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Ultrasonographic guidance for portal vein access during transjugular intrahepatic portosystemic shunt (TIPS) placement

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KEYWORDS
Transjugular intrahepatic portosystemic shunt (TIPS);
Imaging guidance;
Ultrasound;
Portal vein puncture;
Portal hypertension

Abstract
Purpose: The purpose of our study was to retrospectively assess the safety and efficacy of percutaneous real-time ultrasound guidance for portal vein puncture during transjugular intrahepatic portosystemic shunt (TIPS) placement.
Materials and methods: Between January 2011 and November 2018, procedure details and outcome were retrospectively analyzed for 224 patients who underwent TIPS placement using real-time ultrasound guidance for portal vein puncture. There were 175 men and 49 women with a mean age of 52.7 ± 10.6 (SD) years (range: 22—82 years). For each procedure, technical success, primary ultrasound guidance success, portosystemic pressure gradient, duration of the intervention, procedural complications, radiation exposure, mortality and morbidity rates at day 30 post-procedure were recorded for data analysis.
Results: Technical success rate was 100.0% with a success rate of the primary ultrasound guidance of 97.8% (219/224; 95% CI: 95.8—99.7). Mean duration of the procedure was 86.2 ± 41.7 (SD) min (range: 22.0—267.0 min). Mean dose-area product was 62.0 ± 50.2 (SD) Gy.cm^2 (range: 3.7—306.5 Gy.cm^2). Twelve complications (12/224; 5.4%) occurred in ten patients during TIPS procedures including 8 arterial punctures (3.6%) and 4 biliary punctures (1.8%). Four complications (4/224; 1.8%) were clinically significant. Mortality rate at day 30 after the procedure was 9.8% (22/224), without any patient dying from technical complications.

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Conclusion: Real-time ultrasound guidance is a safe technique to assist in the creation of TIPS and may allow for lower radiation exposure.

Transjugular intrahepatic portosystemic shunt (TIPS) placement is currently used for the management of complications of portal hypertension, in particular in patients with variceal bleeding and refractory ascites [1]. However, TIPS placement remains a complex procedure and one of the most challenging steps is the puncture of the portal vein. Many complications that can occur during a TIPS procedure are associated with this step, such as hemoperitoneum, subcapsular or intra-parenchymal hepatic hematomas or biliary tree injuries [2—5]. Several approaches have been tested to improve targeting of the portal vein, including direct portography or splenoportography [6—8], carbon dioxide (CO_2) or iodinated contrast agent wedged hepatic portography [9,10], arterial portography [11], catheterization of the recanalized paraumbilical vein [12], gunsight [13], magnetic resonance angiographic guidance [14,15] and image fusion with pre-procedural computed tomography angiography [16,17]. Ultrasonography has also been used in many different ways to secure the puncture of the portal vein such as transhepatic puncture of portal and hepatic veins using a single-needle pass under ultrasound guidance, which allows the passage of a wire from a percutaneous access to a transjugular route or percutaneous placement of marking wires next to the portal vein to facilitate fluoroscopy-guided entry into the portal vein [18—20]. Three-dimensional ultrasound has also been used to ensure safety and significantly improve the efficacy of portal vein access during TIPS placement [21]. Intravascular ultrasound guidance is also a feasible and effective technique for assisting portal vein targeting during TIPS placement [21]. The use of percutaneous real-time ultrasound guidance of the portal vein during TIPS placement has been initially described by Longo et al. [22] but has not been widely used. In addition, Miraglia et al. reported that the use of this technique resulted in lower radiation exposure, for both patients and operators [23,24]. Few studies have described the practical implementation of ultrasound guidance.

The purpose of our study was to retrospectively assess the safety and efficacy of percutaneous real-time ultrasound guidance for portal vein puncture during TIPS placement.

Materials and methods

Study design

Local ethics committee approval was obtained for this retrospective study, and a waiver for informed consent was granted. From January 2011 to November 2018, 236 TIPS procedures were performed in our institution because of complications resulting from portal hypertension. Ultrasound was systematically used as the first-line guidance for portal vein puncture. Twelve patients were excluded due to missing data. The remaining 224 patients were analyzed retrospectively and constitute our study group. There were 175 men and 49 women with a mean age of 52.7 ± 10.6 (SD) years (range: 22—82 years).

Ultrasound-guided TIPS procedure

TIPS were performed in a flat-panel-based detector angiographic suite (Innova® 4100, General Electric Healthcare) by five senior interventional radiologists with at least two years of experience in TIPS procedures. All procedures were carried out under general anesthesia, using the Rösch-Uchida® portal vein access set (Cook). A 10-Fr sheath was placed in the internal jugular vein using ultrasound guidance and then the right hepatic vein was catheterized, with the alternative being the middle (or even the left) hepatic vein. The Rösch® needle was advanced into the portal vein under percutaneous real-time ultrasound guidance by a second operator, using the 5-MHz curvilinear transducer of a Logic E9® ultrasound unit (General Electric Healthcare).

Two ultrasonographic views, lateral or anterior, were used to visualize both hepatic (with the puncture needle) and portal veins. The transducer was positioned tangentially to the right intercostal spaces to obtain the lateral view (Fig. 1) and in the epigastric area to obtain the anterior view (Fig. 2). Once access to the portal vein system was confirmed by blood aspiration and injection of iodinated contrast material (Fig. 3), a portography was acquired and portal pressure was measured to determine the initial portosystemic pressure gradient (PPG). Variceal embolization was performed at the discretion of the operator, when oesophageal varices were seen on initial portography, using preferentially N-butyl 2-cyanoacrylate (Glubran2®, GEM). Dilatation of the parenchymal tract between the hepatic and portal vein was performed using an 8-mm or 10-mm diameter angioplasty balloon (Ultraverse®, Bard). A 8-mm or 10-mm diameter expanded polytetrafluoroethylene-covered Viatorr® stent (Gore) was then deployed and further dilated with balloon. A final portogram was obtained and the final PPG was measured again after TIPS placement. Additional variceal embolization was performed when persistent spontaneous portosystemic shunts remained visible.

Study endpoints and definitions

For each procedure, technical success, primary ultrasound guidance success, pre- and post-procedural PPG, duration

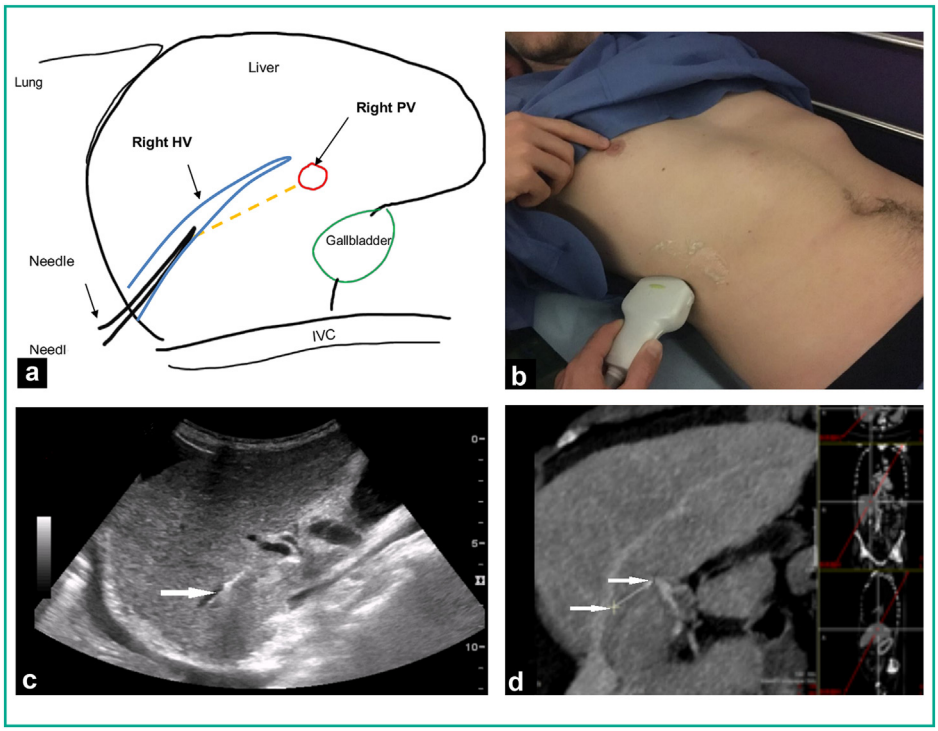

Figure 1. Figure shows intercostal approach for ultrasound guidance for right portal vein puncture. A. Schematic representation shows puncture needle track within the right hepatic vein (HV) in a long axis and the targeted portal vein (Right PV) in a short axis. Yellow dotted line indicates anticipated puncture path. B. Photograph shows location of the transducer in a right intercostal space to visualize intrahepatic structures as shown in figure A. C. Ultrasound image obtained using intercostal approach shows needle tip echo (arrow) within the hepatic vein. D. Computed tomography image in an oblique reconstruction shows anticipated puncture path (arrows).

of the intervention, dose-area product (DAP), fluoroscopy time, procedural complications, mortality and morbidity rates at 30 days after the procedure were recorded for data analysis. Technical success was defined as the successful placement of a stent between a hepatic vein and a branch of the portal vein. Primary ultrasound guidance success was defined as the successful puncture of an intrahepatic portal branch using real-time ultrasound guidance. Pre- and post-procedural PPG were measured during TIPS procedure. The mean radiation dose was measured as the DAP, as recommended by the International Commission on Radiation Units [25]. Duration of the intervention, DAP, and fluoroscopy time were retrospectively documented. Procedural complications, including traversal of the liver capsule, hepatic arterial puncture, biliary puncture, non-target organ puncture were recorded, both those witnessed by operators and those with a significant clinical impact. The mortality and morbidity (hepatic encephalopathy and variceal bleeding) rates noted at 30 days after the procedure. Patency of the TIPS was also evaluated within the 30 days following TIPS placement by duplex and color Doppler ultrasound examination.

Statistical analysis

Data were inputted in an Excel® 2013 spreadsheet (Microsoft). Qualitative variables were expressed as raw numbers, proportions and percentages. Quantitative were reported as means ± standard deviation (SD) and ranges. Estimates were given along with their 95% confidence interval (CI). The differences in DAP between patients with and without variceal embolization were analyzed using the two-sided Student *t*-test, with a significance threshold set at $P < 0.05$.

Results

Patient description

Patient demographic and clinical characteristics prior to TIPS creation are given in Table 1. Alcohol abuse was identified as the primary cause of cirrhosis in 186/224 patients (83%). The indications for TIPS placement are shown in Table 2. TIPS were performed for preventing variceal rebleeding or for treating acute variceal bleeding in 64.3% of patients (144/224) and for treating refractory ascites in 37.5% (84/224). Less common indications were hydrothorax, ectopic variceal bleeding, recurrent portal thrombosis and prior to abdominal surgery. A total of 91/224 patients (40.6%) underwent TIPS procedure in emergency setting and 133/224 (59.4%) as a scheduled procedure. Per-procedural characteristics are given in Table 3.

Procedural success

TIPS creation using primary real-time ultrasound guidance for portal vein access was technically successful in all patients, resulting in the deployment of an appropriate stent shunting from the portal to the hepatic venous system. Most

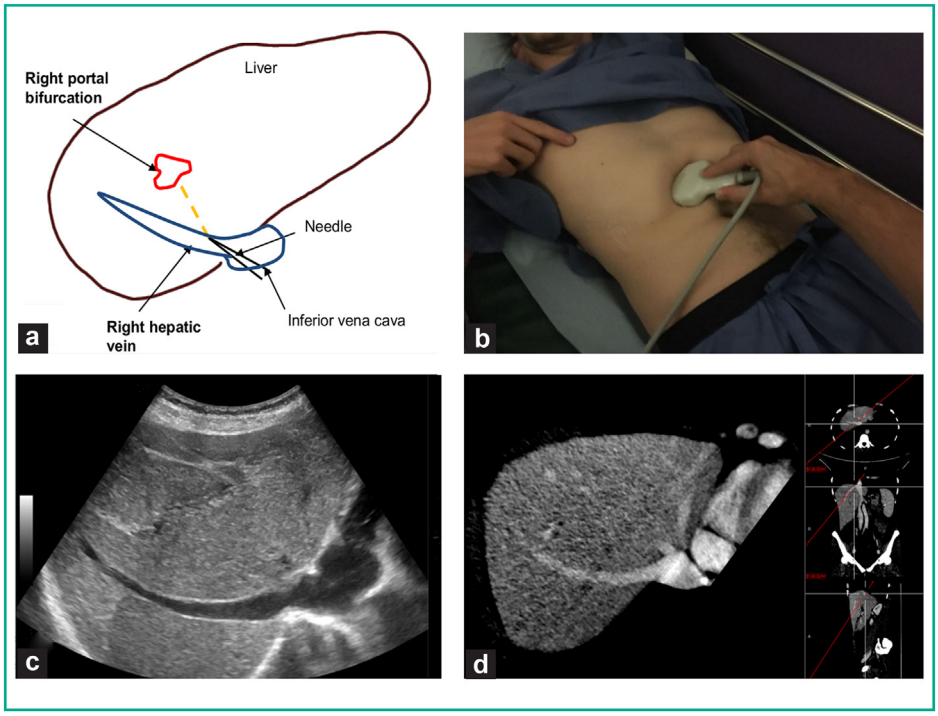

Figure 2. Figure shows epigastric approach for ultrasound guidance for right portal vein puncture. A. Schematic representation shows puncture needle within the right hepatic vein in a long axis and the targeted portal vein in a short axis. Yellow dotted line represents the anticipated puncture path. B. Photograph shows the transducer in the epigastric area to visualize intrahepatic structures as shown in figure A. C. Ultrasound image obtained using epigastric approach shows needle tip echo within the hepatic vein. D. Computed tomography image in an oblique reconstruction shows anticipated puncture path.

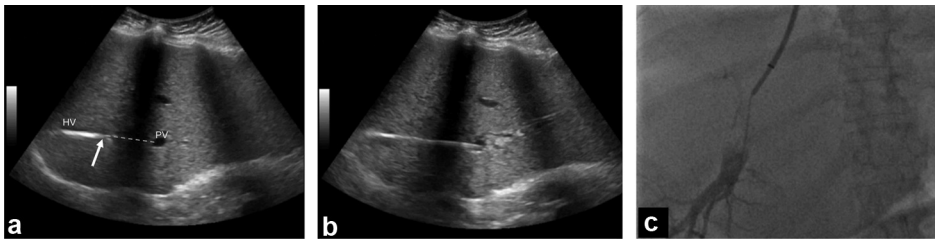

Figure 3. Portal vein puncture under ultrasound guidance during TIPS placement in a 62-year-old woman. A. Ultrasound image using intercostal approach before portal vein puncture shows the needle tip echo (arrow) in the right hepatic vein (HV). The anticipated puncture path from the right hepatic vein to the targeted right portal vein (PV) is shown as yellow dotted line. B. Ultrasound image using intercostal approach shows the needle track with the needle tip echo in the right portal vein during direct puncture from the right hepatic vein. C. Fluoroscopic image shows contrast material into the right portal vein following puncture from the right hepatic vein.

of patients (176/224; 78.6%) had a TIPS placed between the right portal vein and the right hepatic vein.

Intrahepatic portal vein puncture was successfully performed under primary ultrasound guidance in 219/224 patients yielding a technical success rate of 97.8% (95%CI: 95.8—99.7). For the remaining 5 patients, 3 portal vein punctures were performed using fluoroscopy and 2 using wedged portography because of the failure of the ultrasound guidance.

Mean post-procedural PPG was 6.9 ± 3.3 (SD) mm Hg (range: 0.0—20.0 mmHg) and 152 patients (67.6%) had a PPG ≤ 8 mmHg after TIPS placement. Single stent deployment was performed in 189/224 patients (84.4%) and 31/224 (13.8%) and 4/224 (1.8%) patients had respectively one and two additional stents placed because of an initial shortage in the hepatic vein and/or portal vein.

Safety procedure

A total of 12 puncture-related complications (12/224; 5.4%) were reported in 10 patients, including 8 inadvertent arterial punctures and 4 inadvertent biliary punctures. Two patients had both inadvertent arterial puncture and inadvertent biliary puncture. Four of these complications were clinically significant (4/224; 1.8%). One patient had hemobilia, with stable hemodynamic status. Two patient required re-intervention for arterial embolization due to a subcapsular hematoma and an arterioportal fistula. One patient had an arterial injury leading to an ischemic type biliary stricture that required internal-external percutaneous biliary drainage.

Mean DAP was 62.0 ± 50.2 (SD) Gy.cm^2 (range: 3.7—306.5 Gy.cm^2) and mean fluoroscopy time was

Table 1 Demographic and clinical characteristics of 224 patients who underwent TIPS placement with portal vein puncture under ultrasound guidance.

Variable	Value
Gender	
Male	175 (78.1)
Female	49 (21.9)
Age (year)	52.7 ± 10.6 [22.0—82.0]
Cause of liver cirrhosis[a]	
Alcohol-induced	186 (83.0)
Hepatitis B	2 (0.9)
Hepatitis C	16 (7.1)
NASH	3 (1.3)
Other	23 (10.3)
Diabetes	70 (31.3)
Child-Pugh score	8.4 ± 2.0 [5.0—15.0]
Child-Pugh classificatio	
A	35 (15.6)
B	136 (60.7)
C	53 (23.7)
MELD score	14.8 ± 6.6 [6.0—58.0]

SD = Standard deviation. Numbers in brackets are ranges. Numbers in parentheses are percentages.
[a] Some patients had more than one cause of liver cirrhosis.

Table 2 Indications for transjugular intrahepatic portosystemic shunt placement in 224 patients.

Indication for TIPS placement[a]	
Refractory ascites	84 (37.5)
Prophylaxis of variceal bleeding	54 (24.1)
Acute variceal bleeding	90 (40.2)
Other	9 (4.0)

Numbers in parentheses are percentages.
[a] Some patients had more than one indication for TIPS placement.

20.3 ± 15.3 (SD) min (range: 3.1—83.3 min). Mean duration of the procedure was 86.2 ± 41.7 (SD) min (range: 22.0—267.0 min). DAP was significantly higher in patients with variceal embolization (76.2 Gy.cm^2) when compared with patients without embolization (46.3 Gy.cm^2, $P < 0.001$).

Follow-up

Twenty-two patients (9.8%) died within 30 days after TIPS implantation, without any death related to a puncture-related complication. The causes of death are given in Table 4. Seventy patients had hepatic encephalopathy (70/224; 31.3%) and 9 patients (9/224; 4.0%) had repeat variceal bleeding during this 30-days follow-up. Early evaluation of TIPS patency revealed 12 thromboses (5.4%), either managed by anticoagulant therapy alone and/or restenting.

Discussion

In our study, percutaneous ultrasound guidance success rate was 97.8%. This technique failed in only five patients for whom portal vein puncture had to be performed under fluoroscopic guidance, allowing the completion of TIPS creation in all 224 patients. Of interest, as we reviewed every TIPS procedure performed for eight years in our center, there was no selection on patient's characteristics, indication of TIPS or anatomic criteria. Although percutaneous ultrasound guidance for portal vein targeting carries the reputation for being limited by obesity, ascites or liver cirrhosis, our results show that this technique can be used in most patients, with a large variety of anatomic settings.

In our study, puncture-related complications occurred in only 12/224 patients (5.4%) while the reported rates are approximately 6% for arterial punctures, 5% for biliary puncture, 30% for perforation of the liver capsule and 1—6% for hemoperitoneum [1,2]. The results of our study demonstrate that percutaneous real-time ultrasound guidance enables TIPS creation with a low rate of non-target puncture, as already suggested by Rössle [26] and Bettinger et al. [27] with reported complications rates not exceeding 3.4% [27].

The most common complication in our study was arterial puncture. We think that these complications may happen even under ultrasound guidance because of the proximity of portal vein branches to hepatic artery branches, notably in patients with small portal branches and enlarged arteries due to portal hypertension.

The use of percutaneous ultrasound guidance, as described in this study, has several technical advantages. First, it allows real-time monitoring of the puncture, thus limiting the impact of ascites or patient's movements on secure targeting. Second, ultrasound guidance helps determine with confidence which hepatic vein should be catheterized, avoiding multiple needle passes. Third, ultrasound readily helps distinguish portal vein from peri-portal structures so that the operator can avoid non-target puncture.

In our study, the mean DAP was 62.0 Gy.cm^2, which is substantially below the proposed reference level of 525 Gy.cm^2 [28], while being in line with the results of several other researchers using percutaneous real-time ultrasound guidance. Livingstone et al. reported a mean DAP of 63 Gy.cm^2 in 19 patients [29]. Miraglia et al. reported two large surveys on patient radiation exposure during TIPS placement using flat-panel-based detector angiography unit and ultrasound guidance [23,24]. They reported a mean DAP of 129 Gy.cm^2 in a retrospective study including 211 TIPS procedures [23] and a mean DAP of 59.31 Gy.cm^2 in a prospective study involving 45 patients [24]. Based on those results, they proposed a new dose reference level of 150 Gy.cm^2 for TIPS placement [23]. Although it is difficult to compare dosimetric results among studies, our results obtained using a flat-panel-based detector angiographic unit using real-time ultrasound guidance for portal vein targeting resulted in a mean DAP 88% lower than the dose level initially proposed by Miller et al. [28] and 59% lower than the level recently proposed by Miraglia et al. [23]. The use of ultrasound guidance could therefore have an important role in limiting the radiation exposure of patients and operators.

Table 3 Procedure characteristics.

Pre-procedural PPG (mmHg)	16.4 ± 5.5 [4.0—40.0]
Post-procedural PPG (mmHg)	6.9 ± 3.3 [0.0—20.0]
Number of stents	
1	189
2	31
3	5
Stent diameter (mm)	
10	192
8	32
Hepatic vein	
Right	179 (79.9)
Medial	44 (19.6)
Left	1 (0.4)
Portal vein	
Right	200 (89.3)
Left	15 (6.7)
Trunk	9 (4.0)
Needle direction	
RHV-RPV	176 (78.6)
MHV-RPV	24 (10.7)
MHV-LPV	6 (2.7)
MHV-Trunk	14 (6.3)
RHV-Trunk	1 (0.4)
LHV-LPV	1 (0.4)
Variceal embolization	116 (51.8)
Technical success rate	224 (100.0)
Ultrasound guidance success rate	219 (97.8)
Procedure duration (minutes)	86.2 ± 41.7 [22.0—267.0]
Dose-aera product (Gy.cm^2)	62.0 ± 50.2 [3.7—306.5]
Fluoroscopy time (minutes)	20.3 ± 15.3 [3.1—83.3]
Per-procedural complications	12 (5.4)
Arterial punctures	8 (3.6)
Biliary punctures	4 (1.8)
Clinically relevant complications	4/224 (1.8)
Hemobilia	1/224 (0.4)
Subcapsular hematoma	1/224 (0.4)
Arterioportal fistula	1/224 (0.4)
Ischemic type biliary stricture	1 (0.4)

RHV = right hepatic vein; LHV = left hepatic vein; MHV = medial hepatic vein; Trunk = trunk of the portal vein; RPV = right portal vein; LPV = left portal vein; PPG indicates portosystemic puncture gradient. Numbers in brackets are ranges. Numbers in parentheses are percentages

Although the use of fluoroscopy time is not recommended by the Society of Interventional Radiology-Cardiovascular and Intervention Radiology Society of Europe (SIR-CIRSE) international guidelines for radiation monitoring during interventional procedures, it may give information about procedure complexity [30,31]. With a mean value of 20.3 min, the fluoroscopy time measured was in the lower range of published data [23,24,31,32] and beyond proposed reference levels [30,31]. In our study, the mean procedure duration was 86.2 min. It is difficult to analyze this result in comparison to other studies because of variations in protocols and scarcity of published data [30,32].

In our study, the variceal embolization rate was close to 52%, higher than in most other studies. For example, Miraglia et al. reported variceal embolization in only 1/45 patients [24]. In our study, the DAP was significantly lower when embolization was not performed. This further supports the assumption that ultrasound guidance help decrease radiation exposure during TIPS placement.

Our early mortality rate was 9.8%, without any patient dying from technical complications. Mortality was mainly related to the development of hepatic encephalopathy, multiple organ failure or repeat bleeding. Our results are in the lower range of previous published findings showing early (30-days) mortality rates of 7—20% and technical mortality rates of 1.3—4.7% [1]. Using ultrasound guidance, Bettinger et al. reported an early mortality rate of 2.3% and a technical mortality rate of 0.5% [27]. The incidences of hepatic encephalopathy, repeat variceal bleeding and stent

Table 4 Causes of death within the 30 days following transjugular intrahepatic portosystemic shunt placement.

Patient #	Emergency TIPS	MELD score	Indication for TIPS	Cause of death
10	No	27	Refractory ascites	Acute hepatic failure
11	Yes	45	Variceal bleeding	Variceal rebleeding, HE grade IV
19	No	15	Variceal bleeding	Aspiration pneumonia
28	No	20	Refractory ascites, hepatorenal syndrome	HE grade IV
35	Yes	20	Variceal bleeding	Variceal rebleeding, HE grade IV
46	No	9	Refractory ascites	Persistant hemorrhagic shock
51	Yes	24	Variceal bleeding	Variceal rebleeding, HE grade II
101	Yes	28	Variceal bleeding	HE grade III, hepatorenal syndrome
103	No	12	Refractory ascites	HE grade IV
106	No	16	Variceal bleeding	Cardiac failure
113	Yes	8	Variceal bleeding	Multiorgan failure
120	Yes	30	Variceal bleeding	Multiorgan failure
151	Yes	23	Variceal bleeding	Variceal rebleeding, HE grade IV
155	Yes	27	Variceal bleeding	HE grade IV
167	No	16	Variceal bleeding	Cardiac failure
172	Yes	13	Variceal bleeding	Mesenteric ischemia
174	No	17	Refractory ascites	Acute hepatic failure, HE grade IV
189	Yes	28	Variceal bleeding	Multiorgan failure
194	Yes	40	Variceal bleeding	Multiorgan failure
210	Yes	19	Variceal bleeding	HE grade IV
213	Yes	22	Variceal bleeding	Variceal rebleeding
220	Yes	34	Variceal bleeding	Multiorgan failure

HE = Hepatic encephalopathy; MELD = Model for end-stage liver disease; TIPS = Transjugular intrahepatic portosystemic shunt.

dysfunction within the 30 days following TIPS placement were within the range of published data [33].

Other guidance techniques based on ultrasound have been described for portal vein puncture, including three-dimensional ultrasound and intravascular ultrasound (IVUS) (21). Initially designed for interventional cardiac use, IVUS device consists of an 8 to 10-Fr catheter coupled with a 5.5 to 10-MHz ultrasound probe. According to literature data, IVUS seems to offer a good visualization of intrahepatic vascular structures and TIPS devices (cannula, needle and wires) and is used by some authors to ensure portal vein puncture safety during TIPS placement [11,34].

In the past two decades, the indications for TIPS have widened, with robust recommendations validating this technique for the management of portal hypertension-related complications [35—39]. However, the lack of availability of TIPS in non-academic centers causes territorial inequalities in access to TIPS, as recently shown by Thabut et al. [40]. We believe that ultrasound could represent an effective training tool to spread the technique. However, despite several advantages, ultrasound guidance requires a second operator, who is in theory exposed to radiation in case of simultaneous fluoroscopy.

Our study has some limitations. Due to its retrospective nature, the number of punctures needed to successfully catheterize the portal vein could not be documented. It is well known that puncture-associated complications are directly related to the number of needle passes [2]. Therefore, given the low rate of peri-procedural complications observed in our study, a relevant increase of portal vein punctures cannot be attributed to our guidance technique. Another limitation is that the accuracy of real-time ultrasound guidance was not analyzed quantitatively. Future prospective studies should be conducted to further evaluate duration, radiation exposure and number of punctures needed to access portal vein system using ultrasound guidance. Finally, our results were not compared to those obtained in a control group without ultrasound guidance.

In conclusion, the use of percutaneous real-time ultrasound guidance to target the portal vein system during TIPS placement is safe and effective. It is a simple tool to help puncture the portal vein with a low rate of puncture-related complications. This noninvasive and readily available method may also limit radiation exposure to both patient and operator.

Contribution of authors

A. David: conceptualization, methodology, investigation, formal analysis, writing-original draft, vizualization.
R. Liberge: resources, writing-review & editing.
J. Meyer: resources, writing-review & editing.
O. Morla: resources, writing-review & editing.
F. Leaute: resources, writing-review & editing.
I. Archambeaud: resources, writing-review & editing.
J. Gournay: methodology.
D. Trewick: writing-review & editing.
E. Frampas: methodology, writing-review & editing.

C. Perret: methodology, resources, writing-review & editing.

F. Douane: conceptualization, methodology, investigation, writing-original draft, writing-review & editing, vizualization.

Disclosure of interest

The authors declare that they have no competing interest.

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