Postinterventional Passive Expansion of Partially Dilated Transjugular Intrahepatic Portosystemic Shunt Stents

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ABSTRACT

Purpose: To investigate passive transjugular intrahepatic portosystemic shunt (TIPS) stent expansion in patients with intentional "underdilation" (eg, 10-mm stent, 8-mm balloon) during TIPS creation.

Materials and Methods: Custom in-house software was developed for objective quantification of cross-sectional stent area from computed tomography (CT) data. The technique was validated by in vitro experiments. The study included 39 patients (22 men; mean age, 59.2 y) who underwent TIPS creation (VIATORR stent graft [W. L. Gore & Associates, Flagstaff, Arizona]; n = 29; WALLSTENT endoprosthesis [Boston Scientific, Marlborough, Massachusetts], n = 10) with stent underdilation. Follow-up CT data of the patients were used to quantify in vivo stent area changes. Data were analyzed by variance analysis and entered into a general linear model to test for interrelations between stent area changes and clinical (eg, cirrhosis grade) and procedural parameters.

Results: In vitro validation of the in-house software showed good agreement and reproducibility without overestimation of stent area. Mean clinical follow-up time in patients was 787 days (range, 7–2,450 d). At the time of intervention, VIATORR stent grafts and WALLSTENT endoprostheses were dilated to an average of 64.4% ± 2.3% and 65.63% ± 8.52% of nominal area, respectively. At the last imaging follow-up evaluation, this value had increased in all stents to a mean of 87.8% ± 7.9% (VIATORR) and 82.34% ± 19.6% (WALLSTENT) in the TIPS tract ($P < .05$). Multivariate analysis revealed the time after intervention to be the only predictor of stent area in the TIPS tract. There was no significant association between stent expansion and clinical or procedure-related parameters.

Conclusions: The area of self-expanding stents implanted in the liver for TIPS creation with dilation to less than nominal diameter significantly increases over time. This increase has to be considered as an additional factor influencing the long-term portosystemic gradient.

ABBREVIATIONS

HE = hepatic encephalopathy, TIPS = transjugular intrahepatic portosystemic shunt

The creation of a transjugular intrahepatic portosystemic shunt (TIPS) is an established technique for treatment of portal hypertension and its complications. However, TIPS creation may be associated with complications such as deterioration of liver function and hepatic encephalopathy (HE) (1). In addition to patient-related factors, such as pseudointimal hyperplasia, which may lead to narrowing of the TIPS tract, procedure-related factors, such as stent type, size, and most importantly the portosystemic gradient reduction, seem to have an impact on the incidence of HE (1).

A widely proposed technique to balance reduction of portal hypertension on the one hand and occurrence of HE on the other is to calibrate the pressure gradient to the intended value by establishing a TIPS with a stent of 10 mm nominal diameter that is dilated to 6–8 mm only (1–5). It has been shown that self-expanding stents (eg, in peripheral arteries) exert a chronic outward force ultimately leading to passive expansion to their nominal

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diameter (6). A previous study revealed that WALLSTENT endoprostheses (Boston Scientific, Marlborough, Massachusetts) used for TIPS creation expanded to their nominal diameter after 3 months after initial recoil (7). It is, therefore, uncertain whether the stents and stent grafts used for TIPS creation keep this intended diameter or whether further expansion occurs over time, limiting the value of portosystemic gradient calibration at the time of TIPS creation. The purpose of this study was to investigate passive stent expansion after TIPS creation in patients with underdilation during TIPS creation.

MATERIALS AND METHODS

In Vitro Validation of Measuring Technique

In-house software written in MATLAB (MathWorks, Inc, Natick, Massachusetts) was used for measurements of stent area. Using a complex algorithm, the stent boundaries—bearing the highest Hounsfield unit—are automatically detected by the software on computed tomography (CT) images after an initial region of interest is placed within the stent lumen. To validate the measuring technique, 8-mm, 10-mm, and 12-mm diameter WALLSTENT endoprostheses and 8-mm and 10-mmVIATORR stent grafts (W. L. Gore & Associates, Flagstaff, Arizona) were analyzed in vitro. The stents were released and dilated with a non compliant balloon catheter (Mustang; Boston Scientific Ireland, Galway, Ireland) to their nominal diameter in a bath of water at 37°C. The nominal diameter (stent diameter without any restraining outer force) was verified with a caliper measurement. The stents were bent to approximate the shape of an implanted TIPS stent, kept in the bath of water, and scanned by CT in two different double oblique orientations of the stent relative to the scanner. Five orthogonal slices were reconstructed from both orientations for each stent type and diameter, and the respective stent areas were measured (10 for each stent). The measured results were compared with the true stent area. The variation coefficient, which is defined as the ratio of SD to the mean, was calculated to evaluate the reproducibility of the measurements.

The ability to define accurately the smallest diameter within the stent also was investigated. For this purpose, a stenosis with a defined diameter of 6 mm was created in the VIATORR stent graft (8 and 10 mm) and WALLSTENT endoprosthesis (12 mm). Measurements of the smallest diameter were performed four times using the above-described technique. To test for reliability of the in-house software, all stent areas were calculated twice for each reconstructed CT image (control and stenosis group).

In Vivo Assessment of Implanted TIPS Stents

Inclusion and Exclusion Criteria. All patients who underwent a TIPS implantation from January 2005 to March 2013 with either a VIATORR stent graft or WALLSTENT endoprosthesis were screened for study eligibility (N = 351). Inclusion criteria were successful TIPS creation with balloon inflation of less than the nominal stent diameter (eg, 10-mm stent, 8-mm balloon) and available clinical and CT imaging follow-up data. The noncompliant balloons (eg, Mustang) were inflated to their nominal pressure using an inflator (Basix-COMPAK, Merit Medical Systems, Inc, South Jordan, Utah). Patients were excluded from the study if TIPS revision with additional dilation of the tract took place before CT imaging or if pseudointimal hyperplasia or stenosis was noted in the stent lumen during ultrasound or CT follow-up examination. Informed consent was obtained from all patients before the intervention. The retrospective study was approved by the local institutional review board.

Data Acquisition. The study included 39 patients (22 men; mean age, 59.2 y; age range, 40–82 y). Detailed baseline demographics, devices used, and laboratory studies were retrieved from medical records documenting routine clinical follow-up (**Tables 1**, **2**). To assess the presence of HE, the number connection test and critical flicker frequency test were used. HE grading was performed according to the West Haven criteria (8). Patients underwent clinical assessment at the time of CT scanning as well as beyond imaging follow-up as indicated in **Table 1**. Results of neuropsychiatric tests at baseline before TIPS creation were available in 30 of 39 cases (**Table 1**).

Contrast-enhanced CT scans were performed using a 16-slice spiral CT scanner (Mx8000 IDT; Philips Medical

Table 1. Patient Characteristics

Age	59.2 y (range, 40–82 y)
Child-Pugh grade	
A	5 (12.8%)
B	20 (51.3%)
C	14 (35.9%)
Cause of cirrhosis	
Alcoholic liver disease	29 (74.4%)
Hepatitis B or C	8 (20.5%)
Unknown causes	2 (5.1%)
Indication for TIPS	
Refractory ascites	28 (71.8%)
Variceal bleeding	11 (28.2%)
HE evaluation before TIPS (n = 30)	
No HE	12 (40%)
Grade 1	15 (50%)
Grade 2	3 (10%)
Mean clinical follow-up	787 d (range, 7–2,450 d)
Mean imaging follow-up	322 d (range, 2–1,298 d)
VIATORR	337 d (range, 2–1,298 d)
WALLSTENT	435 d (range, 8–1,223 d)

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