

REVIEW ARTICLE

SONOGRAPHIC EVALUATION OF TRANSJUGULAR INTRAHEPATIC PORTOSYSTEMIC SHUNT

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The purpose of this article is to review the role of sonography before, during and after transjugular intrahepatic portosystemic shunt placement. A sonographic assessment of the liver and abdomen is recommended before the procedure. We illustrate several important sonographic findings for the echographer, which may alter the procedure approach or even preclude transjugular intrahepatic portosystemic shunt placement. The most challenging step during the procedure is the puncture of the right portal vein. Sonography can be a helpful tool in reducing the number of needle passes, thereby reducing the risk of hemorrhagic complications. Because of its non-invasive and cost-benefit nature, sonography is useful for transjugular intrahepatic portosystemic shunt follow-up. A baseline study at 24 to 48 hours is recommended to discover procedure-related complications. Long-term follow-up is important to detect malfunction of the shunt. Doppler ultrasound is very accurate in detecting shunt thrombosis. However, no consensus exists on the optimal sonographic screening protocol for detecting stenosis. We describe three sonographic parameters to detect transjugular intrahepatic portosystemic shunt stenosis with high sensitivity. Finally, additional sonographic parameters and potential pitfalls are provided in order to improve sensitivity.

Key-words: Hypertension, portal – Shunts, portosystemic.

Portal hypertension (PH) is the result of an increased resistance to the portal blood flow. Depending on the level of impediment, PH is divided into prehepatic, intrahepatic and posthepatic. There are several diseases leading to PH such as portal vein thrombosis or Budd-Chiari syndrome. However intrahepatic PH as a result of cirrhosis is by far the most frequent cause. In future, the incidence of cirrhosis is not expected to decrease because of alcohol consumption, high prevalence of chronic hepatitis C virus infection worldwide and emergence of non-alcoholic fatty liver disease in Western world (1).

PH is responsible for severe and often lethal complications. Several randomized trials, comparing transjugular intrahepatic portosystemic shunt (TIPS) with other therapeutic options, have shown better secondary prevention of gastrointestinal bleeding from oesophageal, gastric and hemorrhoidal portosystemic collaterals with the use of TIPS (2, 3). Also effective reduction of refractory ascites is achieved with TIPS (3). However, general application of TIPS is not indicated because of higher incidence of hepatic encephalopathy, no survival benefit and high rate of shunt stenosis with the bare metal stents. Therefore, TIPS is used in pa-

tients awaiting liver transplantation and as rescue procedure when other therapies have failed (4). In the past decade, the use of polytetrafluoroethylene-covered stent-grafts has been introduced with high primary patency rate in long-term follow-up, confirmed by several authors (4, 5).

The purpose of this article is to describe the role of sonography in the TIPS story. First, we describe the possible findings with pre-TIPS sonographic assessment, with the intention that the echographer could give complete, accurate information to the interventional radiologist. Further we discuss the role of the sonography during the TIPS procedure. Finally, an attempt is made to find the most useful and accurate sonographic parameters to detect TIPS malfunction. Also possible pitfalls are described in order to improve sensitivity and specificity.

Discussion

Sonographic assessment before TIPS placement

As a result of cirrhosis, the liver surface typically appears irregular on ultrasound images. Also volume reduction of the right hepatic lobe with relative enlargement of the cau-

date lobe is commonly present. Characteristic gray-scale findings in portal hypertension include ascites, splenomegaly, portosystemic collaterals and an enlarged portal vein. As portal hypertension worsens, the flow within the portal vein decreases and may become biphasic or hepatofugal (6). Other important findings which may alter the approach, postpone or even preclude TIPS procedure are described in the following sections:

Hepatic veins

TIPS are constructed through the right or less commonly the middle hepatic vein. Preprocedural determination of the size, localisation and patency of the hepatic veins is therefore helpful, especially because cirrhosis may alter the liver anatomy radically. Alteration in size or localisation of the right hepatic vein can affect the difficulty and success of the TIPS procedure. Occasionally, an anatomic variation of the hepatic vein can be detected (7). Preprocedural evaluation is also important to detect Budd-Chiari syndrome, characterized by severe stenosis or obstruction of all or some hepatic veins, with or without involvement of the inferior vena cava. Doppler ultrasound (DUS) is now generally recommended as screening technique for the disease. A typical finding includes absence of phasic waveform in the hepatic vein on spectral DUS, indicating distal stenosis. However this is a nonspecific finding, also present in cirrhosis and diffuse

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metastatic disease of the liver. More specific features include absent or reversed hepatic venous flow. Further, hepatic vein to hepatic vein collaterals (spider web) are considered virtually pathognomonic of Budd-Chiari syndrome. The other sonographic findings, as a result of cirrhosis and portal hypertension, are mentioned earlier (8).

Portal vein

From the interventionalist's point of view, the main purpose of the pre-TIPS sonogram is to evaluate the patency of the portal vein and detect portal vein thrombosis. Gray-scale features include an echogenic intraluminal thrombus, enlargement of a thrombosed segment of the portal vein and demonstration of cavernous transformation of the portal vein (Fig. 1A). The diagnosis is confirmed by colour DUS demonstrating ab-

sence of flow. Tessler et al. report a sensitivity and specificity of 89% and 92% respectively, to detect portal vein thrombosis (9). When the sonographic evaluation is suspicious but not decisive, such as absence of flow without grey-scale abnormalities, alternative imaging is required. Magnetic resonance and angiography are two worthy options. A potential pitfall occurs when inappropriately high Doppler scale is used, thereby missing low velocity flow, leading to falsely diagnosis of thrombosis. Chronic portal vein thrombosis may result in cavernous transformation, a misnomer used to describe the development of portosystemic and portoportocollaterals, providing hepatopetal blood flow (Fig. 1B). The portoportocollaterals are periportal or pericholecystic blood vessels draining into the intrahepatic portal vein branches. The gallbladder vari-

ces, which appear as small hypoechogenic areas within the gallbladder wall and show flow using colour DUS, strongly suggest the presence of portal vein thrombosis (Fig. 1C) (6). The pre-TIPS sonogram gives also important information about the spatial relationship between the hepatic and portal veins. One potential pitfall is seen in small cirrhotic livers where the right portal vein is located more cranial in relation to the right hepatic vein. Therefore, puncture of the portal vein branch will be too inferior and not sufficiently anterior resulting in more puncture attempts, which leads to a higher hemorrhagic complication risk (7).

Hepatic parenchyma

The pre-TIPS sonographic assessment of the parenchyma is very important because patients with cirrhosis are at high risk for the development of hepatocellular carcinoma. The finding of a focal mass should stimulate further evaluation. Other findings include the presence of polycystic liver disease or biliary dilation (6).

Hepatic artery

Several case reports have documented diffuse liver ischemia with TIPS (10). Mayan et al. suggest that the diffuse hepatic ischemia may be contributed to hepatic arterial insufficiency. In normal physiological conditions, the portal vein provides approximately 70% of hepatic blood supply. However, after TIPS creation, the liver parenchyma relies in greater amount on the hepatic artery (11).

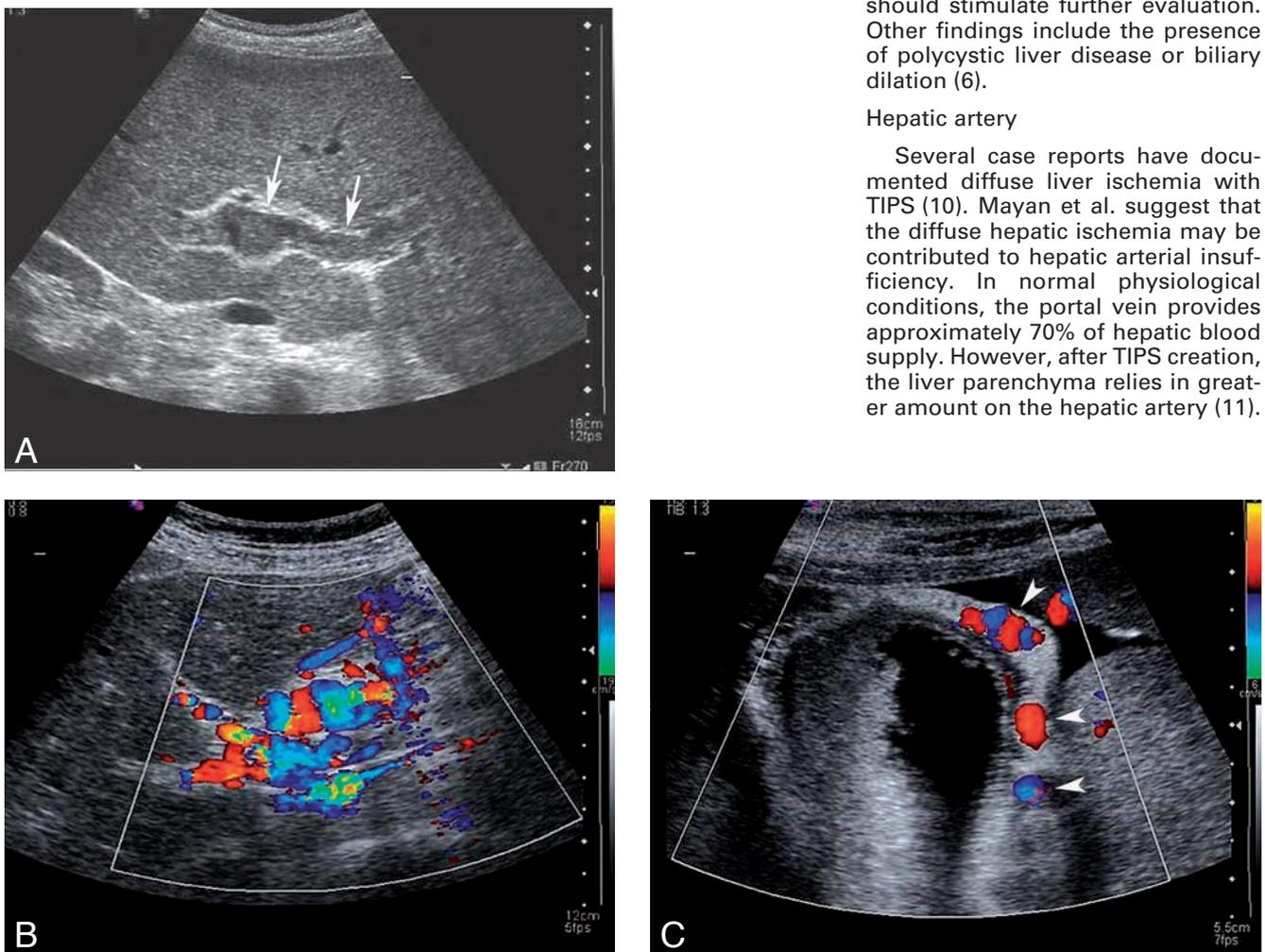


Fig. 1. — Pre-TIPS findings of portal vein thrombosis: (A) An echogenic intraluminal thrombus and enlargement of a thrombosed segment of the right portal vein (arrows); (B) Cavernous transformation of the portal vein; (C) Gallbladder varices (arrowheads). [TIPS = transjugular intrahepatic portosystemic shunt].

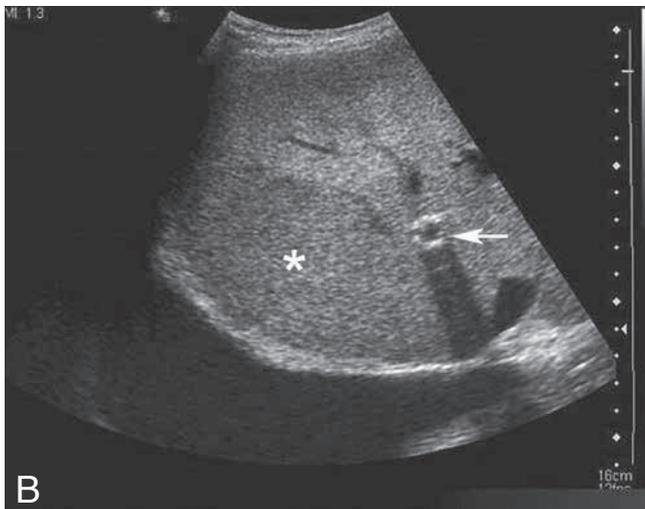
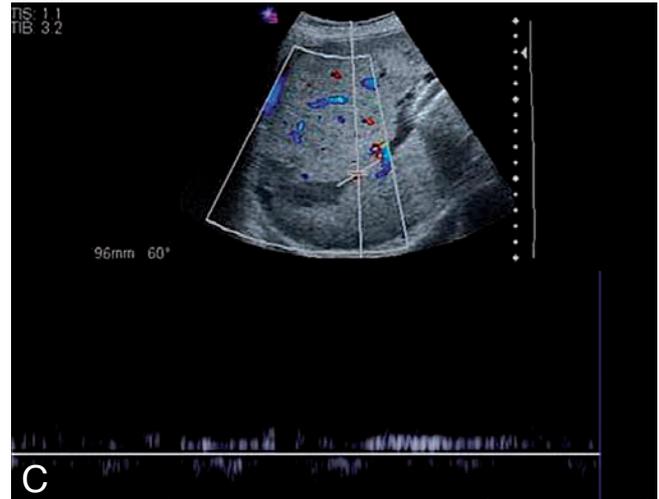
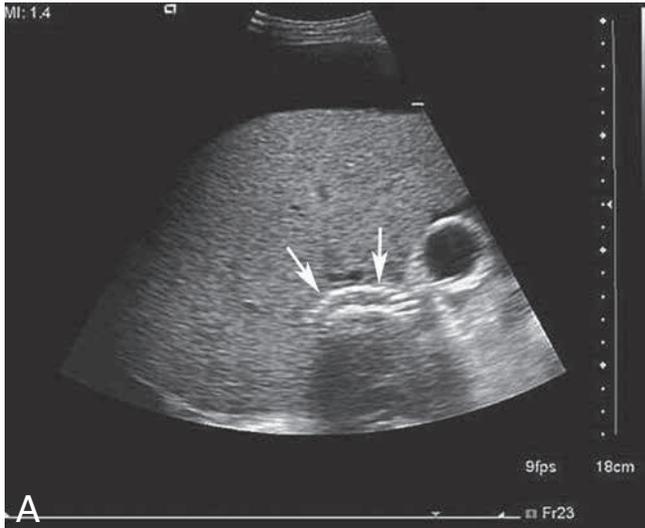


Fig. 2. — (A) Normal baseline gray-scale findings in a patient with alcoholic cirrhosis after TIPS placement (arrows); (B) Follow-up sonographic evaluation after 6 months shows diffuse parenchyma necrosis (asterisk); (C) Spectral DUS of a hepatic artery branch shows a tardus parvus curve.

[TIPS = transjugular intrahepatic portosystemic shunt / DUS = Doppler ultrasound].

Foshager et al. reported a significant increase of the hepatic artery velocity after TIPS placement (12). Conditions in which the arterial blood supply can be insufficient include systemic atherosclerosis and liver transplant patients (Fig. 2). Mayan et al. recommend evaluating the hepatic artery before TIPS placement. If absence of intrahepatic arterial flow is detected, angiography may be performed before the procedure to avoid parenchyma ischemia after TIPS (11).

Sonography during TIPS procedure

In the TIPS procedure, passage of the needle from the hepatic vein through the hepatic parenchyma into the portal vein branch usually is the most challenging step and a common source of complications. One of the significant potential risks is puncture of the extrahepatic portal vein. Without surrounding parenchyma to tamponade, life-threatening intraperitoneal bleeding could occur.

Other complications include puncture of hepatic artery branches, perforation of the gallbladder or the adjacent colon (13).

Many experienced interventional radiologists perform the puncture 'blind' because the portal vein branches are not visible fluoroscopically. In order to decrease the number of needle passes and increase the accuracy of those passes, several methods to target the portal vein are reported including an arterial portography, a portography using a patent paraumbilical vein and an iodinated contrast wedged hepatic venography. Today carbon dioxide wedged hepatic venography is recommended as standard for portal vein branches localization (14). Maleux et al. report carbon dioxide wedged hepatic venography to be a safe, efficient and reliable for right and left portal vein opacification (15). Another proposed technique involves percutaneous placement of fluoroscopically visible intrahepatic

markers, microcoils or a 0,018-inch wire immediately adjacent to or within the portal branch. These markers are placed under sonographic guidance and provide a fixed target during fluoroscopy to facilitate the puncture. The markers also provide a constant reference point during stent deployment. Harman et al. and Roizental et al. report this technique to be safe and useful (14). Finally, several interventionalists use sonography as guidance during the portal vein puncture (13).

Sonographic assessment after TIPS placement

TIPS malfunction results into recurrence of gastrointestinal bleeding and ascites. Early malfunction is usually related to thrombosis, due to technical problems such as kinking or migration of the stent. Delayed malfunction is caused by stenosis. Bare metal stent stenosis is described as pseudointimal hyperplasia as a result of fistulas between the shunt and bile ducts. Second, stenosis can occur at the hepatic vein due to intimal hyperplasia caused by chronic injury from increased high-velocity blood flow (16). Given the fact that TIPS malfunction is relatively frequent with bare metal stents and because of the success of shunt revision, it is crucial to detect stenosis before recurrence of clinical symptoms. Portal angiography is the golden standard for detecting TIPS

malfunction because it is possible to detect shunt stenosis, measure the portosystemic pressure gradient, which has to be lower than 12 mm Hg, and proceed to TIPS revision if necessary. Due to its invasive nature it cannot be used for routine follow-up. Portal angiography is performed on clinical indications and abnormal sonographic findings (17).

At many centers, sonography is used to evaluate the TIPS because it is a non-invasive and relatively inexpensive modality. A baseline DUS is performed at 24 to 48 hours to detect therapy-related complications such as intrahepatic, subcapsular or perihepatic hematomas; biliary obstruction; hemobilia (echogenic debris within the gallbladder); and intraperitoneal bleeding (increased volume or echogenicity of the ascites). The baseline study is also used to evaluate the patency of the bare metal stent. For the covered stents, the baseline DUS has to be repeated optimally 7 to 14 days after TIPS creation because gas artefacts make stent evaluation initially impossible. Air is embedded in the polytetrafluoroethylene fabric, but eventually the air will be absorbed. Further, the sonographic follow-up is performed at 1 month, 3 months, 6 months, 12 months and then annually thereafter in most centers (5, 17).

Sonographic technique

Because most shunts are located relatively deep within the liver parenchyma, usually between the right portal branch and the right hepatic vein, a low-frequency transducer is required for adequate penetration. The distal portion of the stent is usually best imaged from a high anterolateral intercostal or subcostal approach. The right and main portal vein are best evaluated through an intercostal approach. The left portal vein can be imaged sagittally in the subxyphoid region. The proximal portion of the stent and the right hepatic vein are often best seen from a low intercostal or subcostal approach. Further, velocity measurements are preferably performed at the end of a normal expiration. Another important technical issue is the Doppler angle which has to be 60° or less. Finally, appropriate adjustment of the pulse repetition frequency is essential. When evaluating the main portal vein, portal vein branches and peripheral portion of the draining hepatic vein, the Doppler scale should be low. However, when evaluating the stent, the Doppler scale should be increased (17).

The creation of a low-pressure outflow tract for the high-pressure portal system comes with several hemodynamic changes. To detect TIPS malfunction, it is necessary for a radiologist to know the normal DUS findings after shunt creation. The presence of blood flow is easily confirmed with colour DUS (Fig. 3). The velocities in the stent are rather high and vary widely, generally ranging from 65cm/s to 220 cm/s. There is a velocity gradient between the portal and venous side of the TIPS. The mean velocity has been reported as 95 cm/s near the portal side and 120 cm/s in the middle segment of the shunt (18-20). Immediately after TIPS creation, spectral DUS shows venous pulsatility within the stent and the portal vein (18, 21). The flow within the portal vein will increase and is hepatopetal, but within the left and right portal branches the flow is hepatofugal (Fig. 3). Helical flow is commonly seen in the right portal branch, as a result of turbulence in the vicinity of the stent. Finally, because the portal blood is shunted away from the liver, the hepatic arterial blood flow increases (12, 17).

TIPS malfunction

Many studies have shown DUS to be very accurate in detecting shunt thrombosis. Colour DUS shows absence of flow in the lumen of the stent with sensitivity and specificity of approximately 100% (12, 17, 20). On the other hand, the accuracy of DUS in detecting stenosis is controversial. There are no clear DUS

velocity parameters and criteria that have consistently been useful in predicting TIPS stenosis.

Stent velocity

Considerable attention has been paid to stent velocity measurements. All studies started from two basic hemodynamic assumptions. If a significant stenosis is present, a prestenotic velocity decline is noted. Second, a focal increase of velocity is present at the site of stenosis. Based on the first assumption, investigators have attempted to establish a lower limit of normal shunt velocity (Table I). Foshager et al. and Chong et al., using a cut-off of 60 cm/s and 50 cm/s respectively, postulate DUS to be an almost perfect screening test. However, their studies include only a small number of stenosed shunts, 8 and 11 respectively (12, 18). On the contrary, several other studies failed to reproduce these good results (20, 22-25). In order to increase the sensitivity of this parameter, Kanterman et al. even propose a lower velocity limit of 90 cm/s (20). Nonetheless, this involves a huge loss of specificity leading to unnecessary invasive portal angiography. Today, the general consensus is to set the lower velocity limit at 50 cm/s, measured at the portal side of the TIPS.

Another approach is to establish an upper limit of normal peak velocity, based on the second hemodynamic assumption. Identifying a stenotic region is greatly aided by colour DUS, showing focal areas of colour aliasing. These areas should

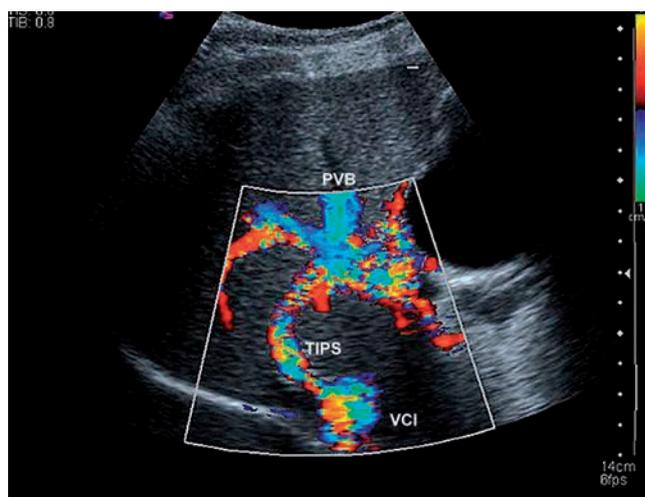


Fig. 3. — Baseline colour DUS shows flow within the TIPS and hepatofugal flow within the portal vein branches.

[DUS = Doppler ultrasound / TIPS = transjugular intrahepatic portosystemic shunt / VCI = vena cava inferior / PVB = portal vein branch].

be sampled with pulsed DUS and peak velocities have to be measured. Foshager et al. reported an upper limit of 200 cm/s at 6 and 12 months. In the first few months, they claim the velocity may well be higher in normal functioning TIPS (12). Kanterman et al. determined a value of 190 cm/s (20). Zizka et al. report a maximum peak velocity of 250 cm/s with a sensitivity of 51% (25).

As mentioned earlier, the maximum velocity will increase and the minimum velocity will decrease in patients with stenotic stents. Therefore, the velocity gradient will increase. Kanterman et al. report a velocity gradient of greater than 100 cm/s has a PPV of 82% for detection of TIPS stenosis. However, the sensitivity is only 56%, probably because accurately determining of 2 parameters is necessary. Also, diffuse stenosis might not result in a abnormal velocity gradient (20).

Temporal change in the stent velocity, in comparison to the baseline study, is another frequently used DUS parameter. Dodd et al. found that either an increase or decrease of more than 50 cm/s in the shunt velocity to be the best DUS parameter to detect TIPS stenosis with a sensitivity of 93% and a specificity of 77% (26). Later, Middleton et al. show rather similar results using a decrease of 40 cm/s and an increase of 60 cm/s as cut-off. Their sensitivity

(75%) was lower and specificity (84%) was slightly higher (17).

Main portal vein velocity

The main portal vein velocity is an additional parameter repeatedly studied. As noted earlier, the velocity will increase after TIPS placement. Several authors report a mean value slightly greater than 40 cm/s (12, 17). Stenosis of the shunt causes the portal vein velocity to decline. Kanterman et al. determined a value of 30 cm/s was the best lower limit with a sensitivity of 82% and a specificity of 77%. Also temporal changes in main portal vein velocity have been investigated by these authors. Using a 20% decrease from the baseline study as cut-off, they obtained a sensitivity of 78% and specificity of 75%. Using a 33% cut-off, their sensitivity decrease to 67%, with specificity unchanged (75%) (20). Zizka et al. used the 33% cut-off value yielding a sensitivity of 51% and a PPV of 100% (25).

Hepatic artery velocity

Hepatic artery velocity increases as a compensatory response to decreased portal perfusion of the liver. Foshager et al. report a statistically significant increase of the mean systolic velocity of 79 cm/s before TIPS placement to 131 cm/s after placement (12). However, Kantermann et al. found no statistically significant difference in hepatic artery velocity

or resistance index between normal and abnormal shunts (20).

Intrahepatic portal vein flow

As a TIPS becomes stenotic, it will no longer function as a low-resistance outflow tract and flow within the right and left portal veins may change from hepatofugal to hepatopetal. This finding was first described by Foshager et al., but no significant conclusion could be drawn because of the limited number of cases in which this parameter was studied (12). Middleton et al. found that temporal change in flow direction is a strong indication for TIPS malfunction with PPV of 92% on the left and 86% in the right portal vein. However, the sensitivity of this parameter is very low (15% and 31% respectively), most likely because conversion from hepatofugal to hepatopetal is a late sign of TIPS malfunction (17).

Pulsatility index

A rather new DUS parameter that deserves attention is the venous pulsatility index. The intention was to develop an easily obtainable parameter, independent of absolute velocity measurements, to identify clinical silent TIPS dysfunction. This index is the venous equivalent to the arterial resistance index, defined as (Vmax-Vmin)/Vmax. As a TIPS is placed between the portal vein and the right

Table I. – Comparison of the sensitivity and specificity of several studies using different lower velocity limits for detecting TIPS stenosis.

	Lower velocity limit	Sensitivity	Specificity
Feldstein et al. (6,19)	50 cm/s (mid stent)	78%	99%
	60 cm/s (mid stent)	84%	89%
	70 cm/s (mid stent)	89%	83%
	80 cm/s (mid stent)	92%	60%
	90 cm/s (mid stent)	93%	55%
Foshager et al. (12)	60 cm/s	100%	95%
Chong et al. (18)	50 cm/s (portal side)	100%	93%
Kanterman et al. (20)	50 cm/s	32%	88%
	60 cm/s	35%	84%
	70 cm/s	44%	68%
	80 cm/s	61%	68%
Haskal et al. (22)	90 cm/s	67%	56%
	50 cm/s	46%	93%
	60 cm/s	57%	89%
Owens et al. (23)	60 cm/s	22%	
Murphy et al. (24)	60 cm/s	25%	93%
Zizka et al. (25)	50 cm/s (portal side)	34%	

[TIPS = transjugular intrahepatic portosystemic shunt].

Table II. — Combination of three DUS parameters predicting TIPS stenosis with high sensitivity.

<i>DUS parameters predicting TIPS stenosis</i>	
Colour DUS	1. Hepatopetal flow within the intrahepatic portal vein branches
Pulsed DUS	2. Peak shunt velocity < 50 cm/s, measured at the portal side of the TIPS
Pulsed DUS	3. Temporal increase or decrease in shunt velocity > 50 cm/s compared with baseline value
[DUS = Doppler ultrasound/ TIPS = transjugular intrahepatic portosystemic shunt].	

heart, pulsatile flow is present immediately after shunt creation. However, when the TIPS becomes stenotic, pulsed DUS shows a flattened, non-pulsatile waveform. Sheiman et al. report a venous pulsatility index less than 0,16 to be 94% sensitive and 87% specific for shunt stenosis. The authors also recommend measuring the venous pulsatility index at the venous side of the stent (21).

Morphologic abnormalities

Despite the resolution limitations, the actual stenosis can occasionally be directly visualized. Also possible kinks or migration of the stent should be looked out for. Further, a survey of the abdomen and pelvis should be performed to detect recurrence of ascites, portosystemic collaterals and/or recanalisation of the paraumbilical vein. Since portal hypertension is most frequently caused by cirrhosis, an echographic follow-up of the liver is obligated to detect hepatocellular cancer.

Combining multiple parameters

No consensus exists on the optimal sonographic screening protocol. As indicated by Haskal et al., some of the controversy may originate from the various definitions of shunt dysfunction, as some authors define stenosis solely on portal angiography findings and others use portosystemic pressure gradient to detect stenosis (22). Also the varying levels of DUS expertise, the complexity of the hemodynamics of a TIPS and the variety of DUS parameters, studied and proposed by various authors, add to the problem. Owens et al. and Murphy et al. even reject the use of DUS for TIPS screening entirely and recommend invasive portal angiography for regular follow-up (23, 24). However, both studies base their findings entirely on one DUS parameter (lower limit of the peak stent velocity). Zizka et al. recognizes the relatively poor sensitivity when using a single DUS parameter. The authors investigated several DUS parameters, including stent upper

velocity limit of > 250 cm/s, stent lower velocity limit of < 50 cm/s and main portal velocity decline of 33% when compared with the baseline study. The sensitivities were only 51%, 34% and 51% respectively. Nevertheless, when using a combination of these three velocity parameters, they achieved 94% sensitivity for detecting shunt stenosis (25). The same result is obtained by Kanterman et al., who investigated the sensitivity of the overall interpretation of the sonographic examination by the radiologist. When using a combination of DUS parameters and additional information, such as stenosis visualisation or recurrence of ascites, their sensitivity increases to 92% (20). Table II presents the combination of three DUS parameters that have consistently shown relatively high sensitivity for detecting TIPS stenosis (6, 19, 26).

Pitfalls and artefacts

In order to try to improve the sensitivity of DUS evaluation, Wachsberg postulates several pitfalls that may hamper the performance and/or interpretation of the examination. The author suspects that the poor results reported by some groups may be caused by unawareness of such pitfalls and artefacts (27). One first potential pitfall occurs when colour DUS of the TIPS is performed at an inappropriate pulse repetition frequency. A low scale may detect high velocity flow incorrect as negative flow, leading to aliasing. This could lead to false-positive diagnosis of stenosis. A low scale should improve the sensitivity for flow. However, if the scale is set very low, paradoxically high flow velocity can be absent, leading to false-positive diagnosis of thrombosis. Also, in patients who are obese, detection of stent flow may be hampered. Repositioning the transducer, in order to bring the stent nearer, can be helpful. As mentioned earlier, intrastent flow jets are a direct sign of TIPS stenosis. Nevertheless, flow jets are commonly visualised with properly functioning bare metal stents at sites of in-

flow from adjacent portal and hepatic vein branches. As numerous velocity cut-offs have been studied in the literature, the respiration variation is a very important pitfall to take under consideration. TIPS velocity decreases by an average of 22 cm/s during deep inspiration. The portal vein velocity might also decelerate at end inspiration. Therefore, flow velocity should be measured at end expiration. Further, flow velocity in the main portal vein is another important parameter. Wachsberg report that portal vein velocity increases in the vicinity of the TIPS, because of the hepatofugal flow within the left portal vein branch joining the main portal vein stream. If the velocity is measured adjacent to the TIPS orifice, an important indicator of shunt insufficiency can be missed (27). Another important DUS parameter is the temporal change from hepatofugal to hepatopetal in the intrahepatic portal vein branches, with high specificity for TIPS stenosis (17). Even so, Wachsberg postulates that the echographer should be cautious for several pitfalls. As mentioned before, the hepatic arterial tree becomes prominent after TIPS creation, whereas the portal vein branches often become very small (12). Therefore, it is important not to rely solely on colour DUS to determine flow direction within the portal vein branches. Rather, one must also carefully evaluate the blood vessel with pulsed DUS. In some patients with TIPS, hepatofugal flow is present in some but not all peripheral portal vein branches, probably due to uneven severity of cirrhosis. In such cases, the echographer must sample several intrahepatic branches in order to determine the predominant direction of flow. Also, flow in the left portal vein can remain hepatopetal if a para-umbilical vein remains patent after TIPS creation. As mentioned before, helical flow within the right portal vein is commonly present in patients with TIPS. In order to determine the net flow direction, one must interrogate distal right portal vein branches (27).

Conclusion

Because of its non-invasive and cost-benefit nature, sonography has an important role in TIPS. The utility of sonography in the pre-TIPS context is widely accepted. Also during the procedure, ultrasound has proven to be helpful in reducing the risk of hemorrhagic complications. A baseline sonographic evaluation is recommended at 24 to 48 hours to detect TIPS procedure-related complications and patency of the bare metal stents. Initial evaluation of the covered stents is possible after 7 to 14 days. DUS is very accurate in detecting TIPS thrombosis. For a long time, the accuracy and sonographic parameters for detecting TIPS stenosis were not uniformly agreed on. Today, the combination of three DUS parameters is widely accepted to detect TIPS stenosis with high sensitivity (Table II).

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