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CLINICAL INVESTIGATION   VENOUS INTERVENTIONS

Inferior Vena Cava Rupture Caused by Balloon Angioplasty During the Treatment of Budd–Chiari Syndrome

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Abstract

Objective Percutaneous transluminal balloon angioplasty (PTA) is the main treatment option for Budd–Chiari syndrome (BCS) with inferior vena cava (IVC) obstruction. However, IVC rupture caused by PTA has never been reported.

Materials and Methods Between August 2004 and December 2016, a consecutive cohort of 617 BCS patients with obstructed IVC who underwent PTA with or without stent placement were reviewed retrospectively to identify IVC rupture. Pre- and post-procedural imaging data, clinical and procedural technical data were analyzed.

Results Of the 617 BCS patients, five patients had IVC rupture caused by PTA (0.81%). Four of these patients had retroperitoneal, intra-hepatic IVC rupture without extravasation into abdominal cavity which was successfully managed conservatively. One patient had supra-hepatic IVC rupture into the pericardial cavity which was surgically treated.

Conclusion IVC rupture is a rare complication of PTA treatment of BCS and most commonly located at the intra-hepatic IVC caused by oversized balloons which does not require additional treatment.

Keywords Budd–Chiari syndrome · Hepatic vein · Inferior vena cava · Angioplasty · Rupture

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Introduction

Budd–Chiari syndrome (BCS) is due to obstruction of hepatic venous outflow at the level of the hepatic veins or the inferior vena cava (IVC). In Asia, BCS patients with obstructed IVC are more common, comprising up to 70% of BCS cases [1–3]. Regardless of membranous or segmental obstruction of the IVC, percutaneous transluminal balloon angioplasty (PTA) is a widely accepted treatment option for these patients [4–8]. Due to its rarity, only a small number of cases of IVC rupture as a complication caused by PTA of BCS are reported. In this report, we present more comprehensive presentation of two distinct types of IVC rupture, the management, and the outcomes.

Materials and Methods

This retrospective study was approved by the university ethics committee, and the waiver of consent was obtained. Between August 2004 and December 2016, 790 BCS patients were studied. Of 790 patients, 617 patients with obstructed IVC who underwent treatment according to the inclusion/exclusion criteria were retrospectively studied. The patient selection algorithm is illustrated in Fig. 1.

The inclusion criteria were as follows: (1) BCS with obstructed IVC who received IVC PTA and (2) IVC PTA performed with a balloon catheter-to-IVC diameter ratio of 1.4–1.8:1 using a large balloon catheter. The balloon was sized based on the diameter of a proximal IVC diameter on the cross-sectional imaging (CT or MRI). If proximal IVC diameter could not be determined due to complete obstruction, distal IVC diameter was adopted. The exclusion criteria were as follows: (1) BCS without obstructed IVC ($n = 136$); (2) BCS patients who had not received IVC PTA ($n = 21$); (3) age < 18 years ($n = 3$); (4) IVC PTA performed using a small balloon with the balloon-to-IVC diameter ratio less than 1.4:1 ($n = 13$). If IVC rupture was confirmed, then preoperative images, therapeutic method for IVC rupture, postoperative images, and follow-up outcomes were reviewed.

On intraoperative DSA images, IVC rupture was suspected if one of the following criteria was met: (1) irregular contour of the IVC wall, (2) localized bulging of the IVC wall, and/or (3) contrast extravasation out of the IVC wall.
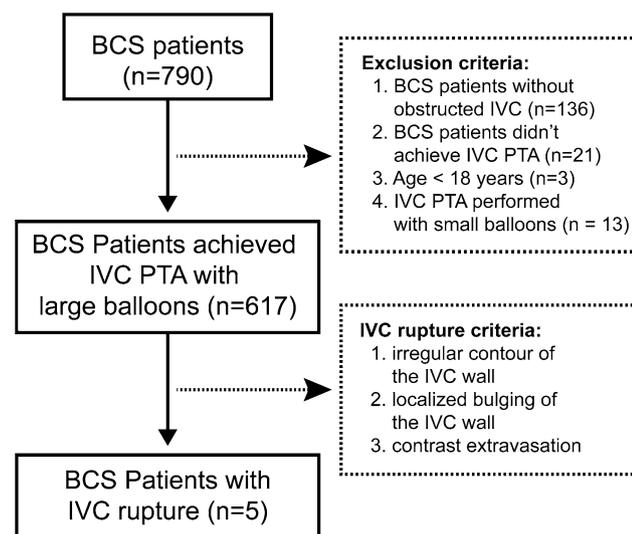
Fig. 1 Algorithm for BCS patients with IVC rupture. *BCS* Budd–Chiari syndrome, *IVC* inferior vena cava. *PTA* percutaneous transluminal balloon angioplasty

Interventional Procedures

All procedures were performed under local anesthesia. No patients were heparinized, and all vital signs were closely monitored during the procedure. In all cases, a balloon catheter-to-IVC diameter ratio of 1.4–1.8:1 was adopted to perform IVC PTA, with a maximal balloon diameter of 30 mm. The balloons used for PTA were from Cook ($n = 327$, LONV^{TM}, Bloomington, Indiana, USA), Balt ($n = 178$, CRISTAL$^®$, Montmorency, France), Bard Inc ($n = 60$, ATLAS$^®$,Tempe, Arizona), and Cordis ($n = 52$, MAXI LD$^®$, Miami Lakes, USA). The balloon lengths were 40 mm or 60 mm. The inflated balloon diameters were 15 mm ($n = 1$), 16 mm ($n = 1$), 18 mm ($n = 1$), 20 mm ($n = 11$), 25 mm ($n = 93$), 26 mm ($n = 58$), 30 mm ($n = 452$). Of 617, 567 patients received PTA only and 50 patients received PTA with stent placement.

IVC venography via transfemoral and/or transjugular approach was performed to evaluate the IVC anatomy, the site and thickness of obstruction, the presence or absence of thrombosis, and collateral circulation. For the patients with IVC occlusion, blunt needle recanalization was performed. After the needle tip was molded to match the shape of the proximal or distal ends of obstructed IVC, the needle was directed toward the obstruction. Under fluoroscopic guidance, the needle was pushed gently to penetrate the IVC obstruction. After traversing the obstructed IVC, the needle was removed; 5-10 mL of contrast medium was injected through the catheter to confirm the tip of the catheter successfully passed through the obstruction and located at the other end of the obstructed IVC or the right atrium. IVC venography demonstrating the both ends of the obstructed IVC was then performed to judge the perforation route in the true lumen. If the tip of the catheter was in the true lumen of the IVC, subsequent PTA was performed to restore the diameter of IVC. For the patients with IVC stenosis, PTA was performed after the stenosis has been successfully traversed with a guide wire. After PTA, IVC venography was performed to confirm the IVC patency and to evaluate possible complications. Deployment of a self-expandable metallic stent with a diameter of 25–30 mm and a length of 50–75 mm (Yong-Tong, Shenyang, China) was performed when the IVC was retracted immediately and re-narrowed after PTA. A post-stent deployment venography was performed to document the patency of the IVC.

When IVC venography showed a sign of IVC rupture, but the patient maintained stable vital signs, the patient was observed on the table for 30 min and the procedure was terminated once the patient's clinical stability was observed. When the patient's vital signs became unstable, the balloon was immediately inserted again to tamponade

the wall injury and surgical repair or endovascular graft placement was emergently performed.

Results

An IVC rupture caused by PTA occurred in 5 of 617 patients (0.81%). The data of patients with IVC rupture are shown in Table 1. IVC ruptures occurred at the intra-hepatic IVC in four patients, and these patients did not require additional treatment as their vital signs were stable during and the post-procedure (Figs. 2, 3). One IVC rupture occurred at the supra-hepatic IVC and the patient bled into the pericardium, and this patient received an emergent surgical repair of the pericardium and IVC. This patient underwent a surgical resection of obstructed membranous IVC about 10 years ago, and an initial IVC PTA with gradually increasing balloon size (6 mm, 16 mm, 25 mm) was performed 1 year ago without IVC rupture. Although patient's postoperative vital signs were stable, the patient died 8 days after the surgery due to respiratory failure with pneumonia.

During the follow-up, the case #1 had a re-occlusion of IVC in 4 months after the procedure and another PTA was performed using a 25-mm-diameter balloon without IVC rupture. The case #2 had no re-occlusion of IVC for 98 months after the procedure. The case #3 was diagnosed with a new, advanced hepatocellular carcinoma (HCC) in 54 months after the procedure, and the patient died of hepatic failure shortly after, but the IVC was patent. The

Table 1 Characteristics of study subjects

Case	#1	#2	#3	#4	#5
Age and gender	42 F	64 F	38 F	68 M	39 F
Symptoms	VT, AP, H, S, P	LE	VT, H, P, LE	VT, LE, P	VT, AP, S, LE
Child–pugh grade	A	A	B	A	B
Surgical history	No	No	No	PTA	SOMR + PTA
Membrane thickness (mm)	20	83	11	33	30
Proximal IVC diameter (mm)	13.3 × 21.6	12.8 × 20.3	14.6 × 17.4	16.7 × 21.5	11.0 × 15.2
Distal IVC diameter (mm)	20.8 × 21.5	14.6 × 19.3	12.7 × 18.8	19.6 × 21.3	12.3 × 15.7
Balloon diameter (mm)	30	30	30	30	25
Proximal area ratio	3.13	3.46	3.54	2.51	3.74
Distal area ratio	2.01	3.19	3.77	2.16	3.24
Surgery date	09/01/2007	30/10/2008	19/06/2009	31/03/2016	05/08/2014
Pain during PTBA	No	No	No	Mild	Severe
Rupture site	Right wall at central retrohepatic IVC	Posterior wall at proximal retrohepatic IVC	Right wall at central retrohepatic IVC	Left wall at central retrohepatic IVC	Supra-hepatic IVC + pericardium
Therapy	Conservative treatment	Conservative treatment	Conservative treatment	Conservative treatment	Surgical repair
Status	Alive	Alive	Deceased	Alive	Deceased
Cause of death			HCC		Respiratory failure
Patency or restenosis	Restenosis	Patency	Patency	Patency	–
Follow-up time (month)	120	98	63	9	–

All cases had primary classifications; *PTA* percutaneous transluminal balloon angioplasty, *IVC* inferior vena cava, *VT* varices in thorax, abdomen and legs, *AP* abdominal pain and distention, *A* ascites, *H* hepatomegaly, *S* splenomegaly, *LE* lower extremity edema, *P* pigmentation, *SOMR* surgical obstructed membranous resection; proximal area ratio refers to the area ratio of proximal IVC area to used balloon catheter area; distal area ratio refers to the area ratio of distal IVC area to used balloon catheter area
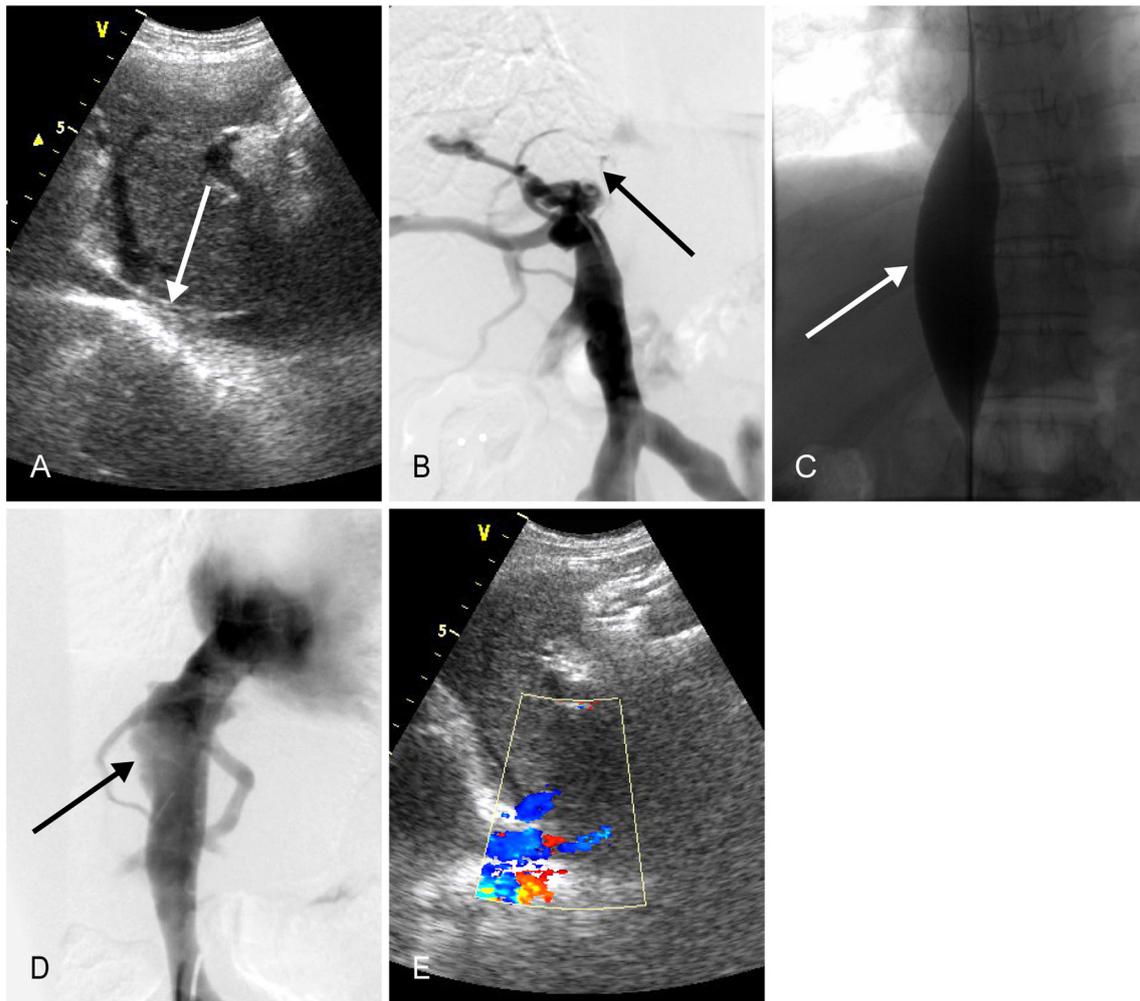
Fig. 2 Case one: A 42-year-old female with membranous obstruction of the inferior vena cava (MOVC). (**A**) Preoperative Doppler ultrasound showing MOVC (white arrow). (**B**) An inferior vena cavogram revealing MOVC (black arrow). (**C**) Dilation of the IVC with a 30-mm-diameter balloon catheter (white arrow). (**D**) An inferior vena cavogram after percutaneous transluminal balloon angioplasty (PTA) showing patency of the IVC with a less distinct right wall at the central retrohepatic region (black arrow), but no contrast extravasation into the abdominal cavity. No additional treatment was performed as the patient's vital signs were stable, (**E**) Doppler ultrasound 3 days after the procedure revealing patency of the IVC without pseudoaneurysm around the IVC

case #4 received a surgical resection of a 25 mm HCC in the right lobe 2 weeks post-PTA. The IVC was patent without a re-occlusion for 9 months after surgery.

Discussion

An IVC rupture caused by PTA during the treatment of BCS is very rare. However, it could become a major complication such as a hemorrhage and could lead to death of patients. In our patient cohort of 617 patients, we report the largest collection of five cases with an IVC rupture rate of 0.8%. In the English literature, only two cases of IVC rupture have been briefly mentioned without detailed description [9, 10]. Han et al. [9] reported one patient with an IVC rupture who was successfully managed with surgical repair among 177 patients with BCS treatment. The other report by Huang et al. [10] showed one case which was successfully treated with stent graft placement at the rupture site among 265 BCS patients. In the non-English literature, additional five cases of IVC rupture were found but without detailed description. Zu et al. [11] reported three cases which were successfully treated with stent graft placement among 1859 patients. Zhou et al. [12] reported one case who was successfully treated with surgical repair among 500 patients. Lastly, Song et al. [13] reported one case which was successfully treated with surgical repair among 42 patients. Unfortunately, the cause analysis or detail description of these IVC rupture cases was not reported in any of these studies.

At the site of IVC obstruction in BCS patients, the basic venous wall anatomical structures appeared maintained.
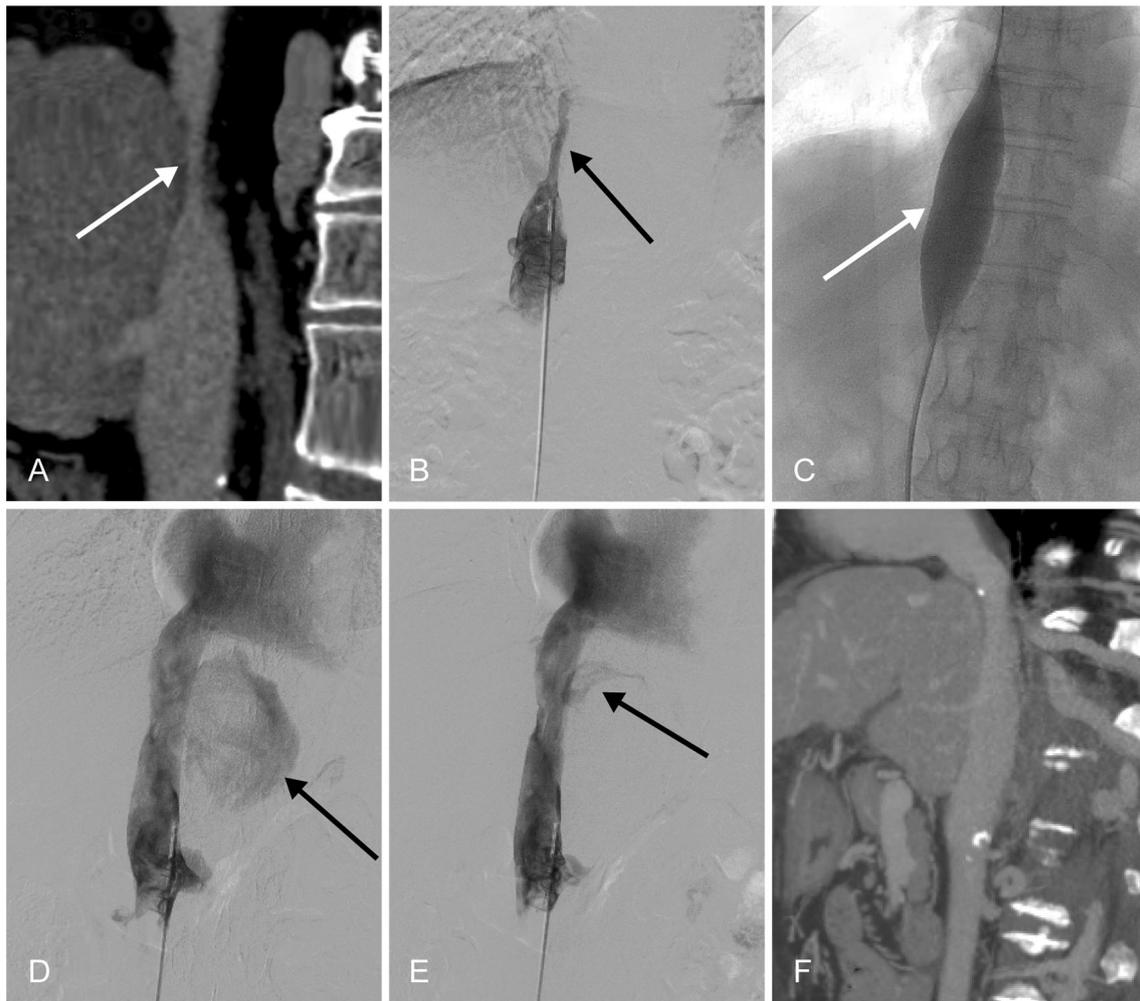
Fig. 3 Case four: A 68-year-old male with segmental obstruction of the IVC (SOVC). (**A**) Multiplanar reconstruction sagittal CT image through the IVC showing SOVC (white arrow). (**B**) An inferior vena cavogram revealing SOVC (black arrow). (**C**) Dilation of the IVC with a 30-mm-diameter balloon catheter (white arrow). (**D**) Inferior vena cavogram immediately after PTA showing IVC disruption and a contained rupture in the left wall (black arrow). (**E**) An inferior vena cavogram 30 min after PTA showing patency of IVC and less contrast extravasation (black arrow). (**F**) Multiplanar reconstruction sagittal CT image through the IVC 5 days after the procedure showing patency of IVC and no pseudoaneurysm around the IVC

However, in histological analysis, it usually showed, up to 4–5 mm, thickening with collagen fibrins and elastic fibers adhering to surrounding tissue. Therefore, the intima transformed into a fibrous laminar structure, with the appearance of organized thrombi of varying ages [14, 15]. No English literature describes this pathophysiology of BCS IVC wall thickening. However, in the non-English literature [16, 17], it was reported that the wall of IVCs in BCS patients is firmer and thicker than non-BCS IVCs, and the severe adhesions to surrounding tissue make surgical repair extremely difficult. In addition, due to the elasticity of IVCs in BCS patients, performing PTA using a smaller balloon ($\leq$ 20 mm) showed a higher rate of re-occlusion or recoiling compared to a larger balloon (> 20 mm) [18]. Therefore, a large diameter balloon ($\geq$ 25 mm) was recommended to maximize the dilation of the obstructed IVC

wall with surrounding adhesive tissue and to decrease the rate of the re-occlusion. Excellent cumulative primary patency rates have been reported using a large balloon ($\geq$ 25 mm) PTA of IVC obstruction [8–10, 19, 20].

In the early era of the endovascular treatment of BCS patients, IVC PTA was performed using a small diameter balloon ($\leq$ 20 mm). However, due to aforementioned reasons, currently, it is widely accepted to perform IVC PTA using a large diameter balloon ($\geq$ 25 mm) and was recommended by the Chinese Society of Interventional Radiology [21]. In this report, we demonstrated the largest cohort of patients treated with large diameter balloons; 98% of our IVC PTA performed with a balloon diameter $\geq$ 25–30-mm. However, this may indirectly support one of the reasons for the IVC ruptures in our study.

With the endovascular treatment of IVC occlusion in BCS patients, two potential causes of IVC rupture can be considered. The IVC rupture Type I is an IVC rupture through a branch vein of the IVC. This type of rupture was usually located at distal end of intra-hepatic IVC because small branches of IVC were commonly found at this site and these are at a risk of rupture with large balloon angioplasty. This type of IVC rupture can be severe and can result in intraperitoneal bleeding because this area is not surrounded by Glisson's capsule. Therefore, this may require an emergent surgical repair or stent graft deployment to prevent serious complications or possibly death. The IVC rupture Type II is an IVC rupture caused by using a large PTA balloon creating a pseudoaneurysm. This type of rupture was also usually located at the intra-hepatic IVC but more mid- to proximal end of the intra-hepatic IVC. The diameter of the supra-hepatic IVC with inflow from the main hepatic veins is normally bigger than that of the intra-hepatic IVC. Therefore, the supra-hepatic IVC can be more resilient for PTA ballooning than the intra-hepatic IVC. The Type II rupture rarely causes severe complications. It may have an irregular contour and localized bulging of the IVC without becoming an exsanguinating intraperitoneal bleeding because the perforation site is surrounded by Glisson's capsule. Therefore, Type II IVC rupture usually does not require any treatment and conservative management is sufficient as observed in our study and others. Using a small diameter balloon is a double-edged sword, as it can avoid Type II IVC rupture but with the down side of re-occlusion of IVC after the procedure in the meantime. Besides, it is difficult to determine which patient will require a small balloon to forecast IVC rupture.

This study has two major limitations including its small sample size and retrospective study design. Due to the rarity of IVC rupture during the treatment of BCS patients, we were only able to capture a small number of samples. This small sample size also led to non-conclusive clinical outcomes of these patients. The study design is a retrospective study with no randomization, and therefore, several known biases of retrospective study can be introduced. Future studies may benefit from a multicentered, larger sampled study.

In conclusion, an IVC rupture caused by PTA is a very rare complication in treatment of BCS patients with IVC occlusion or stenosis. Although this complication is rare, it could be fatal and may be related to using an oversized PTA balloon. In most cases, IVC ruptures occurred at the intra-hepatic IVC with no significant sequelae of rupture, and therefore, no additional treatment is required.

Compliance with Ethical Standards

Conflict of interest The authors declare that they have no conflict of interest.

Ethical Approval For this type of study, formal consent is not required.

Informed Consent For this type of study, consent for publication is not required.

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