) PV shunt pathway is often the technically easiest option with IVUS guidance.[18] Sometimes, the most technically challenging aspect of this shunt pathway is the catheterization of the middle HV. Under fluoroscopic guidance alone, particularly when cirrhotic morphology and presence of ascites alters the normal course of right and middle HVs, selection and differentiation between these two veins can pose a challenge. However, with the use of ICE catheter, which can be withdrawn cephalad to the level of the hepatic venous confluence, and the middle HV can be identified by using the fluoroscopic position of the ICE catheter as a landmark for reference when selecting the middle HV. Additionally, catheterization of the middle HV (or any HV) can be confirmed in real-time by the visualization of the echogenic catheter and wire or perturbations related to saline injection within the target HV (►**Fig. 5**).

Additional ICE Catheter Techniques and Advantages for TIPS Creation

Confirmation of Portal Vein Access

During traditional fluoroscopic TIPS creation, confirmation of puncture of the target PV is dependent on aspiration of

 © 2023. Thieme. All rights reserved.

This document was downloaded for personal use only. Unauthorized distribution is strictly prohibited.

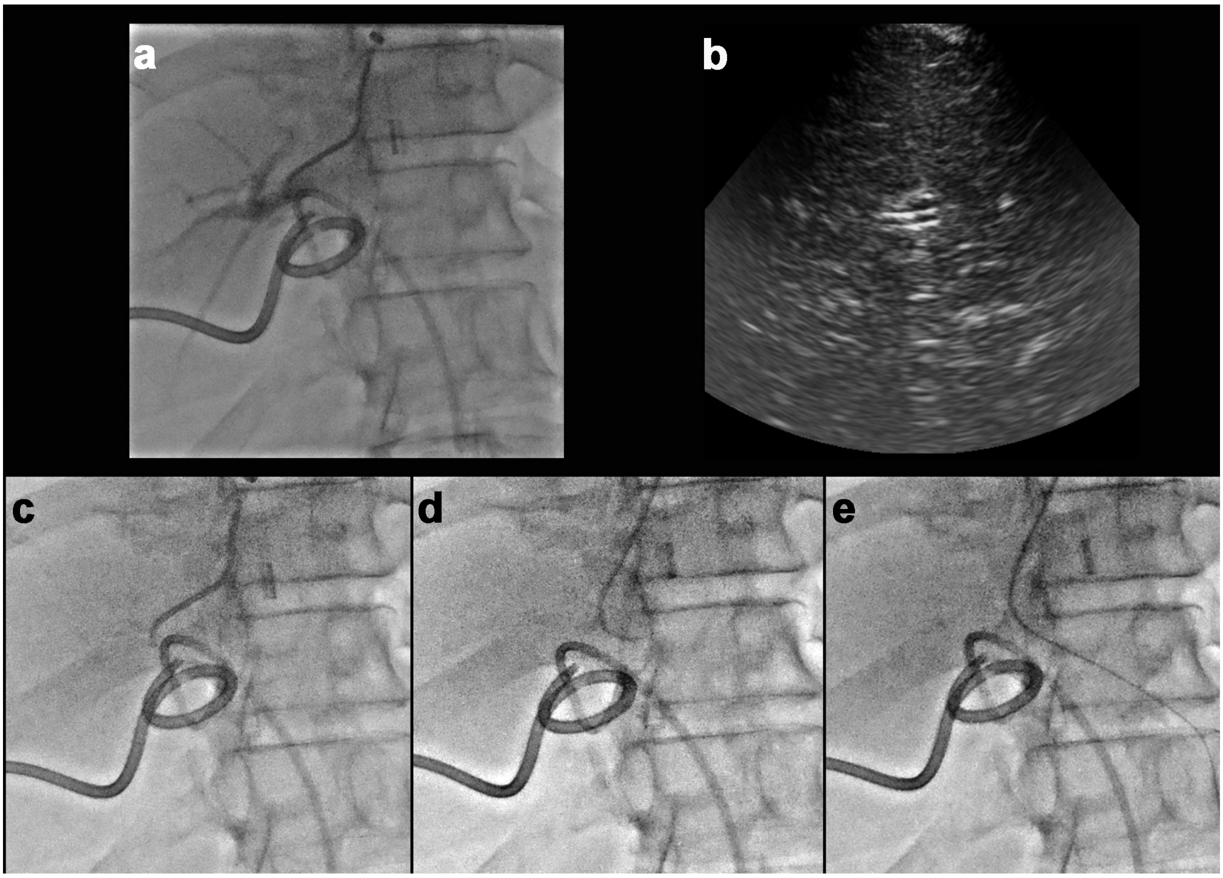

Fig. 3 Fluoroscopic image after accessing the posterior branch right portal vein from the right hepatic vein (**a**) demonstrates the tip of a 4-Fr glide catheter (Terumo, Somerset, NJ) just in the portal vein (yellow arrow). The corresponding IVUS image (**b**) demonstrates clear visualization of the catheter within the posterior branch right portal vein (yellow arrow). Real-time visualization of the catheter within the portal vein allows for more confident retraction and manipulation of the catheter and wire as they are redirected from the peripheral posterior branch right portal vein (**c**), centrally toward the main portal vein (**d**), and then advanced into the splenic vein (**e**). Such a maneuver without the assistance of IVUS risks loss of portal venous access.

blood and confirmatory injection of contrast. However, when using a hollow bore needle such as the Colapinto needle (Cook Medical, Bloomington, IN) tissue may occlude the needle and prevent aspiration. Injection of contrast without the ability to aspirate risks extravascular injection of contrast, and obscuration of future needle punctures. With the aid of IVUS, the tip can be visualized in the target PV in real-time without the need for aspiration or infusion. Upon seeing the needle tip within the PV, the operator can confidently infuse saline and observe perturbations within the PV (►**Fig. 6**) or may simply advance the wire under IVUS guidance to confirm successful PV puncture. A note of caution is to avoid injection of air, as it will obscure sonographic visualization. Finally, in patients with severe periportal fibrosis, it is the author's experience that the larger hollow bore Colapinto needle (Cook Medical) often deflects away from, or will not readily pass through, fibrotic tissue into the PV. In these cases, consider using the smaller Rosch-Uchida needle (Cook Medical) or even a 21-G Chiba needle through the guiding cannula, both of which are also readily visible with IVUS.

Stent Graft Length Measurement and Assessment of Stent Position

One of the most important steps in TIPS creation is appropriately sizing the length of the stent graft. A stent that is too short risks early TIPS malfunction due to turbulent flow and stenosis at the hepatic venous end.[19] A stent that is too long may extend into the right atrium and risks complicating future transplant surgery.[20] Reliance on a 2D fluoroscopic image with only the aid of a digital subtraction venogram and marking pigtail catheter leaves a significant level of uncertainty regarding stent graft sizing. On the other hand, IVUS allows for precise assessment of both the point of puncture into the PV and the location of the confluence of the relevant HV and IVC. The former is the site at which the O-ring of the stent graft should be positioned, and the latter is the site at which the trailing end of the stent graft should terminate. The distance between these two points thus determines the appropriate covered length of the stent graft, and this length can accurately be determined with the IVUS catheter. With a marking pigtail in the usual position across the parenchymal tract, the IVUS catheter is positioned such that the PV puncture site is directly in the middle of the IVUS image.

 © 2023. Thieme. All rights reserved.

This document was downloaded for personal use only. Unauthorized distribution is strictly prohibited.

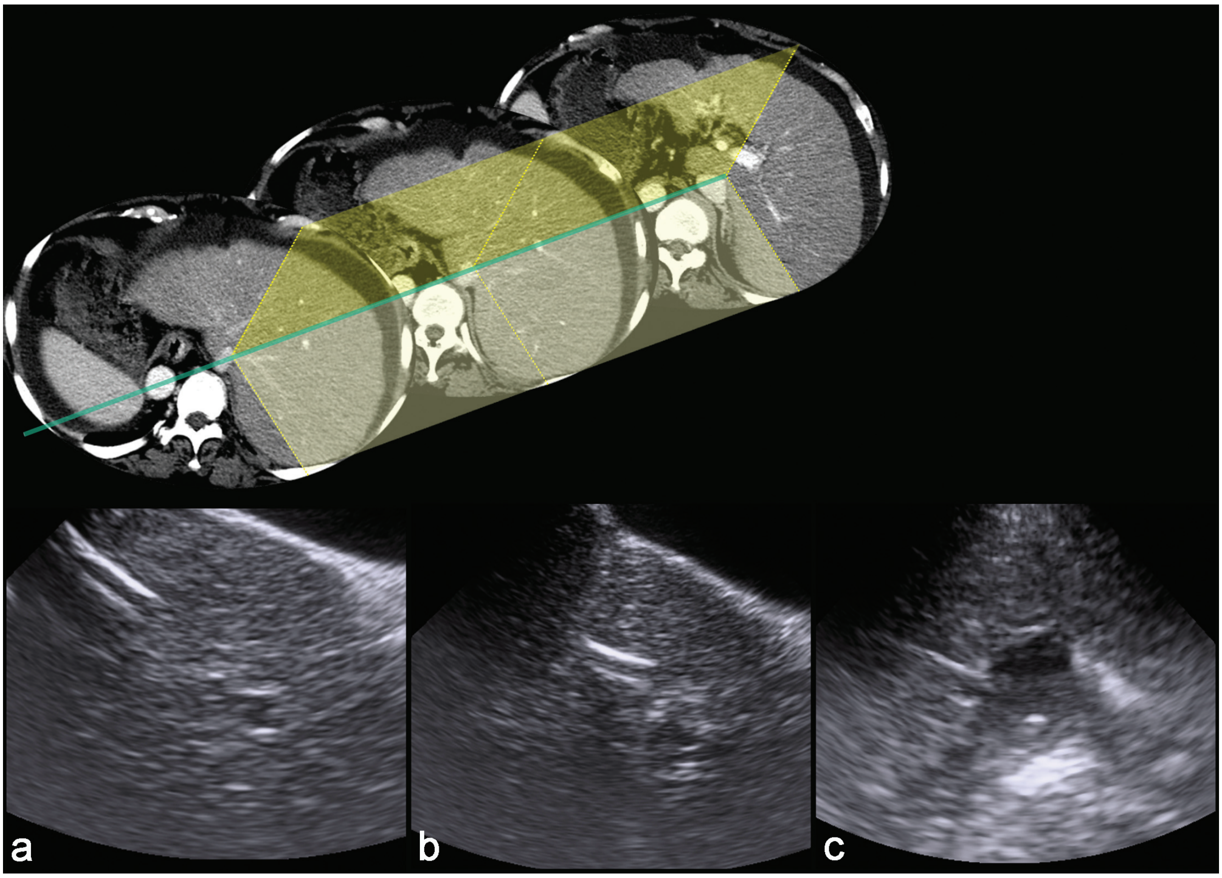

Fig. 4 Transaxial CT images have been flipped in right-to-left orientation to simulate the positioning of the patient on the angiography table, with the IVUS probe positioned in the IVC, as represented by the turquoise line. The shaded yellow trapezoid represents the beginning and ending of ultrasound planes visualized by the probe as it is rotated sequentially in a counterclockwise fashion. The initial IVUS image (**a**) demonstrates the starting position of the Colapinto needle (white arrow) in the right hepatic vein (yellow arrows). Note that the posterior right portal vein (turquoise arrow) is in the same plane as the right hepatic vein. To puncture the right portal vein from the right hepatic vein, the needle must be torqued in a counterclockwise manner, resulting in a needle trajectory that is out of plane with respect to the IVUS. Therefore, the IVUS probe must also be rotated in a counterclockwise fashion to allow visualization of the needle tip (white arrow) as it is advanced along its trajectory (**b**), until the target right portal vein (magenta arrow) is visualized and the Colapinto needle (white arrow) punctures the target vein (**c**).

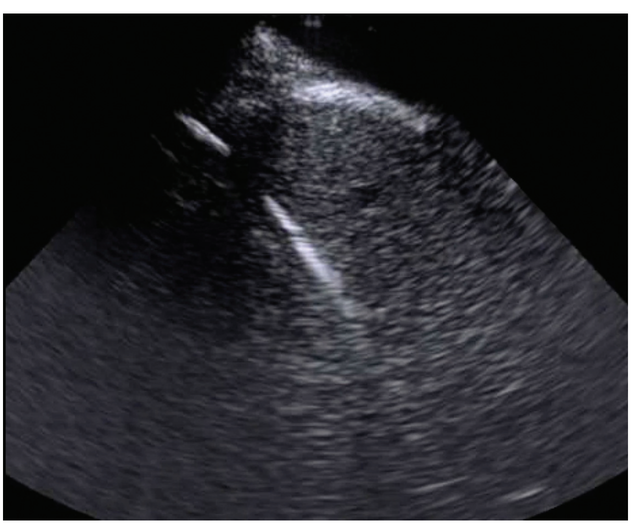

Fig. 5 IVUS image in the plane of the right hepatic vein demonstrates an echogenic 0.035″ Amplatz Super Stiff wire (Boston Scientific, Marlborough, MA) within the right hepatic vein.

Taking a last image hold with the ICE catheter at this position and drawing a perpendicular line from the middle of the probe, the intersection of this line with the pigtail catheter marks the location of the PV puncture site, and thus the ideal location of the O-ring (►**Fig. 7a**). Next, the ICE catheter is withdrawn to the level of the confluence of the relevant HV and IVC, and a last image hold is again obtained. Using the same method, a perpendicular line is drawn from the center of the ICE probe to the pigtail catheter, and this point of intersection marks the ideal location of the trailing end of the stent graft (►**Fig. 7b**). The distance between these two points will determine the length of the covered portion of the stent (►**Fig. 7c**). The Viatorr stent (GORE) can then be deployed under direct visualization with IVUS at the uncovered portion within the PV ensuring appropriate alignment of the O-ring of the stent at the puncture site. If the stent graft is correctly sized, it will not matter if the O-ring is deployed too far into the PV. IVUS allows for real-time visualization of the uncovered portion of the stent as it is pulled back toward the parenchymal tract, ensuring that the O-ring is positioned

 © 2023. Thieme. All rights reserved.

This document was downloaded for personal use only. Unauthorized distribution is strictly prohibited.

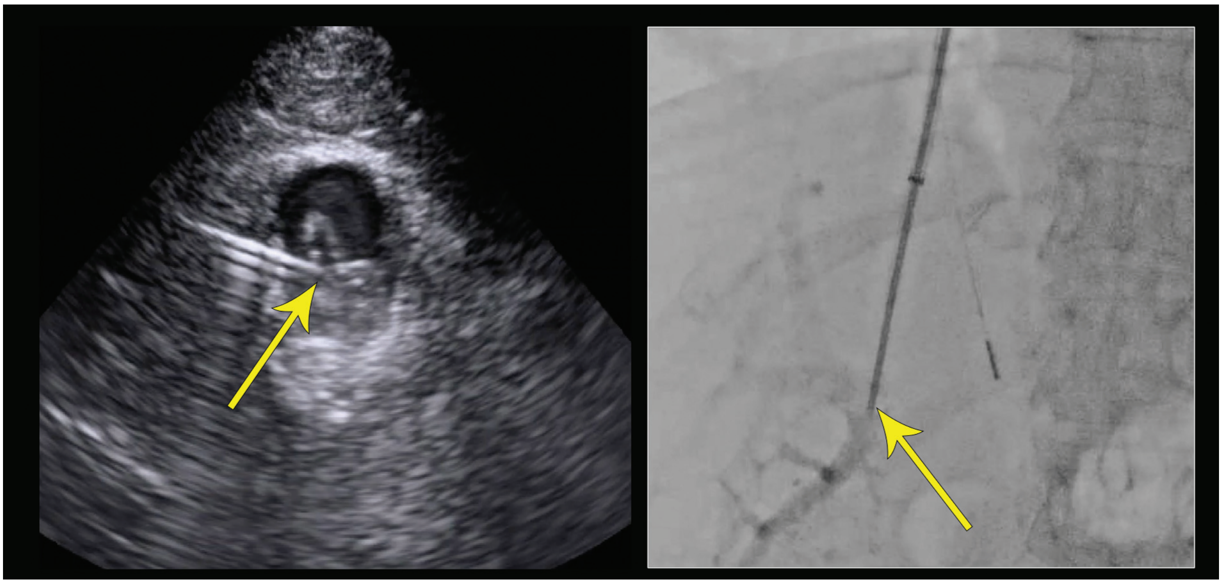

Fig. 6 IVUS confirms the needle tip (yellow arrows) is positioned within the target portal vein. Injection of contrast demonstrates perturbations within the portal vein under real-time ultrasound visualization and opacification of the portal vein under simultaneous fluoroscopic visualization.

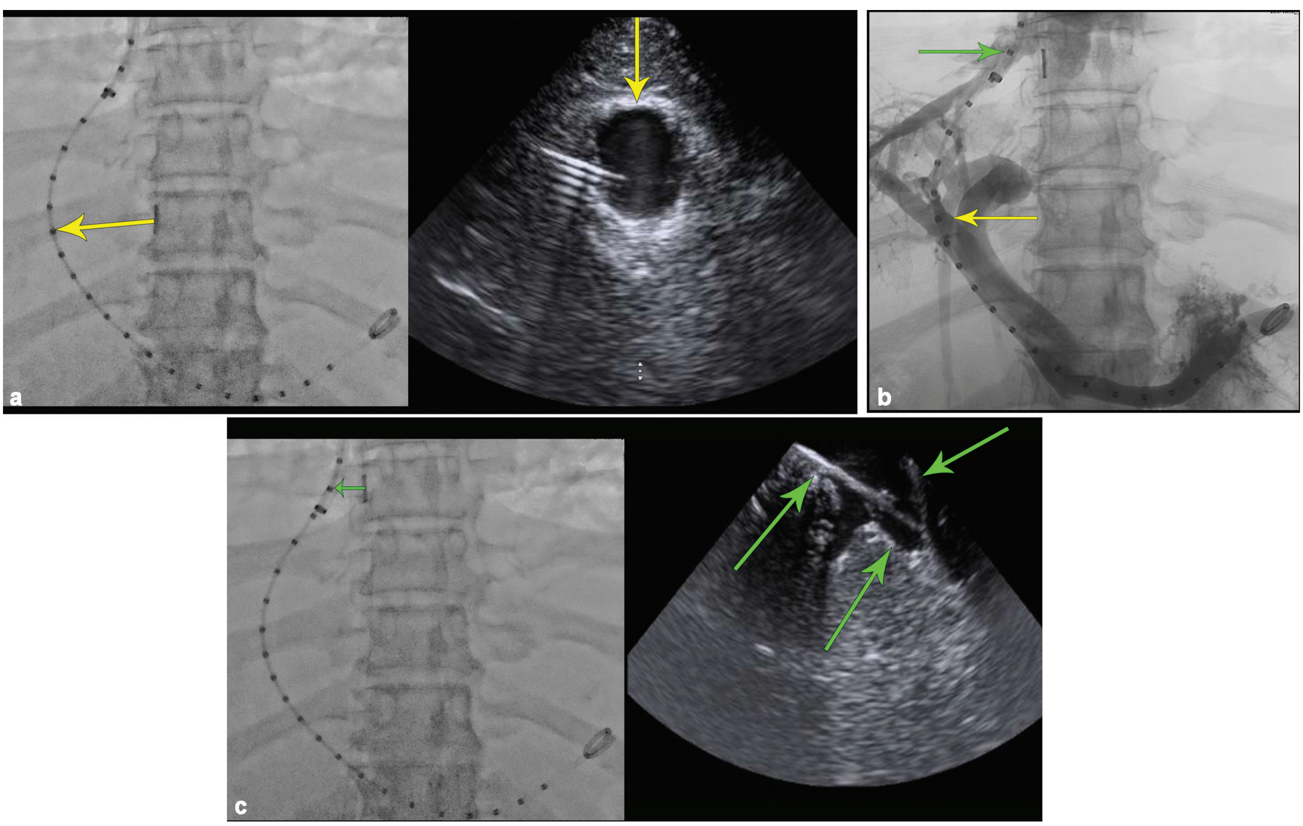

Fig. 7 Concomitant fluoroscopic and IVUS images were obtained during measurement of the TIPS stent length. (**a**) The probe is positioned such that the point of portal venous access is centered on ultrasound (yellow arrow), and the marking pigtail (Merit Medical, Jordan, UT) corresponding to this access site can be extrapolated from the fluoroscopic position of the ultrasound probe (yellow arrow). (**b**) The IVUS probe is pulled back to center the hepatic venous confluence (green arrows) and marking pigtail corresponding to the hepatic venous confluence (green arrow) is extrapolated. (**c**) The distance between the hepatic venous marker (green arrow) and portal venous marker (yellow arrow) determines the length of the covered portion of the Viatorr stent graft (GORE, Flagstaff, AZ). In this case, the distance was 6 cm.

This document was downloaded for personal use only. Unauthorized distribution is strictly prohibited.

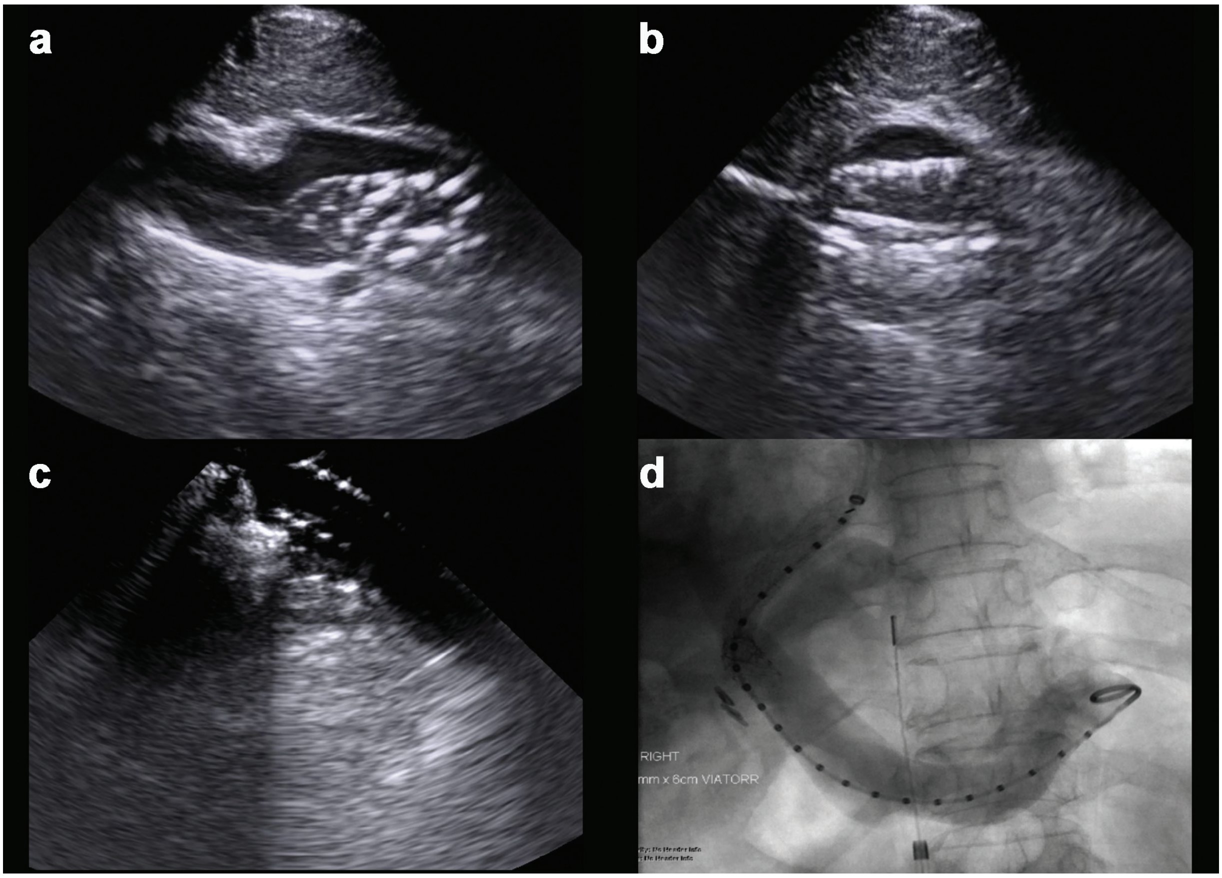

Fig. 8 Under real-time IVUS visualization, the uncovered portion of the stent is unsheathed in the portal vein beyond the PV puncture site (**a**) and is retracted toward the parenchymal tract (yellow arrow). Ultrasound visualization of the stent as it is retracted toward the tract (**b**) facilitates precise positioning of the O-ring, which should be seated at the location of PV puncture (magenta arrows). Accurate positioning of the O-ring ensures that upon complete deployment of the stent (**c**), the trailing edge of the stent will terminate at the confluence of the hepatic vein and IVC (green arrows). Fluoroscopic image from the same patient (**d**) demonstrates final TIPS position.

correctly at the precise location of PV puncture prior to deploying the covered portion of the stent (►**Fig. 8**). This prevents the uncovered portion of the stent graft from being pulled too far into the parenchymal tract, which could lead to stent thrombosis from bile leakage of exposed bile ducts. It also ensures that the covered portion of the stent will not extend into the PV, risking occlusion of more distal PV branches.

Selection of a Safe Trajectory for TIPS Stent Graft Deployment

In addition to identifying an appropriate PV target for TIPS creation, IVUS offers the additional benefit of identifying potential pitfalls during TIPS creation. In patients with liver masses or large cysts, a safe shunt pathway can be selected that avoids transgression and associated complications. Although rare, transgression of the hepatic artery, which is closely associated with the PV, can lead to fatal hemorrhage, liver infarct, and fulminant liver failure. Under IVUS guidance, the hepatic artery can usually be visualized and avoided (►**Fig. 9**).

Benefits of ICE TIPS

IVUS guidance during TIPS not only offers the potential to minimize procedure-related complications, it reduces radiation exposure, procedural time, and contrast utilization.[18,21,22] Kao et al reported a significant reduction in both procedural time (86 vs. 125 minute; $p < 0.01$) and

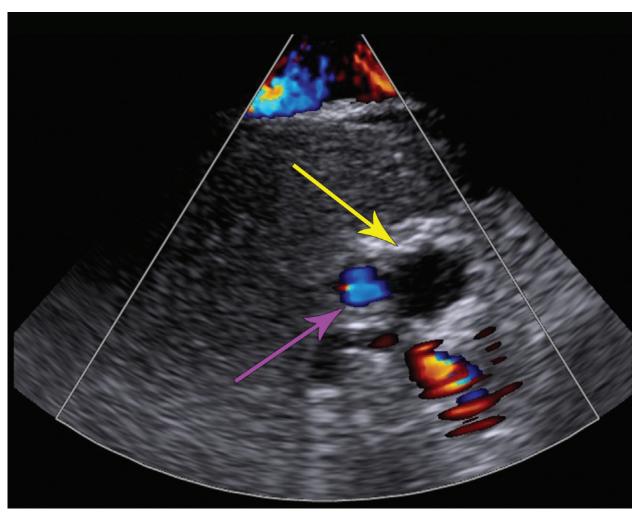

Fig. 9 IVUS image demonstrates the target right portal vein (yellow arrow). The right hepatic artery (magenta arrow) is visualized along the expected trajectory of the TIPS needle. Given the risk of arterial injury, a different shunt pathway was selected.

 © 2023. Thieme. All rights reserved.

This document was downloaded for personal use only. Unauthorized distribution is strictly prohibited.

median fluoroscopy time (19 vs. 34 minute; $p < 0.01$) with the use of IVUS.[21] Similar results were described by Gipson et al.[18] Multiple studies demonstrate a significant reduction in radiation exposure with IVUS,[22] the largest of which is reported by Kao et al (174 vs. 981 mGy; $p < 0.01$).[21] Radiation reduction can be attributed to omission of wedge hepatic venography and decrease in number of needle passes. Additionally, use IVUS probe for stent sizing further decreases radiation dose and contrast volume compared with fluoroscopic TIPS. The former requires only a last image hold, while the latter requires a digital subtraction angiogram with dual injection of contrast via a catheter positioned in the PV and sheath positioned in the HV. The contrast volume reduction can particularly help patients with impaired renal function. These studies support the idea that IVUS guidance facilitates successful TIPS creation in patients with challenging anatomy, improves safety, and reduces procedural metrics such as radiation dose, contrast volume, procedural time, and PV access time. IVUS-guided TIPS creation was successful in cases in which conventional TIPS creation had failed because of PV thrombosis or distorted anatomy.[23]

Conclusion

IVUS is a safe and effective adjunct to TIPS creation and offers many advantages over traditional fluoroscopic TIPS including fewer needle passes, decreased fluoroscopy times, procedure times, and contrast volumes. As it can be disorienting when beginning to utilize IVUS, it is essential to become familiar with the basic rotational anatomy, and to understand the anatomic relationships and landmarks for successful IVUS-guided TIPS creation. Once this skill has been mastered, IVUS can make challenging TIPS cases more straightforward due to the ability to visualize the needle with respect to each patient's unique hepatic anatomy. Inspection of all potential shunt pathways in real-time increases the likelihood for successful and efficient shunt creation, particularly when a less traditional shunt pathway is required. Finally, IVUS facilitates a safe needle trajectory in patients with liver masses and cysts who otherwise would be unable to undergo traditional fluoroscopic TIPS placement.

Conflict of Interest
No conflicts of interest declared for any author.

References

1 Summary Health Statistics Tables for U.S. Adults: National Health Interview Survey;. 2018; Table A-4b A 4c
2 D'Amico G, Morabito A. Noninvasive markers of esophageal varices: another round, not the last. Hepatology 2004;39(01):30–34
3 Zhao R, Lu J, Shi Y, Zhao H, Xu K, Sheng J. Current management of refractory ascites in patients with cirrhosis. J Int Med Res 2018;46 (03):1138–1145
4 Garbuzenko DV, Arefyev NO. Hepatic hydrothorax: an update and review of the literature. World J Hepatol 2017;9(31):1197–1204
5 Bleibel W, Al-Osaimi AM. Hepatic encephalopathy. Saudi J Gastroenterol 2012;18(05):301–309
6 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(04):793–801
7 García-Pagán JC, Caca K, Bureau C, et al; Early TIPS (Transjugular Intrahepatic Portosystemic Shunt) Cooperative Study Group. Early use of TIPS in patients with cirrhosis and variceal bleeding. N Engl J Med 2010;362(25):2370–2379
8 Zaman A, Chalasani N. Bleeding caused by portal hypertension. Gastroenterol Clin North Am 2005;34(04):623–642
9 Gaba RC, Parvinian A. How quickly does ascites respond to TIPS? Clinical follow-up of a cohort of eighty patients. Diagn Interv Radiol 2014;20(04):364–364
10 Siegerstetter V, Deibert P, Ochs A, Olschewski M, Blum HE, Rössle M. Treatment of refractory hepatic hydrothorax with transjugular intrahepatic portosystemic shunt: long-term results in 40 patients. Eur J Gastroenterol Hepatol 2001;13(05):529–534
11 Fanelli F. The evolution of transjugular intrahepatic portosystemic shunt: tips. ISRN Hepatol 2014;2014:762096
12 Thornburg B, Desai K, Hickey R, et al. Portal vein recanalization and transjugular intrahepatic portosystemic shunt creation for chronic portal vein thrombosis: technical considerations. Tech Vasc Interv Radiol 2016;19(01):52–60
13 Englesbe MJ, Kubus J, Muhammad W, et al. Portal vein thrombosis and survival in patients with cirrhosis. Liver Transpl 2010;16(01): 83–90
14 Mancuso A, Fung K, Mela M, et al. TIPS for acute and chronic Budd-Chiari syndrome: a single-centre experience. J Hepatol 2003;38 (06):751–754
15 Hodgson JM, Graham SP, Savakus AD, et al. Clinical percutaneous imaging of coronary anatomy using an over-the-wire ultrasound catheter system. Int J Card Imaging 1989;4(2-4):187–193
16 Farsad K, Kaufman JA. Novel image guidance techniques for portal vein targeting during transjugular intrahepatic portosystemic shunt creation. Tech Vasc Interv Radiol 2016;19(01):10–20
17 RiChard J, Thornburg B. New techniques and devices in transjugular intrahepatic portosystemic shunt placement. Semin Intervent Radiol 2018;35(03):206–214
18 Gipson MG, Smith MT, Durham JD, et al. Intravascular US-guided portal vein access: improved procedural metrics during TIPS creation. J Vasc Interv Radiol 2016;27(08):1140–1147
19 Luo SH, Chu JG, Huang H, Yao KC. Effect of initial stent position on patency of transjugular intrahepatic portosystemic shunt. World J Gastroenterol 2017;23(26):4779–4787
20 Maleux G, Pirenne J, Vaninbroukx J, Aerts R, Nevens F. Are TIPS stent-grafts a contraindication for future liver transplantation? Cardiovasc Intervent Radiol 2004;27(02):140–142
21 Kao SD, Morshedi MM, Narsinh KH, et al. Intravascular ultrasound in the creation of transhepatic portosystemic shunts reduces needle passes, radiation dose, and procedure time: a retrospective study of a single-institution experience. J Vasc Interv Radiol 2016;27(08):1148–1153
22 Ramaswamy RS, Charalel R, Guevara CJ, et al. Propensity-matched comparison of transjugular intrahepatic portosystemic shunt placement techniques: Intracardiac echocardiography (ICE) versus fluoroscopic guidance. Clin Imaging 2019;57:40–44
23 Pillai AK, Andring B, Faulconer N, et al. Utility of intravascular US-guided portal vein access during transjugular intrahepatic portosystemic shunt creation: retrospective comparison with conventional technique in 109 patients. J Vasc Interv Radiol 2016;27 (08):1154–1159

 © 2023. Thieme. All rights reserved.

This document was downloaded for personal use only. Unauthorized distribution is strictly prohibited.