ABSTRACT
Objective: The study aims to assess the technical and clinical results of the transjugular intrahepatic portosystemic shunt (TIPS) procedure carried out under additional transabdominal ultrasound guidance.

Methods: We evaluated the radiation dosage for all TIPS performed with transabdominal ultrasound guidance for PV puncture over four years (n=212, with 210 successfully completed and data available for 206); fluoroscopy time, dose area product (DAP), and skin dose were recorded.

Results: The mean fluoroscopy time was 12 minutes and 9 seconds (SD, 14 minutes and 38 seconds), the mean DAP was 40.3 ± 73.1 Gy.cm², and the mean skin dosage was 404.3 ± 464.8 mGy.

Conclusion: Our findings show that ultrasound-guided PV puncture yields fluoroscopy times and radiation doses significantly lower than the sole published dose reference limits.

KEYWORDS transjugular intrahepatic portosystemic shunt, fluoroscopic, ultrasound

Introduction
Although transjugular intrahepatic portosystemic shunts (TIPS) have been crucial to managing problems associated with portal hypertension, shunt stenosis has been a significant issue. A year following the shunt’s formation, the primary patency loss was around 50% when TIPS were all made with bare metal stents. Although the introduction of PTFE-covered stents has significantly improved patency, stenosis is still present in 8–20 percent of patients a year after the development of TIPS [1–5].

Several methods have been employed to increase the success rate, such as indirect portography, wedge portography with iodinated contrast or CO₂, transabdominal ultrasound (US), and computed tomography (CT) guidance. [6] Since 2004, we have combined fluoroscopy and transabdominal US guidance to conduct TIPS at our facility. The inferior vena cava (IVC) is connected to a branch of the portal vein by a tract known as a direct intrahepatic cavo-portal shunt (DIPS) or a transcaval TIPS. When a suitable hepatic vein is unavailable, this procedure is typically used. Our first case series on US-guided TIPS included technical details and quick results.[7]

Protocols for when and how frequently to screen TIPS functions are not universally agreed upon. One strategy is to wait for the recurrence of portal hypertension symptoms. Patients whose TIPS were implanted to treat ascites can employ this method. This approach is not suggested for patients with a history of variceal bleeding because the first sign of a TIPS issue could be a fatal recurring haemorrhage. Even in patients with ascites, it is advantageous to identify shunt issues before the patient develops severe symptoms because TIPS venography is considerably simpler when the patient does not have a significant amount of ascites. When there are little ascites, the patient is more at ease and may breathe more easily while lying down. However, extensive ascites make the procedure more challenging, encouraging the liver to move cephalad and adding extra density that worsens the fluoroscopy image.
Table 1 Primary reasons for creating a transjugular intrahepatic portosystemic shunt

| Indication                     | Number of patients (%) |
|--------------------------------|------------------------|
| Hepatic hydrothorax            | 5 (2.43)               |
| Refractory ascites             | 78 (37.86)             |
| Budd-Chiari syndrome           | 11 (5.34)              |
| PV/SMV thrombosis              | 18 (8.74)              |
| Variceal haemorrhage           | 94 (45.63)             |
| Not recorded                   | 4 (2)                  |

PV, portal vein; SMV, superior mesenteric vein

Methods

The radiology information system (RIS) and picture archiving and communication system (PACS) were retrospectively reviewed for all TIPS procedures carried out in our institution over four years. The indication for TIPS, fluoroscopy time, DAP (Gy.cm$^2$), and skin dose (mGy) were recorded. The dosimetry details were obtained from the integrated dosimetry within the fluoroscopy machine. The fact that this was a retrospective examination of accepted practice at our institution precluded the need for ethical approval. Furthermore, since this was a retrospective examination of an already created anonymised database, no particular informed consent was required.

Patients

212 operations were completed in total. Table 1 contains a collection of the TIPS generation indicators. Due to blocked hepatic veins, TIPS could not be performed on two individuals. There were no more severe intra-procedural complications. Data from fluoroscopy were acquired for 206. Regardless of their BMI, all patients referred for TIPS underwent ultrasound-guided portal vein access.

Procedure

Five professor-level radiologists performed all procedures under general anaesthesia as the primary operator. All of the radiologists on the faculty level had more than ten years of expertise in interventional radiology. A 10 F sheath was placed into the jugular vein (right, unless obstructed), and a 5 F Cobra catheter was used to cannulate the hepatic vein (typically right, but the middle was also used). The patient was then given a Rösch-Uchida transjugular liver access set (Cook Medical). At this point, the sonographer took a position adjacent to the patient’s right side, with the ultrasound machine’s screen (MicroMaxx, SonoSite, or Sparq, Philips Healthcare) positioned obliquely concerning the patient so that both the operator and sonographer could see it clearly. A curved abdominal probe with a frequency range of 3-5 MHz was used. For insonation, an oblique intercostal route was used, typically between the 9th and 11th ribs, dependent on liver size, with slight movements allowing for target change from right hepatic vein to the right portal vein. The sheath was used to stretch the Rösch-Uchida needle through the hepatic vein wall and immediately visualise it as it went through the liver parenchyma towards the right portal vein. Color Doppler was utilised as necessary, but B-mode was usually sufficient for navigation. The operator could vibrate the needle tip to assist ultrasound visualisation. To observe the target vessels, the sonographer would deliver verbal input on the way the probe travelled. The operator might then adjust the amount of torque on the access set or the position within the hepatic vein to allow PV penetration. If necessary, the access set’s degree of angulation was changed to obtain PV access. The ultrasound image was severely degraded if air was introduced during the access or needle exchange. After gaining direct ultrasound image of the right PV, blood was sucked via the catheter and direct portography was done. After confirming a suitable site, the TIPS procedure was carried out as previously described with balloon dilatation of the track and deployment of VIATORR stent(s) (W.L. Gore & Associates).

Fluoroscopy

Fluoroscopy was performed using a Siemens Artis Zee fluoroscopy system with a large flat panel detector and a 3 fps pulse rate. The radiographer always constrained the field of view by actively coning. As necessary, a few short runs of digital subtraction angiography (DSA) were carried out, with a mean of 35 seconds and a total run time of five to 93 seconds (2 frames per second).

Results

The mean fluoroscopy time in our retrospective research of 206 TIPS procedures was 12 min 9 s (SD, 14 min 38 s; 75th percentile, 26 min 8 s), and the median fluoroscopy time was 16 min 17 s. The mean DAP was 40.3 Gycm$^2$ (standard deviation, 73.1 Gycm$^2$; 75th percentile, 75.2 Gycm$^2$), while the median DAP was 38 Gycm$^2$.

The mean skin dose was 404 mGy (standard deviation: 465 mGy; 75th percentile: 488.4 mGy), and the median skin dose was 257 mGy. Table 2 shows that fluoroscopy times and dosages were lower than RAD-IR DRLs. In Table 2, median values for fluoroscopy time, DAP, and skin dosage are compared to median values from RAD-IR data.

Discussion

Our findings demonstrate that, compared to the established reference values, transabdominal ultrasound-guided PV puncture during TIPS yields shorter fluoroscopy periods and reduced patient dose. Direct vision of the needle tip decreases the possibility of problems during PV puncture and the potential reduction in radiation dosage [8]. In addition, it enables the selection of a puncture site that will give a favourable angle for the TIPS tract [9]. There were no serious problems with the operation.
Table 2 Fluoroscopy times, dosage products and skin doses for procedures involving transjugular intrahepatic portosystemic shunts in our cohort were compared with reference levels from (22)

| Fluoroscopy time (min:s) | Range   | Mean±SD | Median |
|-------------------------|---------|---------|--------|
| RAD-IR DRL              | 04:47–112:41 | 60:00 ± 12:10 | 31:00 |
| Data set                |         | 12:10 ± 14:39 | 16:16 |
| DAP (Gy·cm²)            | 5.0–479.5 | 524 ± 40.4 | 251 |
| RAD-IR DRL              |         | 40.4 ± 73.0 | 39 |
| Data set                |         |          |      |
| Skin dose (mGy)         | 36–3256 | 3000 ± 405 | 1490 |
| RAD-IR DRL              |         | 405 ± 464 | 258 |
| Data set                |         |          |      |

SD, standard deviation; RAD-IR, Radiation Doses in Interventional Radiology Procedures study; DRL dose reference level; DAP, dose area product

Additional Image Guidance during TIPS

During the typical TIPS surgery, many attempts are typically attempted. However, there are several benefits to reducing the number of attempts when developing the TIPS tract. These include a greater likelihood of success, lower complications, shorter operation time, and less radiation exposure. The ability to see the tract being produced in real-time is the main benefit of extra transabdominal US. The US also has the added benefits of being widely accessible, having a good resolution, and is reasonably priced.

A thorough introduction to the unique anatomy is crucial even before the patient is taken in for treatment. The US helps determine the cannula tip’s location, the needle’s path through the liver parenchyma, and the needle’s entrance into the portal vein. When using traditional TIPS, the US aids in confirming that the vein chosen is the RHV and is located behind the PV’s right branch (RPV). In cases where ascites and variations in the volume of liver parenchyma are present, the middle hepatic vein (MHV) may occasionally be mistaken for the right hepatic vein (RHV) on fluoroscopy.

To build the shunt, intravascular ultrasonography (IVUS) offers good guidance. [10,11] TIPS is carried out from the jugular access, and the IVUS probe is inserted from the transcranial access. The liver’s caudate lobe may be used to execute the tract. A closer perspective also reduces the risk of damaging the hepatic arteries and biliary radicles. However, considerations like availability and additional cost should be taken into account. Both transvenously and percutaneously, a TIPS tract has been fabricated using CT. [12,13] According to some findings, magnetic resonance imaging (MRI) could be used to provide more picture direction. [14]

Widened Spectrum of Indications for TIPS

Some of the relative contraindications previously specified in the AASLD recommendations are now indications rather than contraindications for TIPS. [15] BCS has been added as an indicator in a later release. [16] BCS was the most frequent etiology in our study. A new use for TIPS is acute portal vein thrombosis, where it is helpful in recanalization and lowers the risk of developing portal cavernoma in the future. [17,18] These conclusions require a suitable review of the TIPS guidelines. [19]

The study’s drawback is that it is retrospective in nature. We don’t have any recordings of how many times we tried to make the tract or how long it took. Although not all patients recorded their radiation dosage, a tiny subset of those in the current cohort had noticeably low radiation exposure. [20]

In one of our patients, the liver was extremely fatty and strongly echogenic, making ultrasound-guided navigation impossible. Despite the majority of our patients having cirrhosis and frequently having shrunken, atypical livers, there were few difficulties in obtaining adequate images of the necessary anatomy (the right PV and hepatic vein), and there were no issues with real-time needle tip guidance through the liver parenchyma. Portal vein thrombosis cases were included in this. However, the use of ultrasound may be impacted by the rising rates of obesity and nonalcoholic fatty liver disease. It is important to highlight that while we employed the Rösch-Uchida set, the only significant cohort of TIPS for PV targeting that included real-time ultrasound guidance was carried out with the Colapinto needle [21]. Therefore, both methods now in use for TIPS production allow for real-time ultrasonography guidance.

We have demonstrated that the RAD-IR study’s fluoroscopy time is almost one-third shorter than ours [22]. In addition, our approach significantly reduces the exposure: our mean DAP measures are 14% of the RAD-IR study, and skin dose is 16%. Newer technology and elements like care placement and pulsed rather than continuous fluoroscopy are some reasons why this is proportionally a higher reduction than the fluoroscopy time. A variety of centres conducted the RAD-IR study from 1999 to 2002, and it is noteworthy how fluoroscopy technology and methods have advanced dramatically during the past 15 years. For example, older wedge venography methods demanded more DSA and more lateral and oblique projections, which raised the dose.

Conclusion

We have demonstrated that the dosages produced by transabdominal ultrasound-guided PV puncture during TIPS are significantly lower than those produced by published DRLs. Transabdominal US is a more appealing instrument than IVUS because of its universality and real-time guidance. More patients will benefit from US advice since it broadens the range of indications by including some illnesses previously thought to be contraindications, such as acute PVT and destroyed hepatic veins. We advise that extra US advice be utilized consistently for all TIPS procedures because it improves success rates to almost 100%, lowers peri-procedural problems, lowers radiation doses, and broadens the range of indications for TIPS.
Funding
This work did not receive any grant from funding agencies in the public, commercial, or not-for-profit sectors.

Conflict of interest
There are no conflicts of interest to declare by any of the authors of this study.

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