Introduction

Prior to the clinical introduction of transjugular intrahepatic portosystemic shunt (TIPS) in the late 1980s, decompression of the portal system necessitated creation of an extrahepatic surgical shunt. The concept of a TIPS was initially conceived after inadvertent portal vein puncture during transjugular cholangiography in the late 1960s. The first report of successful transjugular portosystemic shunt creation was published in 1969. The shunts were composed of various materials such as Teflon, silastic and spring coil tubing coated with silicone-based copolymer. However, shunt patency was a major hindrance to wider adoption as most of the shunts occluded within hours to days after placement. The advent of bare metallic stents heralded the wider clinical availability of TIPS for the treatment of sequelae of portal hypertension in the 1990s. The subsequent development of expandable polytetrafluoroethylene covered stents further improved shunt patency. Today, TIPS is a well established therapeutic modality for (1) refractory variceal bleeding and (2) ascites in patients who do not tolerate repeated large volume paracentesis. Evidence for the use of TIPS to treat other conditions, including primary prophylaxis in patients with high risk acute variceal bleeding, gastric and ectopic variceal bleeding, primary treatment of medically refractory ascites, recurrent ascites following liver transplantation, hepatorenal syndrome, Budd-Chiari syndrome and portal vein thrombosis continues to be accumulated. TIPS is classically one of the more challenging procedures in interventional radiology and has required relatively high radiation doses and contrast volumes. Much of the difficulty lies in manipulating and guiding a puncture needle towards the right portal vein under limited two-dimensional fluoroscopic guidance. Intravascular ultrasound (IVUS) has been described as an adjunctive real-time imaging modality that may potentially facilitate portal vein access.

Portal Venous Access

Conventional transjugular portosystemic shunt creation technique involves obtaining vascular access via the right internal jugular vein, although some operators have found it easier to cannulate the right hepatic vein from the left internal jugular vein. Through the jugular access, a liver access set (Rosch-Uchida, Has- kal or Ring; Cook Medical, Bloomington, IN, USA) is placed into the right hepatic vein. The Rosch Uchida liver access set contains...
a 10 Fr 40 cm introducer sheath and an inner 14 gauge 51.5 cm stiffening cannula through which a 5 Fr catheter and an inner 0.038 inch 62.5 cm trocar stylet assembly are placed. The liver access set is then rotated towards the expected location of the right portal vein—usually anterior in the standard anatomical configuration. Once the entire assembly is well-positioned in the right hepatic vein and wedged against the vein wall, the 5 Fr catheter and stylet assembly is advanced towards the right portal vein. Operators often feel a “popping” sensation when they enter the portal vein. The assembly is then advanced 1 cm beyond the portal vein and the stylet removed from the 5 Fr catheter. The catheter is withdrawn and aspirated until blood return is observed. Contrast is injected to confirm catheter position within the portal system.

Due to the limited visualization provided by traditional two dimensional fluoroscopy systems, TIPS may often involve several needle punctures, and up to 35 needle punctures in a single procedure have been reported. Hepatic arterial and other non-target organ puncture (Fig. 1) has been described to occur in 1% to 6% of all TIPS cases. Clinical sequelae of these inadvertent needle punctures generally tend to be limited and are symptomatic in less than 2% of cases. Occasionally hepatic arterial injury leads to significant morbidity and even mortality. In one case report, a patient became hemodynamically unstable four hours following a TIPS procedure that had been complicated by hepatic arterial cannulation and injury. CT and conventional angiography demonstrated arterial extravasation and plug embolization was performed at a right hepatic arterial branch. Despite recovery of hemodynamic stability, the patient’s serum bilirubin continued to rise and the patient eventually died of fulminant liver failure. Biliary puncture occurs in fewer than 5% of TIPS cases. However, biliary transection raises the risk of fistula formation and significant morbidity and even mortality. In certain cases, the umbilical vein can be cannulated for a contrast portogram. However, this approach necessitates an adequately sized recanalized umbilical vein and an additional venous access site. Some centers have found success with transhepatic or trans-splenic placement of marker wires within the portal veins as a target for needle puncture.

One of the drawbacks of this technique is the additional needle puncture through highly vascular organs with associated risks of hemorrhage and organ damage. Due to the risks, many operators perform embolization along the tract. With the exception of CO₂ wedge portograms, the use of the aforementioned techniques has been generally reserved for special circumstances and TIPS is performed today with similar technique since its clinical introduction in the 1990s.

Intravascular Ultrasound

IVUS systems were first introduced in the 1980s. Initial transducers were designed to evaluate blood vessel walls. As a result, they were high frequency, in the 20 to 40 MHz range, with limited tissue penetration. In the early 2000s, lower frequency 9 MHz transducers were developed to image cardiac chambers during electrophysiology procedures. These systems featured mechanical ultrasound transducer tipped catheters which rotated at 1,800 rpm to provide a cross sectional view in the radial plane with 5 cm tissue penetration (Fig. 2). While it provided a comprehensive view of the anatomy at each level, the 360° image suffered from high levels of anatomical distortion and lack of color and pulse wave Doppler capabilities.

More recently, phased array ultrasound transducers with a 90° longitudinal side firing view have been developed. The ACUSON AcuNav system (Siemens Healthineers, Erlangen, Germany) features an 8 or 10 Fr diameter and 90 cm long catheter containing an phased array ultrasound transducer at the distal tip. The transducer has a variable 5 to 10 MHz frequency with up to 15 cm tissue penetration. The ViewFlex Xtra Intracardiac Echocardiography catheter (St. Jude Medical, St. Paul, MN, USA) features a 9 Fr 90 cm ultrasound-tipped catheter with a fixed 9 MHz frequency providing a roughly 18 cm tissue penetration. Both of these catheter probes can be steered at the distal tip in the anterior-posterior and medial-lateral planes and provide functional analysis with color and pulse wave Doppler. When placed at the level of the retrohepatic IVC, the side-firing ultrasound probes provide a longitudinal 90° view of the hepatic parenchyma and vessels. The

Fig. 1. (A) Hepatic arterial cannulation (arrowhead) and associated colonic puncture with resulting intraluminal contrast leakage (arrow) during a conventional transjugular intrahepatic portosystemic shunt procedure. (B) Follow-up computed tomography performed 6 hours following the procedure confirmed presence of contrast within bowel (arrow) and trace amounts in the peritoneum, corresponding to locations seen on intra-procedural fluoroscopy.
portal access needle tip can be visualized in real time as the transhepatic access set inner cannula and stylet assembly is advanced from the hepatic vein to the portal vein. Further, there is no need to advance the assembly beyond the portal vein as the needle tip can be visualized in real-time as it enters the portal vein (Fig. 3).

Fig. 2. A 51-year-old female with a history of hepatitis C virus infection status post remote orthotopic liver transplant complicated by recurrent cirrhosis, esophageal varices and presenting with hematochezia and hematemesis. (A-C) Computed tomography performed prior to the procedure demonstrated large portal venous thrombus with evidence of cavernous transformation (arrowheads). (D) Fluoroscopic images demonstrating successful transjugular intrahepatic portosystemic shunt placement with the help of intravascular ultrasound (arrowhead).

Fig. 3. A 57-year-old obese female with hematemesis secondary to extensive acute mesenteric, splenic and portal venous thrombosis following sleeve gastrectomy. (A, B) Computed tomography performed prior to the procedure demonstrated acute thrombosis of the portal veins (arrowheads). The presence of chronic portal venous thrombosis and co-morbid conditions would have made conventional transjugular intrahepatic portosystemic shunt (TIPS) placement more difficult and risky. The decision was made to attempt portal decompression with a TIPS under intravascular ultrasound guidance. Intraprocedural intravascular sonographic images of the right portal vein (RPV) taken during evaluation (C) and needle advancement (D). The needle was advanced towards the RPV (E) to an intraluminal position (F). Digital subtraction angiograms demonstrating extensive splenic, mesenteric and portal venous thrombosis (arrowheads) following needle puncture and cannulation of the portal vein (G, H) and stent placement (I, J).
Current Literature

The use of IVUS in hepatic interventions was first described for direct portocaval shunting whereby a shunt is placed between the portal vein and the retrohepatic IVC through the caudate lobe. Its use for TIPS guidance was first described in 2004. Using the aforementioned AcuNav catheter, the authors were able to place TIPS in three swine after one or two needle punctures without the use of wedged portography. No post-procedural complication was reported. The first retrospective clinical series of 25 cases using IVUS compared to 75 cases using conventional technique was published in 2012. Cases were performed using left internal jugular vein for placement of the liver access set and left common femoral vein for insertion of the IVUS catheter. The authors found no difference in number of passes, fluoroscopy time or rate of inadvertent needle puncture in the two groups. Recently, three reports of retrospective single center case series were published in the Journal of Vascular and Interventional Radiology (Table 1).

The first of the three reports described a series of TIPS cases that were performed using conventional (n = 26), marker wire (n = 18) and IVUS (n = 24) guidance. Marker wire cases involved transhepatic or trans-splenic placement of an 0.018 inch wire into the portal vein through a 21 gauge Chiba needle using fluoroscopic and percutaneous ultrasound guidance. Cases were performed with the Colapinto needle from a right internal jugular access. There were 9 total operators, 8 of whom performed IVUS guided TIPS in addition to conventional TIPS. There were 6 direct portocaval shunt cases included, 3 performed with marker wire and 3 with IVUS guidance. Two dual TIPS cases were included, one using conventional and the other with marker wire guidance. Eleven cases involved variceal embolization which were equally distributed among the three groups. The authors found a decreased amount of fluoroscopy time, air kerma, contrast agent volume, and total procedure time when using IVUS on post hoc pairwise comparison with fluoroscopy. In fact, the use of IVUS was also associated with decreased fluoroscopy time, contrast agent volume and total procedure time even when compared to marker wire. The decreased procedure time could not be attributed to portal vein access time as the 16 minutes difference in the means did not reach statistical difference. Technical success, hemodynamic success and mean portosystemic gradient reduction were similar in the two groups. Likewise, no statistically significant difference in procedural complications was discovered. There were, however more cases of stent malpositioning and contrast agent-induced renal failure in the IVUS group even though IVUS provides an additional modality to assess stent positioning and generally decreases contrast volume usage during TIPS. These may be cases of correlation rather than causation, as IVUS likely was selected in a patient that would have been prone to renal failure or increased rate of stent malposition due to the use of less conventional routes, such as middle hepatic vein to left portal vein, that are more easily achieved with IVUS.

The second paper described a case series of 49 conventional and 40 IVUS TIPS. Cases were performed with the Rosch Uchida transjugular access set from a right internal jugular access. The majority of IVUS access sites were at the right common femoral vein, although two cases involved two right internal jugular access sites for the liver access set and IVUS catheter. There were 4 conventional operators and 2 IVUS operators. Direct portocaval shunts were excluded from the analysis. All cases involving transjugular liver biopsy, variceal embolization, portal venoplasty and thrombolysis were excluded. The authors found statistically significant decreases in number of needle passes, contrast volume,

Table 1. A Summary of Outcomes of IVUS-guided Transjugular Intrahepatic Portosystemic Shunt in the Literature

<table>
<thead>
<tr>
<th>First author</th>
<th>Year (year)</th>
<th>No. of cases</th>
<th>No. of needle passes</th>
<th>Needle passes</th>
<th>Portal vein access time (min)</th>
<th>Fluoroscopy time (min)</th>
<th>Contrast agent volume (mL)</th>
<th>Procedure time (min)</th>
<th>Air kerma (mGy)</th>
<th>Dose area product (Gy·cm²)</th>
</tr>
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<tbody>
<tr>
<td>Farsad</td>
<td>2012</td>
<td>25</td>
<td>21</td>
<td>21</td>
<td>0.67 ± 1.15</td>
<td>6.74 ± 0.97</td>
<td>0.52 ± 0.247</td>
<td>0.56 ± 0.247</td>
<td>1.13 ± 0.38</td>
<td>0.67 ± 0.38</td>
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<tr>
<td>Iyamu</td>
<td>2015</td>
<td>55</td>
<td>26</td>
<td>26</td>
<td>0.67 ± 1.15</td>
<td>6.74 ± 0.97</td>
<td>0.52 ± 0.247</td>
<td>0.56 ± 0.247</td>
<td>1.13 ± 0.38</td>
<td>0.67 ± 0.38</td>
</tr>
<tr>
<td>Gipson</td>
<td>2016</td>
<td>24</td>
<td>26</td>
<td>26</td>
<td>0.67 ± 1.15</td>
<td>6.74 ± 0.97</td>
<td>0.52 ± 0.247</td>
<td>0.56 ± 0.247</td>
<td>1.13 ± 0.38</td>
<td>0.67 ± 0.38</td>
</tr>
<tr>
<td>Kao</td>
<td>2016</td>
<td>40</td>
<td>49</td>
<td>49</td>
<td>0.67 ± 1.15</td>
<td>6.74 ± 0.97</td>
<td>0.52 ± 0.247</td>
<td>0.56 ± 0.247</td>
<td>1.13 ± 0.38</td>
<td>0.67 ± 0.38</td>
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Values are presented as number only, number of IVUS/number of conventional, or ratio (IVUS/conventional). Actual reported values are presented in parentheses. Mean values are displayed for Farsad’s and Iyamu’s reports. Median values are displayed for Gipson’s and Kao’s reports.

IVUS, intravascular ultrasound; -, not reported.
fluoroscopy time, radiation dose and procedure time associated with IVUS. There was no difference in portosystemic gradient reduction.

The third paper described the largest case series of IVUS-guided TIPS to date, with 55 IVUS and 54 conventional TIPS. Cases were performed using the Haskal Transjugular Portal Access set which includes a 16 gauge Ross modified Colapinto needle. Overall, there was decreased radiation dose and portal access time, defined as the time from hepatic venogram to portal venogram, associated with IVUS guidance. However, when further subset analysis was done between experienced and inexperienced operators, defined as having performed fewer than 20 TIPS as the primary operator prior to the study period, no difference was seen in the experienced operators with the use of IVUS. The authors also noted gradual decreases in portal access time over the three-year study period in the IVUS group, suggestive of an initial learning curve. Further, there were fewer needle pass-related capsular perforation rates in the IVUS group.

It is important to remember that the existing literature is limited to retrospective single-center case series and findings may not be widely reproducible. These results likely reflect certain institutional factors, including practice models, operator familiarity and preferences. While the human studies listed above featured generally well-match patient cohorts in terms of age, severity and etiology of liver disease, there were proportional differences in the indications for TIPS in several papers. Although the differences did not meet statistical significance, the distinction in TIPS indications is not insignificant, as TIPS for refractory variceal hemorrhage is more often performed on an urgent or emergent basis compared to refractory ascites. Furthermore, these case series featured varying overlap between the IVUS and conventional operators. In some papers, almost all TIPS operators performed both IVUS and conventional TIPS whereas in others, some operators exclusively performed TIPS with either IVUS guidance or conventional technique. It is not entirely clear whether the conventional and IVUS cases were performed at the same rates over study periods. There likely was a shift towards using IVUS as commonly seen with any new modality and the results may at least partially reflect study period-related confounding variables.

Conclusions

Although the current literature on the use of IVUS in TIPS is limited to single-center retrospective series, they suggest that the use of IVUS is associated with reduced portal access time, procedure time, contrast volume and radiation dosage. Available data on numbers of needle passes and rates of capsular perforation are mixed. Despite the limitations of the available reports, the authors believe that the use of IVUS should be strongly considered whenever there is known obstructing tumor mass, unfavorable vascular anatomy, Budd-Chiari syndrome and hepatic or portal venous thrombosis. Together, the recent literature provides evidence supporting the broader use of IVUS in TIPS regardless of the presence of complicating factors. The improved visualization afforded by IVUS has meant that historical relative contraindications to TIPS, such as Budd-Chiari syndrome and portal vein thrombosis are no longer effective. In fact, TIPS is used now as part of the treatment of portal venous thrombosis and/or Budd Chiari syndrome in certain cases. Accurate and comprehensive visualization of the hepatic vasculature is highly beneficial for the safety and efficacy of TIPS creation. IVUS represents an important, and some may argue crucial, modality in the TIPS interventionist’s armamentarium.

Conflicts of Interest

No potential conflict of interest relevant to this article was reported.

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References