Intracardiac Echocardiography–Guided TIPS: A Primer for New Operators

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Semin Intervent Radiol 2020;37:405–413

Transjugular intrahepatic portosystemic shunt (TIPS) creation is an effective intervention to address complications of decompensated portal hypertension, most commonly variceal hemorrhage and refractory ascites. While TIPS is considered challenging, reported technical success rate is high at 95%.^{1,2} Variant anatomy and relative contraindications such as portal vein thrombosis pose additional challenges and can reduce likelihood of success.^{3,4} Most operators consider puncture of the portal vein to be the technically difficult part of TIPS creation, which frequently requires multiple needle passes. Existing methods for the guidance of a needle pass into the portal vein do not provide real-time feedback and multiple needle passes are not without risk. Indirect portal venogram via injection of contrast or CO₂ increases risk of hepatic laceration and air embolus, respectively. Direct venogram via percutaneous needle puncture of the portal system carries a heightened risk of hemorrhage.^{3,5,6} Needle passes without real-time imaging guidance can lead to complications such as extrahepatic portal vein puncture, extracapsular puncture, hemoperitoneum, and hemobilia.^{3,4}

Intracardiac echocardiography is a recent advancement in TIPS guidance and has been associated with reduced fluoroscopy time, overall procedure time, contrast agent use, and rate of extracapsular puncture.^{7,8} The added real-time visualization of intracardiac echocardiography (ICE) also allows for novel approaches to cases that were once relative contraindications for TIPS. For example, Hedge et al⁹ described successfully positioning a TIPS shunt between hepatic cysts in a patient with polycystic liver disease (PCLD). Moreover, anatomical variations that once complicated TIPS procedures can be routinely accomplished with ICE guidance. In light of this recent technical advancement, we have written this article as a primer for adoption of ICE guidance during TIPS creation.

Preprocedure

Patient selection and preprocedural evaluation are critical to success. The initial evaluation should include a thorough history that emphasizes cardiac status, signs of portal hypertension, evidence of hepatic encephalopathy, and previous attempts at control of decompensation. Review of available imaging should be completed in addition to a contrast-enhanced computed tomography (CT) or magnetic resonance imaging obtained within the last month. Any history of cardiac disease should prompt a transthoracic echo. Review of imaging should focus on portal vein patency/branch anatomy, hepatic vein and portal vein relationships, and the presence of suspicious masses/hepatocellular carcinoma or large cysts along the expected needle path.³ Comprehensive laboratories should be obtained which include a complete blood cell count, comprehensive metabolic panel, and coagulation panel within 24 hours of the procedure. Furthermore, a MELD-Na score should be calculated to assess post-TIPS outcomes with elective procedures being avoided in patients scoring a MELD > 18 to 24.¹⁰ In the case of acute variceal bleeding, after endoscopic variceal ligation, TIPS should ideally be performed within 72 hours of presentation for best postprocedural outcomes.^{11,12}

Procedure

Access Sets

There are multiple available TIPS sets, which include the Rosch-Uchida, Ring, and Haskal sets. The Rosch-Uchida sets provide a curved stiffening cannula and trocar stylet, which improves stability during puncture of the portal vein. The stiffened cannula also more easily allows a single operator to maneuver both the ultrasound probe and the needle simultaneously. The Ring and Haskal sets use a modified Colapinto needle which follows a curved trajectory. The larger 16G Colapinto needle

Fig. 1 The intracardiac echo probe is equipped with a linear phase array multifrequency transducer at its tip. The white and black arrows represent the angulation controls of the intracardiac echocardiography catheter in the anterior-posterior and left-right directions, respectively; however, we opt for manual rotation of the entire probe for finer control.

works well in most cases and allows for immediate passage of a 0.035-inch stiff wire. A 21G Chiba needle (either through a Colapinto needle or the metal cannula) is useful in situations requiring straight and sharp penetration of the fibrotic liver, albeit at the cost of needing subsequent upsizing to an 0.035-inch system for Viatorr delivery.

Intracardiac Echo Device

The ICE catheter used in our institution is an 8-Fr side firing AcuNav (Siemens, Erlangen, DL) ultrasound probe that operates at 5.5 to 10 MHz with a maximum penetration of 16 cm (→ Fig. 1).¹³ It generates an image similar to a transabdominal ultrasound as opposed to the 360-degree axial intravascular ultrasound images. The probe is mounted on a 90-cm catheter and interfaces with compatible Siemens ultrasound units (ACUSON). This ultrasound unit can also be used with standard probes and has similar controls including color/pulsed Doppler, depth control, focus control, image, and cine clip storage. Typically, this device is used for advanced cardiac and electrophysiologic interventions and may be present in cardiac catheterization laboratories.

A standard valved 9 Fr × 30 cm sheath is used to uncover the probe as it is not an over-the-wire device and steerability is limited. The device has two twist rings on the hub that control probe angulation, but we have not routinely used these in clinical practice. Instead, we have resorted to a more manual controlled rotation of the probe itself.

The ICE catheter can be placed via a femoral or jugular access. After initial experience with femoral access, we have moved to tandem puncture of the jugular vein, facilitating single-operator TIPS. To promote ergonomics, we typically use the lateral jugular puncture for the ICE probe so that the long probe/attachment assembly can be draped away from the working TIPS sheath (→ Fig. 2). Femoral placement may be preferred if more working space is needed or multiple operators are involved.

Initial Visualization and Hepatic Vein Cannulation

TIPS is typically performed under general anesthesia due to painful tract dilation and technical complexity. Following jugular venous access, the ICE probe is advanced to the level of the hepatic vein confluence and subsequently into the

Fig. 2 (a) A depiction of the working field with intravascular access provided through tandem puncture of the jugular vein. (b) A depiction of the working field with the ICE probe draped outside of the immediate working field and inserted through the lateral access site. ICE, intracardiac echocardiography; TIPS, transjugular intrahepatic portosystemic shunt.

Fig. 3 The intracardiac echocardiography probe (arrow) position within the intrahepatic inferior vena cava at the level of the main portal vein, noted fluoroscopically. This position facilitates clear visualization of the main, right, and left portal veins. 5 Fr catheter access into the main portal vein has been achieved; gentle contrast injection confirms tip within the splenic vein.

intrahepatic inferior vena cava (IVC) to the level of the undivided right portal vein (►Fig. 3). Due to the close approximation of the IVC and liver parenchyma at this location, a clear ultrasound window is ubiquitously available. Finally, the probe is moved between these stations to study the orientation of the hepatic veins with respect to portal vein branches.

We then proceed with tandem jugular venous access, right atrial pressure measurement, and hepatic vein cannulation with the TIPS sheath. Upfront ICE evaluation not only helps the operator gain experience with interpretation of anatomy,

particularly how the distance between hepatic and portal vein branches changes with probe manipulation, but also allows for consideration of nonstandard shunt placements if anatomically favorable (e.g., middle hepatic vein to right portal vein). Furthermore, ICE imaging used in conjunction with cross-sectional imaging can be helpful to elucidate catheter position when the venography is unclear, in particular, after cannulation of an accessory right hepatic vein or when there is significant distortion of usual hepatic vein anatomy due to advanced fibrosis.

An intentional, reproducible approach to anatomic orientation with ICE is advised early in the learning curve. ►Fig. 4 correlates ICE probe imaging with anatomic localization. In general, visualization in the medial to lateral plane can be increased by increasing ultrasound depth. The posterior–anterior plane can be manipulated by catheter rotation, and adjustments in the craniocaudal orientation can be achieved by moving the probe in the associated direction. Our protocol, described in ►Figs. 4 to 6, is to first position the probe near the origin of the hepatic veins, then rotate the probe posteriorly to localize the aorta/echogenic retroperitoneal fat, followed by anterior rotation of the probe to identify the right hepatic, middle hepatic, and right portal veins sequentially. The ICE probe is then advanced into the infrahepatic IVC, where anterior probe rotation initially results in identification of the posterior right portal vein followed by the confluence of the anterior and posterior branches of the right portal vein, undivided right portal vein, right/left portal vein confluence, and finally the main portal vein.

Needle Advancement and Portal Vein Puncture

Unlike with conventional TIPS where needle advancement occurs in a single, forceful motion, incremental advancement and adjustment of trajectory is recommended with ICE guidance. An approximate trajectory for the TIPS needle should be determined based on ultrasound assessment of the hepatic veins and account for both the anterior and

Fig. 4 (a, b) The venous phase CT image through the level of the hepatic veins is intentionally flipped left/right to provide anatomic orientation for the intracardiac echocardiography (ICE) images in ►Figs. 5 and 6. The probe fires in an axial fashion from the inferior vena cava, along the axis of the hepatic veins which makes it useful for initial orientation. The letters in this figure correlate to the ultrasound images listed in ►Fig. 6; B+C indicates the right hepatic vein; F indicates the middle hepatic vein. D+E shows portions of the right portal vein (PV), G shows the main portal vein, which is well oriented for ICE imaging in this patient. In general, the portal veins tend to run orthogonal to the ultrasound beam making orientation more difficult.

Fig. 5 An illustration depicting the direction of the intracardiac echocardiography (ICE) catheter's probe from the operator's point of view, when in-line with the tandem jugular vein access. (a) The initial orientation of the ICE probe at ~30 degrees or 5 o'clock. (b) The orientation of the ICE probe after an anterior sweep of the ICE catheter in the counterclockwise direction. (c) The approximate orientation of the main portal vein. The labeling in this illustration corresponds with Figs. 4 and 5.

Fig. 6 A counterclockwise sweep of the intracardiac echocardiography catheter while positioned at the hepatic vein confluence from a jugular vein approach. (a) The peritoneal space or lung, which is characterized by an absence of vascular structures on ultrasound and shadowing. See the corresponding plane of imaging noted in ►Fig. 4. (b) The right hepatic vein containing an echogenic catheter. (c) The right hepatic vein and posterior branch of the right portal vein. (d) The posterior and anterior branches of the right hepatic vein. (e) The confluence of the posterior and anterior branches of the right portal vein. (f) The middle hepatic vein and right portal vein. (g) The main portal vein.

Fig. 7 (a) The needle tip (arrowhead) can be seen in the liver parenchyma directed anteriorly and inferiorly toward the right portal vein (arrow). (b) The dashed arrow depicts the 0.035-inch guide wire within the confluence of the anterior and posterior right portal vein.

inferior displacement required for portal vein puncture. Notably, with fibrotic tissue, the TIPS cannula will need to be over rotated anteriorly to account for the inherent inferior deflection encountered while traversing fibrotic liver parenchyma. Ideally, the needle will be positioned peripheral to the portal vein target to allow for the inherent medial/central movement of the needle when it is rotated anteriorly. In contrast to conventional TIPS, the needle should be advanced incrementally while panning the ICE probe to monitor the predicted trajectory. At each increment, the needle's path can be corrected as needed. Often the TIPS needle needs to be bent more acutely than the standard angle provided in the kit, particularly with advanced parenchymal fibrosis. With conventional TIPS, needle angulation is adjusted with trial and error. With ICE guidance, immediate feedback with respect to adequacy of anterior and mediolateral needle trajectory is obtained with incremental needle advancement. The needle “throw” can therefore be adjusted without a full advancement into the central or periportal space, minimizing risk of complication.

Deformation of the portal vein wall and subsequent release with puncture is a reliable sign of intraluminal needle tip position. Confirmation of portal vein puncture can also be obtained by clearing the lumen with saline, aspirating blood, and injecting contrast. Care must be taken not to inject air, which may impair subsequent ultrasound guidance. If the needle tip position in the target portal vein is confirmed by ICE, we often proceed directly to wire passage without contrast injection (→**Fig. 7**). Following sonographic confirmation of intraluminal wire advancement, the procedure follows conventional protocol (→**Fig. 8**).

Troubleshooting

As with any new technique, there is a learning curve. Two common scenarios and tips for resolving them are listed below.

Poor Visualization/Image Quality

Insonation through the introducer sheath is possible, but typically degrades image quality, particularly if the probe is

Fig. 8 A representation of simultaneous portal vein (catheter) and hepatic vein (sheath) injections used for stent sizing. Normal portal vein anatomy is demonstrated with antegrade flow of contrast. The intracardiac echocardiography catheter (black arrow) is positioned at the level of the main right portal vein. A Blakemore tube is noted in the background (star).

positioned by the metallic marker ring. Once the probe is in the IVC, the sheath should be pulled back to the level of the hepatic veins, leaving the probe free floating. The probe can be safely advanced back and forth at this point.

Notably, the ICE probe is multifrequency and can be adjusted on the machine with the inherent tradeoff between depth and spatial resolution.

Inability to Get the Needle Tip into the Portal Vein

Intraprocedural three-dimensional relationships are difficult given the limited degrees of freedom with the ICE probe and the desired puncture needle. Portal vein puncture is particularly difficult in patients with advanced fibrosis. Adding to the preset curvature of the Colapinto needle outside the body

enables more anterior angulation in vivo. If periportal fibrosis is severe, coaxial advancement of 65 cm × 21G Chiba needle through the larger but duller Colapinto needle can be helpful toward the end of the “throw.”

Cases

Institutional review board approval was not required for these case reports.

Case 1: Middle Hepatic Vein to Right Portal Vein TIPS

A 64-year-old female presented with a history of cryptogenic cirrhosis with refractory ascites, mild hepatic encephalopathy, and stage I esophageal varices. The patient had been failing medical management with 160 mg QD Lasix, 400 mg QD spironolactone, weekly paracentesis, and IV albumin BID. She was deemed a suitable candidate for TIPS. Her laboratory test results preprocedurally were notable for INR of 1.4, platelet count of 140, and MELD-Na score of 16.

A multiphase CT scan from a week prior was used for evaluation of the hepatic and portal vein anatomy. A suitable route was proposed from the right hepatic vein to the right portal vein prior to intervention. The ICE catheter was positioned in the intrahepatic IVC at approximately the level of the hepatic vein confluence, and the right hepatic vein was initially cannulated with confirmation by venogram. Under ICE evaluation, a minor posterior branch of the right portal vein could be visualized in plane with the right hepatic vein. However, significant anterior rotation of the ICE catheter was required to visualize the confluence of the right portal vein. From this, it was determined that a right hepatic to right portal vein puncture would be unfavorable due to both the degree of anterior rotation and path distance. Therefore, the middle hepatic vein was evaluated and ultimately chosen as the initial starting point due to the significantly less anterior rotation required for puncture (→ Fig. 9). The shunt was placed into the right and left portal vein confluence without complication.

Fig. 9 Baseline sonographic evaluation with the intracardiac echocardiography catheter reveals a favorable transhepatic trajectory from the middle hepatic vein (MHV) to the right portal vein (RPV). Consequently, the MHV was intentionally chosen for TIPS access.

While the right hepatic vein is generally preferred in conventional TIPS procedures, the middle hepatic vein has become an equally viable choice for ICE TIPS due to the reduced risk of extrahepatic puncture provided by real-time imaging.⁸ ICE TIPS allows an operator to select the most appropriate hepatic vein based on an in vivo anatomical assessment. This provides a significant advantage over preplanned routes based on prior CTA imaging in our experience.

Case 2: Portal Vein Thrombosis

A 73-year-old male with hepatitis C virus cirrhosis underwent TIPS in anticipation of a liver transplant. The patient was noted to have extensive, near-occlusive thrombus of the main portal vein, splenic vein, and superior mesenteric vein. Upon ultrasound assessment, the eccentric thrombus was identified in the main portal vein (→ Fig. 10). The right and middle hepatic veins were then assessed for route selection. The right hepatic vein to right anterior portal vein was ultimately selected for shunt placement based on ICE evaluation and the shunt was successfully placed using the technique described here. The nonocclusive eccentric main portal vein thrombosis would have likely made CO₂ opacification ineffective and required percutaneous portal vein thrombectomy prior to the TIPS procedure. The ability to puncture the portal system and confirm intraluminal placement directly via ultrasound reduced procedural complexity as well as the bleeding risks associated with percutaneous portal vein access. Ultrasound also facilitated localizing the portal puncture site and the hepatic vein–IVC confluence for stent length measurement (→ Fig. 11).

Case 3: Cavernous Transformation of the Portal Vein

A 56-year-old male presented with a history of alcohol-related cirrhosis, mild hepatic encephalopathy, and three prior episodes of esophageal variceal hemorrhage treated with endoscopic banding. Multiphase CT demonstrated chronic occlusion of the main portal vein with cavernous transformation and large esophageal varices. Due to the

Fig. 10 A nonocclusive eccentric thrombus (arrow) occluding the main portal vein as seen by intracardiac echocardiography catheter. Ultrasound confirmation of needle tip position within the thrombosed vein was used in lieu of contrast injection to obtain portal vein access.

Fig. 11 The intracardiac echocardiography (ICE) probe is used as a mark for stent placement and length determination. The ICE probe (arrow) is located at (a) the level of the portal vein puncture as assessed by ultrasound imaging and (b) subsequently moved to the hepatic vein–inferior vena cava (HV–IVC) confluence. Distance between these two probe positions is measured fluoroscopically via the marker pigtail. As there was PV thrombosis, injected contrast did not delineate the level of the PV puncture well, but ICE directly visualizes the site of puncture. Depending on the acuity of the thrombosis, pull back of the uncovered portion of the Viatorr may also be unreliable.

patient's high risk of rebleeding from his esophageal varices, he was deemed a suitable candidate for portal vein recanalization TIPS (PVR-TIPS). His preprocedural laboratory test results were significant for an INR of 1.4, platelet count of 49, and MELD-Na score of 12.

Transsplenic access was obtained; however, the portal vein was unable to be recanalized (►Fig. 12a). Ultrasound evaluation of the liver was performed, which showed no suitable portal vein for transhepatic access. We instead decided to place a TIPS from the right hepatic vein to the dominant cavernous collateral, which measured up to 9 mm. The ICE catheter was positioned in the infrahepatic IVC. The right hepatic vein was accessed and the position confirmed by ICE (►Fig. 12b), and the dominant collateral was targeted. The TIPS needle was then advanced into the collateral and the shunt was placed (►Fig. 12c, d). Given the number of collateral vessels, it would have been difficult to accurately access the target collateral without ultrasound guidance.

Discussion

Ultrasound guided TIPS improves upon conventional TIPS by decreasing procedure time, contrast volumes, radiation usage, and needle passes associated with extracapsular portal vein puncture. Needing to maneuver both a TIPS needle and ultrasound probe in offset planes adds a significant degree of complexity to the procedure. Despite this complexity, Pillai et al reported that at baseline less-experienced physicians new to ICE TIPS took significantly less time than conventional methods at 28 minutes $\pm$ 16 to 48 minutes $\pm$ 30 ($n = 26$) ($P = .01$) respectively.¹⁴ Furthermore, by the third year of their study, the mean procedure time for ICE TIPS decreased from 39 minutes $\pm$ 7 to

26 minutes $\pm$ 2 across both experienced and less-experienced operators with a total mean time of 31 minutes $\pm$ 19 for the study period. The inherent learning curve associated with ICE TIPS can be overcome quickly with guided use. To that end, this review serves as a primer for new operators.

With ICE guidance, the conventional wisdom of right hepatic vein to right portal vein shunt placement has been challenged in favor of an individualized, in vivo ultrasound assessment of hepatic and portal vein anatomy and a priori selection of optimal needle path between the two systems. This assessment also obviates the need for portal system opacification allowing for TIPS in patients with severe contrast allergies, severe nephropathy, and acute portal vein thrombosis. Optimized route selection and real-time needle guidance decrease contrast volumes, radiation exposure, and needle passes.

The method of needle advancement is another important distinguishing feature between conventional and ultrasound-guided TIPS. With conventional techniques, the needle is passed in one, swift motion through the liver parenchyma in a predetermined trajectory based on fluoroscopic landmarks. With ICE-guided TIPS, the needle is passed incrementally and adjustments are made without a full pass, minimizing unnecessary needle advancement through the central hepatic triads. Real-time sonographic feedback of needle trajectory significantly improves puncture probability leading to the decreased procedure time, needle passes, and extracapsular puncture associated with ICE TIPS.

In conclusion, ICE guidance is an important technological advancement, making the otherwise well-established TIPS creation quicker and safer for a wider range of anatomy and indications. This guide can serve as a primer for inexperienced users and increasing comfort with the procedure is expected quickly.

Fig. 12 (a) Portal venography demonstrating the cavernous collateral (arrow) as well as additional smaller cavernous collaterals (arrowheads). (b) Intracardiac echocardiography (ICE) image demonstrating multiple cavernous collaterals in the porta hepatis (arrows). (c) ICE image demonstrating the needle tip (arrowheads) directed anteriorly and inferiorly toward the dominant cavernous collateral (arrow). (d) Completion venography demonstrating placement of the transjugular intrahepatic portosystemic shunt from the right hepatic vein to the dominant cavernous collateral (arrow). The cardinal vein has also been embolized with coils (star).

Financial Disclosures

P.S.T.: Grant funding—AUR (GERRAF).

K.M.S.: Investor—Exact Sciences.

J.D.L.: Consultant/Advisory board—Avantec.

R.K.R.: Advisory board—Argon Medical, consultant—Cook Medical, consultant—B. Braun.

Conflict of Interest

None declared.

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