Article published online: 2024-04-19

Original Article

Safety and Efficacy of Overdilation of 10 mm Viatorr Transjugular Intrahepatic Portosystemic Shunt Stents Using 12 mm Balloons

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Arab J Intervent Radiol

Abstract

Objective The aim of this study was to evaluate overdilation of 10-mm standard and 8–10 mm controlled-expansion Viatorr stents to 12 mm during transjugular intrahepatic portosystemic shunt (TIPS) placement when insufficient reduction (<50%) in portosystemic gradient (PSG) is achieved with standard 10 mm dilation.

Materials and Methods It is a single-institution, institutional review board-approved, retrospective review of TIPS (2013–2022) to identify patients in the overdilation group (12 mm dilation of a 10-mm stent) and a control group (10 mm dilation of a 10-mm stent) matched for age, indication, stent type, Model for End-Stage Liver Disease (MELD) score, pre-TIPS PSG, and variceal embolization. Stent diameter, technical success, clinical outcomes, and adverse events were assessed for both groups.

Results TIPS was created for the overdilation group ($n = 35$, 57 ± 11 years, 69% male; MELD: 14 ± 5) and control group ($n = 35$, 57 ± 11 years, 83% male; MELD: 14 ± 5). Overdilation to 12 mm adequately reduced PSG by more than 50% (55 vs. 65% in the control group, $p = 0.11$). The stent diameter was larger in the overdilation group on cross-sectional imaging (9.8 ± 0.2 vs. 9.5 ± 0.4 mm, $p < 0.001$), with an estimated 57% higher volume flow rate ($p = 0.002$). Patients were followed for a median of 11.3 months (range: 0.03–75) and 15.6 months (range: 0.03–106) in the overdilation and control groups, respectively. There was an equivalent rate of ascites resolution (56 vs. 63%, $p = 0.68$) and rebleeding (13 vs. 17%, $p = 0.82$) in the overdilation and control groups, with a similar risk of new-onset hepatic encephalopathy (41 vs. 33%, $p = 0.51$) and TIPS occlusion (11 vs. 9%, $p = 0.69$). Overdilation did not result in any instance of stent fracture.

Conclusion Overdilation of 10-mm Viatorr stents with 12 mm balloons may provide benefit by potentially reducing PSG further for patients initially having inadequate PSG reduction with short-term safety.

Keywords
- portal hypertension
- ascites
- gastrointestinal bleeding
- transjugular intrahepatic portosystemic shunt
- stent dilation
- hepatic encephalopathy

DOI https://doi.org/10.1055/s-0044-1782662.
ISSN 2542-7075.

Thieme Medical and Scientific Publishers Pvt. Ltd., A-12, 2nd Floor, Sector 2, Noida-201301 UP, India

Introduction

Transjugular intrahepatic portosystemic shunt (TIPS) has been established as an effective treatment for the sequelae of portal hypertension that includes acute gastrointestinal (GI) bleeding, ascites refractory to diuretics or requiring serial paracenteses, and hepatic hydrothorax.[1,2] Even though the technical success rate of TIPS is high (95%), an adequate reduction in portosystemic gradient (PSG) is paramount for its clinical success.[1] Multiple guidelines (American College of Radiology [ACR] and American Association for the Study of Liver Diseases [AASLD]) have recommended reduction in the PSG to a target of 12 mm Hg after TIPS placement.[3,4] The risk of recurrent GI bleeding has been shown to be 0.4% when PSG is reduced to less than 12 mm Hg and patients with refractory ascites in whom PSG is reduced to less than 12 mm Hg have better control of ascites and better survival than patients receiving serial paracentesis.[5,6] Percentage reduction in PSG is an alternate to achieving the threshold PSG, especially in patients initially having extremely high or low PSG, with the risk of rebleeding being 18%, 7%, and 1% with reduction in PSG by 0%, 25 to 50%, and more than 50% respectively.[5]

Viatorr TIPS stents used to be available in different sizes (8, 10, and 12 mm diameters). Some studies comparing stents of different diameters have shown that larger diameter stents are associated with a greater reduction in PSG and are associated with better outcomes (e.g., recurrence free probability 82.9 vs. 41.9%, $p = 0.002$), whereas other studies have shown equivalent or better outcomes with smaller stent diameter.[7–10] During a TIPS procedure, the stent is gradually dilated until the desired PSG is achieved; however, in some cases the PSG may not be reduced to desired threshold even after the stent has been maximally dilated. There is no option to further reduce PSG other than placing a parallel / second TIPS. However, a parallel TIPS not only requires a second procedure, but its safety and effectiveness have not been evaluated outside of a few case reports and case series, with one retrospective study that was done in patients with Budd-Chiari syndrome.[11–13] Another potential technique to further reduce PSG is to overdilate the 10 mm stent by dilating it beyond its manufacturer-recommended diameter. However, the safety, effectiveness, and clinical outcomes of this technique are yet to be evaluated.

Hence, the purpose of this study is to evaluate technical success, clinical outcomes, and long-term patency of 10-mm Viatorr stents overdilated to 12 mm.

Materials and Methods

Institutional review board approval with waiver of informed consent was obtained for this Health Insurance Portability and Accountability Act (HIPAA) compliant, single center, retrospective, case–control study.

TIPS Procedure

Each TIPS procedure was performed by board certified Interventional Radiologists in an angiography suite. The type of stent used was determined by the treating interventional radiologist in light of different patient factors (e.g., preprocedural PSG measurements, indication for TIPS, length of hepatic parenchymal tract, baseline symptoms of hepatic encephalopathy [HE]). After deployment of the stent, the stent was sequentially dilated until the desired PSG reduction (>50%) was achieved. In patients where 10 mm dilation (maximum recommended dilation of a 10-mm stent) was unable to reduce the PSG by more than 50%, dilation with a 12 mm balloon was attempted. Technical success was defined as the successful deployment of the stent at the desired location with adequate reduction in PSG after balloon dilation to the desired maximum diameter (10 or 12 mm).

Study Population

All patients undergoing consecutive TIPS procedures between January 2013 and February 2022 were identified from the departmental procedure database. Inclusion criteria were as follows: (a) placement of a 10-mm standard or 8–10 mm controlled expansion (CX) Viatorr TIPS stent (GORE VIATORR TIPS Endoprosthesis, Gore Medical, Flagstaff, Arizona, United States) and (b) maximum dilation of the TIPS stent with a 10 mm (Conquest 40 PTA Dilatation Catheter, BD, Tempe, Arizona, United States) or 12 mm (Atlas Gold PTA Dilatation Catheter, BD, Tempe, Arizona, United States) balloon. Exclusion criteria were as follows: (a) placement of stent other than Viatorr stent (e.g., Wall stent [WALLSTENT Endoprosthesis, Boston Scientific, Marlborough, Massachusetts, United States]) and (b) maximum dilation of the stent using a balloon smaller than 10 mm. Patients whose stent was maximally dilated to 12 mm were assigned to the 12 mm group (overdilation group) and patients whose stent was maximally dilated to 10 mm were assigned to the 10 mm group (control group).

Propensity Score Matching

The following variables were collected for both groups to perform propensity score matching: age, MELD scores, indication for TIPS placement, pre-TIPS PSG, type of stent placed (10-mm standard or 8-10 mm CX) and whether varices were embolized. Nearest-neighbor (1-to-1) propensity score matching was used to select matching patients from the control group for every patient in the overdilation group. Student's *t*-test and chi-squared test were used to validate the match.

Data Collection

Baseline demographics, HE and grade, pre- and postprocedural PSG (in the 12 mm group, PSG values after 10 mm dilation and before final 12 mm dilation were also collected), procedural complications, need for TIPS revision/reduction, clinical outcomes, time to death or last follow-up, and hospital stay after the procedure were assessed through chart review of the electronic medical record.

Hemodynamic Outcomes

Hemodynamic outcomes included PSG reduction and percentage reduction in PSG. PSG reduction was calculated as: post_TIPS PSG - pre_TIPS PSG, and percentage reduction in PSG was calculated as: $\frac{\text{PSG reduction}}{\text{Pre-TIPS PSG}}\ x\ 100$.

Clinical Outcomes

Clinical outcomes that were assessed included (1) resolution or recurrence of the clinical symptom for which the procedure was performed, including ascites resolution or improvement, resolution or recurrence of GI bleeding, hydrothorax resolution or reduction and resolution of shortness of breath due to hydrothorax; (2) need for TIPS revision and rates of TIPS occlusion; and (3) incidence and severity of new onset HE along with need for TIPS reduction for its management. Patients were followed until death or last known follow-up.

Stent Measurement and Assessment

Stent diameter and integrity were measured and assessed in both groups on the latest cross-sectional computed tomography (CT) imaging available. The CT images were retrieved from the Picture Archiving and Communications System (PACS), and postprocessing and measurements were conducted using MIM Version 7 (MIM Software Inc., Cleveland, Ohio, United States). In cases where TIPS revision or reduction was performed, the imaging immediately prior to the reintervention was used for measurements to avoid confounding. To minimize bias, the reviewer was blinded to the treatment cohort. The diameter was measured at three locations: (1) at the cranial part of the sent, (2) halfway between the cranial part of the stent and the ring (±5mm), and (3) at the ring. The measurements were made using a previously established technique, where the CT was reoriented for every measurement such that the longitudinal axis of the stent was vertical on coronal and sagittal planes, with the measurement taken on the axial plane.[14] The measurements were made from the center of the metal struts (window width: 1100; window level: 300 to minimize the effect of blooming, ►**Fig. 1**). The mean of all measurements was calculated and reported. Time from TIPS to the cross-sectional imaging was also recorded. Measurement of the stents during the procedure (on fluoroscopic images) was attempted; however, a majority of the images saved in PACS were secondary captures, and calibrated measurements could not be obtained. Flow through the stent was calculated using Poiseuille's equation: $\text{Volume Flow rate } (Q) = \frac{\pi r^4 \Delta P}{8 l \eta}$, with r being the radius (measured on MIM), ΔP being the difference in pressure between two ends of the stent (PSG), l being the length of the stent (collected from the report), and η being the viscosity of blood.[15] Assuming the same viscosity in both groups, the percentage difference between volume flow rates was calculated as: $\frac{Q_{\text{overdilation}} - Q_{\text{control}}}{Q_{\text{control}}} \; x\, 100$.

Statistical Analysis

Continuous variables were reported as mean with range and/or standard deviation and were compared using paired or unpaired Student's *t*-test. Categorical variables were reported as frequencies and percentage and compared using chi-squared test. A *p*-value less than 0.05 was considered statistically significant. Statistical analysis was performed using R version 4.1.2.[16]

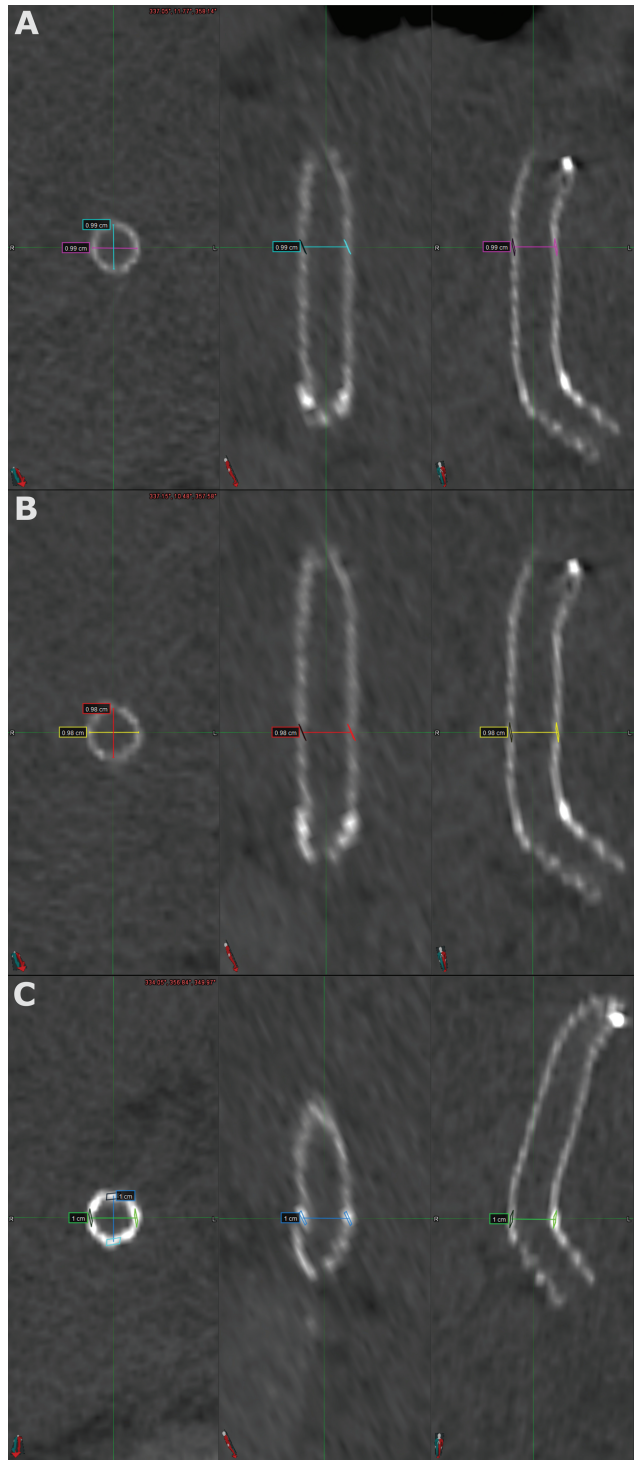

Fig. 1 Measurement of transjugular intrahepatic portosystemic diameters on cross-sectional computed tomographic imaging (width: 1100, level: 300). (**A**) Cranial part of stent, (**B**) between cranial part and ring, and (**C**) at the ring.

Results

After review of the departmental procedural database, 35 patients were identified who underwent 12 mm dilation of a 10-mm TIPS stent and met the inclusion and exclusion

Table 1 Results of propensity score matching

	Overdilation group ($n = 35$)	Control group ($n = 35$)	p-Value
Age	57 ± 9	57 ± 11	0.91
Indication			0.72
Ascites	18 (51%)	16 (46%)	
Budd-Chiari syndrome	1 (3%)	0	
GI bleeding	8 (23%)	6 (17%)	
Hepatic hydrothorax	2 (6%)	2 (6%)	
PVT	5 (14%)	9 (26%)	
Small portal vein	1 (3%)	2 (6%)	
MELD	14 ± 5	14 ± 5	0.89
Pre-TIPS PSG	17 ± 6	15 ± 6	0.24
Stent type			0.47
10 mm Viatorr	15 (43%)	18 (51%)	
8–10 mm CX Viatorr	20 (57%)	17 (48%)	
Variceal embolization			1
Yes	8 (23%)	8 (23%)	
No	27 (77%)	27 (77%)	

Continuous variables are reported as mean (±standard deviation) and categorical variables are reported as number with percentage in parentheses. Abbreviations: CX, controlled expansion; GI, gastrointestinal bleeding; MELD, Model for End-stage Liver Disease; PSG, portosystemic gradient; PVT, portal vein thrombosis; TIPS, transjugular intrahepatic portosystemic.

criteria (overdilation group). The mean age of the patients was 57 ± 9, 69% male, mean MELD of 14 ± 5, the most common indication was refractory ascites (51%) followed by GI bleeding (23%), a majority had an 8 to 10 mm CX stent placed (57%), and variceal embolization/sclerosis occurring in 23% of patients. Nearest neighbor (1 to 1) propensity score matching conducted for these six variables identified a control group of 35 patients (mean age: 57 ± 11 years, 83% male) from among patients who underwent 10 mm dilation of a 10-mm stent. The match was verified using *t*-test and chi-squared test, as outlined in ►**Table 1**.

Majority of the population was male in both the overdilation and control groups (69% and 83%, $p = 0.16$). A majority of the patients had cirrhosis (94% vs. 97%, $p = 0.56$), with alcohol being the most common cause of cirrhosis (49% vs. 40%, $p = 0.71$). HE was present prior to the procedure in six patients in the overdilation group and in two patients in the control group ($p = 0.13$), with 50% of these patients having grade I HE in both groups. Details of all baseline characteristics in both groups are presented in ►**Table 2**.

Hemodynamic Outcomes

TIPS creation was technically successful in all patients in both groups. PSG was reduced by a mean of 10 mm Hg (from 17 ± 6 to 7 ± 3 mm Hg, $p < 0.001$) in the overdilation group and 10 mm Hg (from 15 ± 5 to 6 ± 3 mmHg, $p < 0.001$) in the control group. Even though the post-TIPS PSG was lower in the control group (6 ± 3 vs. 7 ± 3 mm Hg, $p = 0.049$), the absolute reduction (10 ± 5 vs. 10 ± 4 mm Hg, $p = 0.93$) and percentage reduction (55% vs. 65%, $p = 0.11$) of PSG were similar between both groups (►**Table 3**).

In the overdilation group, PSG values after 10 mm dilation (before the stent was finally dilated to 12 mm) were available for 14/35 patients, and were compared with the PSG values in control group (►**Table 3**). PSG was reduced by 7 mm Hg, compared to 10 mm Hg in the control group ($p = 0.07$). The percentage reduction was significantly lower when the stent was dilated to 10 mm in the overdilation group, at 40%, compared to 65% in the control group ($p = 0.008$). Overdilation to 12 mm significantly increased this PSG reduction to 55%, which was then similar to the reduction seen in the control group ($p = 0.11$).

Subset analysis of patients receiving the 8–10 mm CX TIPS stent ($n = 20$ for 12 mm, $n = 17$ for 10 mm) revealed that the PSG was reduced by 9 mm Hg (from 17 ± 7 to 8 ± 3 mm Hg, $p < 0.001$) in the overdilation group and by 9 mm Hg (from 16 ± 5 to 7 ± 3 mm Hg, $p < 0.001$) in the control group. There was no significant difference in the reduction in PSG ($p = 0.81$). The PSG was reduced by 50% in the overdilation group compared to 55% in the control group ($p = 0.51$).

Clinical Outcomes

Patients were followed for a median of 11.3 months (range: 0.03–75) and 15.6 months (range: 0.03–106) in the overdilation and control groups, respectively. In patients with refractory ascites, ascites resolution was seen in 10/18 (56%) patients in the overdilation group compared to 10/16 (62%) patients in the control group ($p = 0.68$). In patients with

Table 2 Demographics and baseline parameters

	Overdilation group ($n = 35$)	Control group ($n = 35$)	*p*-Value
Gender			0.16
Female	11 (31%)	6 (17%)	
Male	24 (69%)	29 (83%)	
Cirrhosis			0.56
Yes	33 (94%)	34 (97%)	
No	2 (6%)	1 (3%)	
Cause of cirrhosis			0.71
Alcohol	17 (49%)	14 (40%)	
Alcohol and HCV	4 (11%)	2 (6%)	
Alcohol and NASH	1 (3%)	3 (9%)	
HBV	1 (3%)	2 (6%)	
HCV	1 (3%)	2 (6%)	
NASH	7 (20%)	5 (14%)	
Other	4 (11%)	7 (20%)	
Source of GI bleeding			0.13
Esophageal varices	5 (63%)	1 (17%)	
GE varices	2 (25%)	0	
Jejunal varices	0	1 (17%)	
Portal gastropathy	1 (13%)	1 (17%)	
Stomal varices	0	2 (33%)	
Unknown	0	1 (17%)	
Pre-TIPS ascites			0.16
Absent	5 (14%)	11 (31%)	
Slight	5 (14%)	2 (6%)	
Moderate/severe	25 (71%)	22 (63%)	
Pre-TIPS encephalopathy			0.13
Yes	6 (17%)	2 (6%)	
No	29 (83%)	33 (94%)	
Pre-TIPS encephalopathy grade	$n = 6$	$n = 2$	0.8
1	3 (50%)	1 (50%)	
2	2 (33%)	1 (50%)	
4	1 (17%)	0	
MELD-Na	15 ± 5	15 ± 5	0.98

Continuous variables are reported as mean (±standard deviation) and categorical variables are reported as number with percentage in parentheses. Abbreviations: GE, gastroesophageal; GI, gastrointestinal; HBV, hepatitis B virus; HCV, hepatitis C virus; MELD-Na, Model for End-stage Liver Disease – Sodium; NASH, nonalcoholic steatohepatitis; TIPS, transjugular intrahepatic portosystemic shunt.

variceal bleeding, the bleeding resolved in all patients in both groups, and rebleeding rates were similar in both groups—1/8 (13%) patients in the overdilation group compared to 1/6 (17%) patients in the control group ($p = 0.82$). Shortness of breath due to hepatic hydrothorax resolved in all patients in both groups ($p = 1$). There was reduction in hydrothorax in all patients in both groups ($p = 1$), with complete resolution in one patient in the overdilation group and in both patients in the control group ($p = 0.25$).

TIPS occlusion (requiring thrombectomy and repeat dilation) was needed in 4/35 (11%) patients in the overdilation group, compared to 3/11 (9%) patients in the control group ($p = 0.69$). Relining with a new Viatorr was also performed in two of these four cases in the overdilation group. Other TIPS revision procedures were needed in two cases in the overdilation group (mild narrowing seen, stent was redilated), and in one case in the control group (the cranial end was extended with another stent).

Table 3 Procedural outcomes and PSG reduction

	Overdilation group ($n = 35$)	Control group ($n = 35$)	p-Value
Technical success	35 (100%)	35 (100%)	
Complications	7 (20%)	9 (26%)	0.32
Acute kidney injury	2	1	
Acute liver injury	1	2	
Sepsis	1	1	
Incarcerated umbilical hernia		2	
Abdominal pain		1	
Atrial fibrillation	1		
Heart failure	1		
Hepatic artery bleeding		1	
Respiratory failure	1		
Perisplenic hematoma		1	
Transfusion required			0.69
Yes	4 (11%)	3 (9%)	
No	31 (89%)	32 (91%)	
Infection after TIPS			1
Yes	2 (6%)	2 (6%)	
No	33 (94%)	33 (94%)	
PSG reduction after 10 mm dilation in the overdilation group[a]			
Post-TIPS PSG (mm Hg)	10 ± 2	6 ± 3	<0.001
PSG reduction (mm Hg)	7 ± 4	10 ± 4	0.07
Percentage reduction in PSG	40%	65%	0.008
PSG Reduction after 12 mm dilation in the overdilation group			
Post-TIPS PSG (mm Hg)	7 ± 3	6 ± 3	0.049
PSG reduction (mm Hg)	10 ± 5	10 ± 4	0.93
Percentage reduction in PSG	55%	65%	0.11

Continuous variables are reported as mean (±standard deviation) and categorical variables are reported as number with percentage in parentheses. Percentage reduction is reported as a percentage.
Abbreviations: PSG, portosystemic gradient; TIPS, transjugular intrahepatic portosystemic shunt.
[a]PSG measurements after 10 mm dilation in the overdilation group were available for 14/35 patients

New onset HE was seen in 11/33 (33%) patients in the control group and in 12/27 (41%) of patients in the overdilation group ($p = 0.51$). Grade 2 HE was most common in both groups (comprising of 42% and 64% in the overdilation and control groups, respectively). This was successfully managed medically with lactulose and rifaximin in most of the patients, with TIPS reduction required in three and two patients in the overdilation and control groups, respectively ($p = 0.64$). Clinical outcomes are presented in ►**Table 4**.

Stent Integrity and Diameters

Follow-up cross-sectional CT imaging was available in 53 patients (26 of 35 patients in overdilation group and 27 of 35 patients in control group). Imaging was performed 5 ± 6 months and 13 ± 25 months after the TIPS procedure in overdilation and control groups, respectively ($p = 0.12$). All stents in both groups were patent and no signs of damage to the metallic components were noted. On measurement, the mean diameter (of all 3 locations) was 9.8 ± 0.2 mm in the overdilation group compared to 9.5 ± 0.4 mm in the control group ($p < 0.001$, ►**Table 5**). Using Poiseuille's equation, and assuming viscosity to be constant, the volume flow rate was 57% higher in the overdilation group as compared to the control group ($p = 0.002$).

Discussion

This study demonstrates that in cases where standard dilation of a TIPS stent to 10 mm is unable to achieve an adequate reduction in PSG, overdilation to 12 mm can be used to achieve additional reduction in PSG with a 100% technical success rate. Similar rates of refractory ascites resolution (56 vs. 63%) and rebleeding (13 vs. 17%) were seen in both groups, with a similar risk of TIPS occlusion (11 vs. 9%). No

Table 4 Clinical outcomes after TIPS

	Overdilation group ($n = 35$)	Control group ($n = 35$)	*p*-Value
Duration of stay (days)	12 ± 15	7 ± 5	0.08
Time to last follow-up or death (months)	19 ± 19	24 ± 25	0.31
Refractory ascites resolution	n = 18	n = 16	0.68
Yes	10 (56%)	10 (62%)	
No	8 (44%)	6 (38%)	
Rebleeding	$n = 8$	$n = 6$	0.82
Yes	1 (13%)	1 (17%)	
No	7 (87%)	5 (83%)	
Hepatic hydrothorax symptom resolution	$n = 2$	$n = 2$	
Yes	2 (100%)	2 (100%)	
No	0 (0%)	0 (0%)	
TIPS occlusion			0.69
Yes	4 (11%)	3 (9%)	
No	31 (89%)	32 (91%)	
New onset encephalopathy	n = 29	n = 33	0.51
Yes	12 (41%)	11 (33%)	
No	17 (59%)	22 (67%)	
Encephalopathy grade	n = 12	n = 11	0.51
1	3 (25%)	3 (27%)	
2	5 (42%)	7 (64%)	
3	3 (25%)	1 (9%)	
4	1 (8%)	0 (0%)	
TIPS reduction			0.64
Yes	3 (9%)	2 (6%)	
No	32 (91%)	33 (94%)	

Continuous variables are reported as mean (±standard deviation) and categorical variables are reported as proportions.
Abbreviation: TIPS, transjugular intrahepatic portosystemic shunt.

detectable damage occurred to the TIPS stent due to overdilation, as evaluated by cross-sectional imaging, and the increased diameter persisted on long-term follow-up in the overdilation group compared to the control group (9.8 vs. 9.5 mm, $p < 0.001$).

Overdilation of a TIPS stent beyond its recommended diameter is a technique that has not been evaluated before with Viatorr stents. It is not recommended by the manufacturer due to the risk of stent damage or fracture. In this cohort, overdilation was performed safely in all cases, without any additional risk of immediate or delayed complications. The rate of TIPS occlusion was similar to that seen in patients with standard dilation and there was no apparent stent damage, or loss of integrity seen on follow-up cross-sectional imaging.

Adequate portal decompression of patients is important for successful management of symptoms from portal hypertension. Studies have demonstrated that stents with larger

Table 5 Measurement of TIPS stent (mm) at all locations for both groups

Location	Overdilation group ($n = 26$)	Control group ($n = 27$)	*p*-Value
1. Cranial part of stent (mm)	9.8 ± 0.3	9.4 ± 0.5	0.005
2. Between ring and cranial part of stent (mm)	9.8 ± 0.3	9.4 ± 0.5	0.002
3. Ring (mm)	9.9 ± 0.2	9.6 ± 0.3	<0.001
Mean of the 3 locations (mm)	9.8 ± 0.2	9.5 ± 0.4	<0.001

Abbreviation: TIPS, transjugular intrahepatic portosystemic shunt.

diameters lead to more PSG reduction and better symptom control.[7,8] Once a stent is placed, it is expanded sequentially with larger sized balloons until adequate PSG reduction is achieved. However, if adequate PSG reduction is not achieved even after maximum recommended dilation of the stent, it is not technically feasible to remove the stent and place a stent with a larger diameter. And the only other option, the placement of another/parallel TIPS (which requires the creation of another portosystemic tract, and may increase the risk of complications and overshunting) has not been studied for these indications outside of a few case reports.[11–13] Overdilation of the stent is a feasible and technically easy option in this case to achieve additional PSG reduction, and can possibly be considered as a first step when adequate portal decompression is not achieved with standard dilation.

Overdilation of the stent led to an adequate rate of clinical symptom resolution (i.e., ascites resolution, GI bleeding resolution and recurrence, and hydrothorax resolution) comparable to that seen in the control group. The additional PSG reduction achieved with overdilation was beneficial in helping these patients reach an adequate clinical response, without the need for another/parallel TIPS placement.

While more PSG reduction can lead to adequate portal decompression and better clinical response, it can also lead to overshunting, thus causing HE. Studies have demonstrated that using smaller diameter stents may reduce the risk of HE.[9,10] There may be concern that overdilation of a stent may lead to an increased risk of HE; however, in this study the rate of new-onset HE was similar between both the overdilation and control groups, thus providing evidence that overdilation can lead to additional PSG reduction, without increasing the risk of HE.

Even though overdilation led to increased PSG reduction at the time of the procedure, whether the increased diameter persisted over time or not is an important factor for sustained portal decompression. The average diameter of the stents, as measured on cross-sectional CT imaging, was 9.8 ± 0.2 mm at 5 ± 6 months in the overdilation group, and this was statistically higher than the average diameter of 9.5 ± 0.4 mm in the control group ($p < 0.001$). Taking into account the length of the stent used and the pressure difference across the stent (the PSG), and assuming the viscosity of the blood to be constant, the estimated flow through the stent would be 57% higher in the overdilation group compared to the control group by using Poiseuille's equation.[15]

Limitations

Limitations of this study include retrospective study design, use of a specific stent type (Viatorr, though this is the most widely used stent in the United States), and heterogeneous population using both the standard and CX Viatorr stents. Measurements of the stent diameter after 10 mm and then after 12 mm dilation could not be obtained from the fluoroscopy images during the procedure. Even though the measurements obtained on the follow-up CT were standardized and the reviewer was blinded to the treatment cohort to minimize bias, the difference of 0.3 mm in the stent diameter may not be significant due to the subjectivity associated with measuring the stent diameter on CT scans. PSG measurements following 10 mm dilation were not saved in all overdilation procedures and were available for only 14/35 patients. Finally, damage to the nonradiopaque portion of the stent could not be evaluated on CT imaging. However, since the rate of stent dysfunction was similar to that seen in the control group, overdilation did not cause damage that resulted in clinically significant TIPS dysfunction.

Conclusion

Overdilation of a 10- and 8 to 10 mm CX Viatorr TIPS stent by 12 mm balloon angioplasty increases PSG reduction, bringing patients to an adequate hemodynamic and clinical response, with resolution of symptoms of portal hypertension, and maintenance of the larger diameter over time, without an increased risk of HE or other complications.

Institutional Review Board (IRB) Approval

IRB-exempt approval was obtained from the IRB. The requirement for informed consent was waived by the IRB.

Conflict of Interest

None declared.

References

1 Dariushnia SR, Haskal ZJ, Midia M, et al; Society of Interventional Radiology Standards of Practice Committee. Quality improvement guidelines for transjugular intrahepatic portosystemic shunts. J Vasc Interv Radiol 2016;27(01):1–7

2 Boike JR, Thornburg BG, Asrani SK, et al; Advancing Liver Therapeutic Approaches (ALTA) Consortium. North American practice-based recommendations for transjugular intrahepatic portosystemic shunts in portal hypertension. Clin Gastroenterol Hepatol 2022;20(08):1636–1662.e36

3 American College of Radiology. ACR–SIR–SPR Practice Parameter for the Creation of a Transjugular Intrahepatic Portosystemic Shunt (TIPS). Revised 2022 (Resolution 18); Available at: https://www.acr.org/-/media/ACR/Files/Practice-Parameters/TIPS.pdf. Accessed September 05, 2022

4 Boyer TD, Haskal ZJAmerican Association for the Study of Liver Diseases. The role of transjugular intrahepatic portosystemic shunt in the management of portal hypertension. Hepatology 2005;41(02):386–400

5 Rössle M, Siegerstetter V, Olschewski M, Ochs A, Berger E, Haag K. How much reduction in portal pressure is necessary to prevent variceal rebleeding? A longitudinal study in 225 patients with transjugular intrahepatic portosystemic shunts. Am J Gastroenterol 2001;96(12):3379–3383

6 Narahara Y, Kanazawa H, Fukuda T, et al. Transjugular intrahepatic portosystemic shunt versus paracentesis plus albumin in patients with refractory ascites who have good hepatic and renal function: a prospective randomized trial. J Gastroenterol 2011;46(01):78–85

7 Riggio O, Ridola L, Angeloni S, et al. Clinical efficacy of transjugular intrahepatic portosystemic shunt created with covered stents with different diameters: results of a randomized controlled trial. J Hepatol 2010;53(02):267–272

8 Miraglia R, Maruzzelli L, Tuzzolino F, Petridis I, D'Amico M, Luca A. Transjugular intrahepatic portosystemic shunts in patients with

cirrhosis with refractory ascites: comparison of clinical outcomes by using 8- and 10-mm PTFE-covered stents. Radiology 2017;284 (01):281–288
9 Wang Q, Lv Y, Bai M, et al. Eight millimetre covered TIPS does not compromise shunt function but reduces hepatic encephalopathy in preventing variceal rebleeding. J Hepatol 2017;67(03): 508–516
10 Praktiknjo M, Abu-Omar J, Chang J, et al. Controlled underdilation using novel VIATORR® controlled expansion stents improves survival after transjugular intrahepatic portosystemic shunt implantation. JHEP Rep Innov Hepatol 2021;3(03):100264
11 He FL, Wang L, Yue ZD, Zhao HW, Liu FQ. Parallel transjugular intrahepatic portosystemic shunt for controlling portal hypertension complications in cirrhotic patients. World J Gastroenterol 2014;20(33):11835–11839
12 Raissi D, Yu Q, Nisiewicz M, Krohmer S. Parallel transjugular intrahepatic portosystemic shunt with Viatorr® stents for primary TIPS insufficiency: case series and review of literature. World J Hepatol 2019;11(02):217–225
13 Alwarraky MS, Elzohary HA, Melegy MA, Mohamed A. Parallel transjugular intrahepatic portosystemic shunt (TIPS) for TIPS dysfunction: technical and patency outcome. Egypt J Radiol Nucl Med 2020;51(01):229
14 Miraglia R, Maruzzelli L, Di Piazza A, et al. Transjugular intrahepatic portosystemic shunt using the new gore Viatorr controlled expansion endoprosthesis: prospective, single-center, preliminary experience. Cardiovasc Intervent Radiol 2019;42 (01):78–86
15 Gooch JW. Hagen-Poiseuille Equation. In: Gooch J.W. (eds) Encyclopedic Dictionary of Polymers. New York, NY: Springer; 2011:355; available at: https://doi.org/10.1007/978-1-4419-6247-8_5752
16 R Core Team. R: A Language and Environment for Statistical Computing. Published online 2021. Accessed February 13, 2024 at: https://www.R-project.org/

