

Usefulness of a balloon-expandable, covered stent for the transjugular intrahepatic portosystemic shunt

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Abstract

The availability of polytetrafluoroethylene (PTFE) covered, self-expandable nitinol stents in 2001 considerably improved the patency, response rates and survival of the transjugular intrahepatic portosystemic shunt (TIPS). Side effects of portosystemic shunting such as hepatic encephalopathy (HE) and worsening of hepatic function, however, remained a problem. To reduce HE, underdilatation of nitinol stents has been practiced for many years. However, as shown recently, underdilatation was a flop since, due to their intrinsic memory, nitinol stents always expanded to reach their nominal diameter of 8 or 10 mm. To overcome this problem and to be able to perform permanent shunts with a smaller diameter of < 8 mm, we studied the usefulness of a balloon-expandable, covered, metallic stent which allowed adjustment to any diameter between 5 and 12 mm. **Methods:** 30 patients with cirrhosis and symptomatic portal hypertension were included. The mean Child-Pugh score was 8 ± 2 . 17 patients had refractory ascites, 9 patients variceal bleeding and four patients other indications for the TIPS. **Results:** The TIPS was successfully implanted in all patients within 69.6 ± 21.8 min. The shunt reduced the portosystemic pressure gradient by $57.5 \pm 14.2\%$ with a mean stent diameter of 7.4 ± 1.0 mm ($5 - 10.3$ mm). During a mean follow-up of 330 ± 249 days, shunt revision was necessary in 5 patients (17%), four of them had insufficient response and received stent dilatation and one patient had stent misplacement requiring a parallel shunt. Three patients (10%) developed HE. **Conclusions:** The covered, balloon-expandable stent could be placed accurately and allowed creation of adapted shunts with smaller diameters as usual. This resulted in a comparatively low rate of HE.

Keywords: balloon-expandable; stent; portal hypertension; transjugular intrahepatic portosystemic shunt

Introduction

In the beginning of the transjugular intrahepatic portosystemic shunt (TIPS) procedure in the late 1980s and early 1990s balloon-expandable stainless steel stents such as the Palmaz-stent, were used frequently [1-4]. This type of stent allowed stepwise dilatation with the aim to optimize shunt function. Later in the 1990s, numerous brands of nitinol stents were marketed and increasingly used probably because of their better flexibility and easier placement. The release of the polytetrafluoroethylene (PTFE) covered version in 2002 (Viatorr, W.L.Gore, Flagstaff, USA) eventually terminated the implantation of uncovered balloon-expandable metallic stents.

Hepatic encephalopathy (HE) is the major and most frequent complication of the TIPS [5]. Its incidence and severity depend on the individual risk of the patient (pre-TIPS HE, age, Child-Pugh class) and the diameter of the stent which determines the degree of shunting [5-11]. Thus, larger stent diameters with a greater reduction in the portosystemic pressure gradient (the difference between the portal and right atrial pressures) have a

higher incidence of TIPS-induced HE. As demonstrated previously, HE occurred almost exclusively in patients with post-TIPS pressure gradients of less than 12 mm Hg, while variceal rebleeding occurred when gradients exceeded the threshold of 12 mm Hg [12, 13]. This suggests a very narrow therapeutic window of the TIPS approaching the threshold of 12 mm Hg. The accurate adjustment of the threshold requires stents with variable diameters. This goal can seldom be achieved by nitinol stents which always expand

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towards their nominal diameter and which cannot retain a given smaller diameter [14-17]. This is why underdilatation of nitinol stents has an only temporary benefit and does not sufficiently decrease the risk of shunt-induced HE [17].

This study evaluates the usefulness of a balloon-expandable stainless steel stent covered with PTFE. The stent can be dilated to any size between 5 and 12 mm allowing a graded and permanent adjustment of the portosystemic pressure gradient to a desired value.

Patients and methods

The prospective cohort study includes 30 unselected patients who received a TIPS implantation in two centers. Data were deposited in our TIPS-registry which was approved by our local Ethics Committee. All patients gave their written consent to the recording, analysis and publishing of the data.

Before the TIPS intervention, echocardiography was performed showing an ejection fraction of > 50% and a normal E/A ratio excluding diastolic dysfunction. The TIPS implantation was performed as described previously [4, 18]. Before the intervention, the portal bifurcation was located sonographically and a metallic marker was placed on the skin to approximately indicate its position. After transjugular access, a right portal branch was punctured under sonographic guidance. Splenoportography was then performed and varices occluded with bucrylate when necessary. After measurement of the portosystemic pressure gradient, the parenchymal tract was opacified to exclude arterial or biliary communications. Finally, a covered balloon-expandable stent (Bentley, Hechingen, Germany) was implanted. Stents were dilated gradually and pressure measurements were performed after each dilatation. In patients with HE before the intervention or a bilirubin concentration of above 3 mg/dl, stent expansion aimed at a pressure gradient of 12 ± 1 mmHg. In patients with a baseline pressure gradient of < 20 mmHg pressure gradients were reduced to below 12 mmHg aiming at a reduction by 40 to 50% of baseline. Pressure measurements before and after stent placement were performed in the portal vein and the right atrium to calculate the porto-atrial pressure gradient [19]. Stent diameters were determined from angiographic pictures [20] using the software of the IMPACS system (AGFA IMPAX EE R20 XV SU3, Agfa HealthCare NV - Mortsel, Belgium).

Patients were seen in 3-month intervals after their discharge. A reduction of the post-TIPS portal vein flow velocity by > 50% or to < 30 cm/sec or a stent flow velocity of < 40 cm/sec or > 200 cm/sec were defined as significant shunt insufficiency [18]. In addition, insufficient response or recurrence of the complication(s) of portal hypertension, which indicated the TIPS intervention, gave rise for radiological revision. Clinically overt HE was assessed according to the New-Haven criteria [21].

Statistics

Continuous variables are expressed as mean with standard deviation as well as median with the corresponding range whereas categorial variables are reported as frequencies

and percentages. P values of 0.05 or lower were considered statistically significant.

Results

The characteristics of the patients are summarized in Table 1. Most of the patients had alcoholic cirrhosis of Child-Pugh stage B and received the TIPS intervention for treatment of refractory ascites. Relevant additional complications such as hepato-renal syndrome, hepatic hydrothorax, and HE were seen in 27, 7, and 10% of patients, respectively.

Table 1 Characteristics of the 30 patients.

Variable	Value	Percentage (%)
Age (years)		
mean ± SD	56.5 ± 9.5	
median (range)	62 (32 - 84)	
Child-Pugh class (n, %)		
A	9	30
B	18	60
C	3	10
Child-Pugh score		
mean ± SD	8 ± 2	
median (range)	8 (5 - 11)	
MELD score		
mean ± SD	12 ± 3	
median (range)	12 (6 - 28)	
TIPS indication (n, %)		
Ascites	17	57
-with hepatorenal syndrome	8	
-with Hydrothorax	2	
Variceal bleeding	9	30
Budd-Chiari-syndrome	1	
Portal hypertensive gastropathy	1	
Portal vein thrombosis	1	
Before abdominal surgery	1	
High risk or hepatic Encephalopathy before TIPS (n, %)	3	10
Mean follow-up, days	330 ± 249	
Median follow-up, days (range)	255 (6 - 1029)	

Technical aspects

After having punctured the portal vein, the length of the parenchymal tract and the exact position of the hepatic vein exit and the portal vein entrance were determined by retrograde hand injection of contrast dye into the hepatic vein and the tissue tract. Thereafter, the stent was placed. Because of the small size of the device of 5 F only, predilatation of the tissue tract was not necessary before its introduction. As demonstrated in Figure 1, inflation

of the balloon leads to expansion of the stent from both ends. This is why migration during stent expansion did not occur and distal as well as proximal ends could be placed with great accuracy. The metallic marker on the skin helps to orientate and facilitates stent placement. Balloon expansion was stopped when a desired smallest diameter of the stent was reached and pressure measurements were performed (Figure 2). If necessary, dilatation was repeated until the desired gradient has been achieved (Figure 3). As shown in Figures 2 and 3, stent visibility is excellent even in patients with tense ascites.

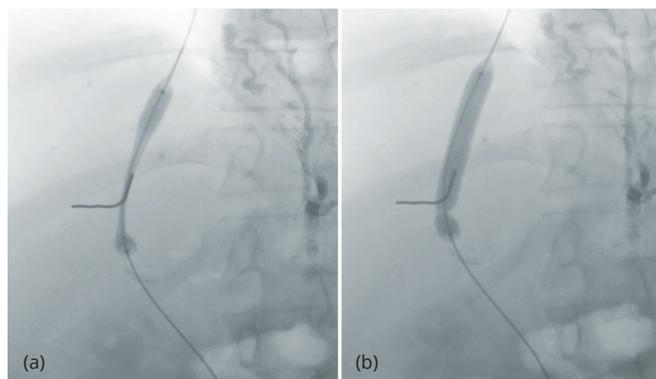


Figure 1 Placement of the Bentley stent. Dilatation begins from the ends of the stent preventing migration during expansion.

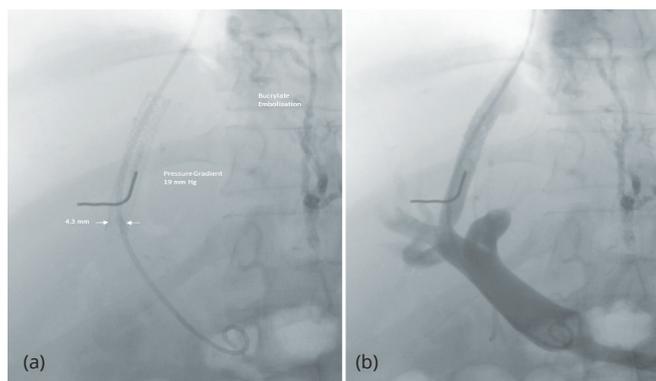


Figure 2 TIPS implantation in a patient with Child-Pugh class C with variceal bleeding and tense ascites. Embolization of varices using bucrylate has been performed before stent placement. (a) Cautious dilatation of the stent to a smallest diameter of 4.3 mm. This resulted in a reduction of the pressure gradient by 34% from 31 to 19 mmHg, (b) Angiography shows considerable shunt flow and prograde portal perfusion as well.

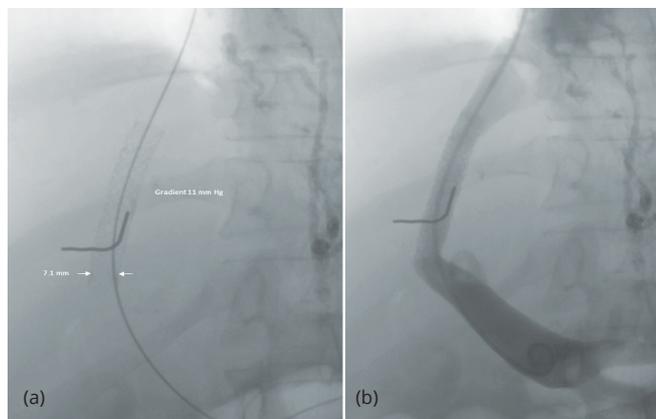


Figure 3 Same patient as in Figure 2. Because of the presence of tense ascites a greater reduction of the pressure gradient seemed to be necessary. (a) A second dilatation of the stent including its smallest portion was performed to result in a diameter of 7.1 mm which resulted in a pressure gradient of 11 mmHg, (b) Although the diameter did not even reach 8 mm, the hepatic portal perfusion was completely lost.

Physical variables of the procedure are summarized in Table 2. The mean pressure gradient after TIPS was 8.9 ± 3.8 mmHg where 21 patients had a final pressure gradient of < 12 mmHg and nine patients a gradient of ≥ 12 mmHg. The smallest diameter of the implanted stent ranged from 5.0 to 10.3 mm with a mean of 7.4 ± 0.95 mm. Twenty patients had a smallest diameter of < 8 mm.

Table 2 Physical variables: Pressures, stent diameter, and characteristics of the intervention (mean +/- SD).

	Number of patients	Mean \pm SD	Median (range)
Pressure gradient before TIPS (mmHg)		20.5 ± 5.4	19 (12 - 38)
Pressure gradient after TIPS (mmHg)		8.9 ± 3.8	8 (1 - 25)
Number of patients with gradients of			
< 8 mmHg	12		
< 10 mm Hg	18		
< 12 mm Hg	21		
≥ 12 mm Hg	9		
Reduction of the pressure gradient by TIPS (%)		57.5 ± 14.2	57.6 (30 - 92)
Smallest stent diameter (radiological measurement, mm)		7.4 ± 1.0	7.6 (5.0 - 10.3)
Number of patients with a smallest stent diameter of			
≤ 6 mm	4		
$> 6 - \leq 7$ mm	8		
$> 7 - \leq 8$ mm	10		
> 8 mm	8		
Duration of intervention (Min)		69.6 ± 21.8	60 (35 - 150)
Duration of radiation (Min)		16.4 ± 8.4	12 (6 - 38)

Clinical aspects

During follow-up of 330 ± 249 days (median 255, 6-1029 days) rebleeding occurred in 3 (10%) and ascites in 2 patients, all of them received a TIPS revision. HE occurred in 3 patients. One of these patients developed debilitating HE requiring occlusion of the TIPS. Seven patients (23%) died between 137 and 625 days after the TIPS implantation. No patient had clinically overt cardiac decompensation during follow-up after TIPS. This was also true for three patients with elevated pro-BNP concentrations (1021-1139 pg/ml) before TIPS implantation.

Patency

Patency was assessed by duplex-sonography and confirmed by shunt revision. Five patients without sufficient response received revision. In four of them the patent stent was dilated to further reduce the pressure gradient. Only one patient had shunt insufficiency because the stent did not cover the whole length of the parenchymal tract. A parallel shunt was placed because recatheterization of the shunt was not possible.

Discussion

HE is the most frequent and undesirable adverse event of the TIPS procedure, a reason for exclusion of patients at risk. In spite of this, some patients may develop severe HE after TIPS and require TIPS reduction or occlusion [18, 22]. In addition to patients' selection, post-TIPS HE may be prevented by reducing the shunt diameter to a degree just needed to effectively improve the indicating symptom. For instance, similar to drug treatment, a 20% reduction in the pressure gradient, which may be reached with small stent diameters of 5 to 7 mm, may be sufficient to prevent variceal rebleeding and to improve survival [23]. This is supported by recent studies and a recent recommendation telling that a reduction of the pressure gradient by 10% effectively prevents rebleeding [24]. In patients with ascites the situation is not as clear. Therefore, wider shunts are implanted to guarantee treatment response.

To reduce the risk of HE, many interventionalists dilated the stents only partially. Secondary enlargement of the diameter was intended in case of insufficient response. However, recent studies demonstrate that nitinol stents always expand until they reach their nominal diameter [14-17]. Thus, 10 mm stents expanded during follow-up by 1.5 mm almost always reaching their nominal diameter [14]. This is why underdilatation of nitinol stents is of transient value and does not prevent HE [17]. To overcome this problem, a new type of nitinol stent (Viatorr CX) was released in 2016. This stent allows gradual expansion to a diameter of 8, 9 or 10 mm. However, considering the individual risk of HE, smaller shunts (< 8 mm) may be considered in many patients at risk for post-TIPS HE or liver failure. This may be achieved using a balloon-expandable metallic stents which maintains its given diameter over time. In case of insufficient response and lack of side effects, the shunt can be revised and expanded.

This study demonstrates the usefulness of a balloon-expandable, covered stent for creation of the TIPS. Exact placement could be achieved in 29/30 patients and long-term patency was comparable to covered nitinol stents [25-26]. Most important, stent diameters could be adjusted as warranted to a diameter of 5.0 to 10.3 mm to result in a desired reduction of the pressure gradient. Thus, 20 patients received a stent diameter of < 8 mm and nine patients had a final pressure gradient of ≥ 12 mmHg. This may be the reason for the low incidence of post-TIPS HE of 10% only. In comparison, two recent studies using 8 or 10 mm covered nitinol stents had a risk of HE of 18% and 40%, respectively [27, 28]. On the other hand, non-response may be increased but could easily be resolved by enlargement of the stent.

The placement of the stent is easy and fast. Due to the small diameter of the stent device, predilatation of the tissue tract and introduction of a sheath is not necessary. The stent which is mounted on a balloon catheter can be placed right away. When compared with the covered nitinol stent (Viatorr), the balloon expandable stent is less expensive and the sheath and balloon catheter can be saved as well.

Conclusion

This covered and balloon-expandable, metallic stent seems to be ideal in patients with decompensated liver function and a higher risk of hepatic encephalopathy. In these patients, a stent diameter of < 8 mm may reduce severe post-TIPS complications.

Conflicts of interest

Authors declare no conflicts of interest.

References

- [1] Palmaz JC. The experimental basis of TIPS: Lessons from the laboratory with the Palmaz Stent. In: Conn HO, Palmaz J, Rösch J, Rössle M, editors. Transjugular intrahepatic portosystemic shunts. New York, Tokyo. Igaku-Shoin Medical Publisher. 1996:177-196.
- [2] Rössle M, Richter GM, Nöldge G, Palmaz JC, Wenz W, et al. New non-operative treatment for variceal haemorrhage. *Lancet* 1989; 2 (8655):153.
- [3] Richter GM, Palmaz JC, Nöldge G, Rössle M, Siegerstetter V, et al. Der transjugulare intrahepatische portosystemische Stent-Shunt (TIPSS). Eine neue nichtoperative, perkutane Methode. *Radiologe*. 1989; 29:406-411.
- [4] Rössle M, Haag K, Ochs A, Sellinger M, Nöldge G, et al. The transjugular intrahepatic portosystemic stent-shunt procedure for variceal bleeding. *N Engl J Med*. 1994; 330(3):165-171.
- [5] Bettinger D, Schultheiss M, Boettler T, Muljono M, Thimme R, et al. Procedure and shunt-related complications and mortality of the transjugular intrahepatic portosystemic shunt (TIPSS). *Aliment Pharmacol Ther*. 2016; 44(10):1051-1061.
- [6] Nolte W, Wiltfang G, Schindler C, Münke H, Unterberg K, et al. Portosystemic hepatic encephalopathy after transjugular intrahepatic portosystemic shunt in patients with cirrhosis: Clinical, laboratory, psychometric, and electroencephalographic investigations. *Hepatology*. 1998; 28(5):1215-1225.
- [7] Rössle M, Piotraschke J. Transjugular intrahepatic portosystemic shunt and hepatic encephalopathy. *Dig Dis*. 1996; 14 Suppl 1:12-19.
- [8] Riggio O, Angeloni S, Salvatori FM, De Santis A, Cerini F, et al. Incidence, natural history, and risk factors of hepatic encephalopathy after transjugular intrahepatic portosystemic shunt with polytetrafluoroethylene-covered stent grafts. *Am J Gastroenterol*. 2008; 103(11):2738-2746.
- [9] Jalan R, Elton RA, Redhead DN, Finlayson ND, Hayes PC. Analysis of prognostic variables in the prediction of mortality, shunt failure, variceal rebleeding and encephalopathy following the transjugular intrahepatic portosystemic stent-shunt for variceal haemorrhage. *J Hepatol*. 1995; 23(2):123-128.
- [10] Bai M, Qi X, Yang Z, Yin Z, Nie Y, et al. Predictors of hepatic encephalopathy after transjugular intrahepatic portosystemic shunt in cirrhotic patients: A systematic review. *J Gastroenterol Hepatol*. 2011; 26(6):943-951.
- [11] Casadaban LC, Parvinian A, Minocha J, Lakhoo J, Grant CW, et al. Clearing the confusion over hepatic encephalopathy after TIPS creation: Incidence, prognostic factors, and clinical outcomes. *Dig Dis Sci*. 2015; 60:1059-1066.
- [12] Casado M, Bosch J, Garcia-Pagan JC, Bru C, Banares R, et al. Clinical events after transjugular intrahepatic portosystemic shunt: Correlation with hemodynamic findings. *Gastroenterology*. 1998; 114(6):1296-1303.
- [13] Rössle M, Siegerstetter V, Olschewski M, Ochs A, Berger E, et al. How much reduction in portal pressure is necessary to prevent variceal rebleeding? A longitudinal study in 225 patients with a transjugular intrahepatic portosystemic shunt. *Am J Gastroenterol*. 2001; 96(12):3379-3383.
- [14] Mollaiyan Mollaiyan A, Bettinger D, Rössle M. The underdilatation of nitinol stents at TIPS implantation: Solution or illusion? *Eur J Radiol*. 2017; 89:123-128.
- [15] Borghol S, Perarnau JM, Pucheux J, D'Alteroche I, Ayoub J, et al. Short- and long-term evolution of the endoluminal diameter of underdilated stents in transjugular intrahepatic portosystemic shunt. *Diagn Interv Imaging*. 2016; 97(11):1103-1107.
- [16] Pieper CC, Sprinkart AM, Nadal J, Hippe V, Meyer C, et al. Postinterventional passive expansion of partially dilated transjugular intrahepatic portosystemic shunt stents. *J Vasc Interv Radiol*. 2015; 26(3):388-394.

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- [17] Gaba RC, Parvianian A, Minocha J, Casadaban LC, Knuttinen MG, et al. Should transjugular intrahepatic portosystemic shunt stent be underdilated? *J Vasc Interv Radiol*. 2015; 26(3):382–387.
- [18] Rössle M. TIPS: 25 years later. *J Hepatol*. 2013; 59(5):1081–1093.
- [19] Rössle M, Blanke P, Fritz B, Schultheiss M, Bettinger D. Free hepatic vein pressure is not useful to calculate the portal pressure gradient in cirrhosis: A morphologic and hemodynamic study. *J Vasc Interv Radiol*. 2016; 27(8):1130–1137.
- [20] Hoffmann KR, Dmochowski J, Nazareth DP, Miskolczi L, Nemes B, et al. Vessel size measurements in angiograms: Manual measurements. *Med Phys*. 2003; 30(4):681–688.
- [21] AASLD, EASL. Hepatic encephalopathy in chronic liver disease: 2014 Practice Guideline by the European Association for the study of the liver and the American Association for the study of liver diseases. *J Hepatol*. 2014; 61(3):642–659.
- [22] Schultheiss M, Bettinger D, Boettler T, Thimme R, Rössle M. Severe Hepatic Encephalopathy after Transjugular Intrahepatic Portosystemic Shunt (TIPS): Value of Shunt Reduction and Occlusion. *JSM Hepat*. 2017; 2(1):1009.
- [23] Abraldes JG, Tarantino I, Turnes J, Garcia-Pagan JC, Rhodes J, et al. Hemodynamic response to pharmacological treatment of portal hypertension and long-term prognosis of cirrhosis. *Hepatology*. 2003; 37:902–908.
- [24] De Franchis R, Baveno VI Faculty. Expanding consensus in portal hypertension: Report of the Baveno VI Consensus Workshop: Stratifying risk and individualizing care for portal hypertension. *J Hepatol*. 2015; 63(3):743–752.
- [25] Bureau C, Garcia-Pagan JC, Otal P, Pomier-Layrargues G, Chabbert V, et al. Improved clinical outcome using polytetrafluoroethylene-coated stents for TIPS: Results of a randomised study. *Gastroenterology*. 2004; 126(2):469–475.
- [26] Perarnau JM, Le Gouge A, Nicolas C, d'Alteroche L, Borentain P, et al. Covered vs. uncovered stents for transjugular intrahepatic portosystemic shunt: A randomized controlled trial. *J Hepatol*. 2014; 60(5):962–968.
- [27] Sauerbruch T, Mengel M, Dollinger M, Zipprich A, Rössle M, et al. Prevention of rebleeding from esophageal varices in patients with cirrhosis receiving small-diameter stents versus hemodynamically controlled medical therapy. *Gastroenterology*. 2015; 149(3):660–668.
- [28] Holster L, Tjwa E, Moelker A, Wils A, Hansen BE, et al. Covered transjugular intrahepatic portosystemic shunt versus endoscopic therapy plus β -blocker for prevention of variceal rebleeding. *Hepatology*. 2016; 63(2):581–589.