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TECHNICAL NOTE

Sharp Central Venous Recanalization in Hemodialysis Patients: A Single-Institution Experience

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Abstract
Purpose We report our institutional experience with sharp central venous recanalization in chronic hemodialysis patients who failed standard techniques.
Materials and Methods Since January 2014, a series of seven consecutive patients (four males and three females), mean age 35 years (18–65 years), underwent sharp central venous recanalization. Indications included obtaining hemodialysis access ($n = 6$) and restoration of superior vena cava (SVC) patency to alleviate occlusion symptoms and restore fistula function ($n = 1$). The transseptal needle was used for sharp recanalization in six patients, while it could not be introduced in one patient due to total occlusion of the inferior vena cava. Instead, transmediastinal SVC access using Chiba needle was obtained.
Results Technical success was achieved in all cases. SVC recanalization achieved symptoms' relief and restored fistula function in the symptomatic patient. One patient underwent arteriovenous fistula creation on the recanalized side 3 months after the procedure. The remaining catheters were functional at median follow-up time of 9 months (1–14 months). Two major complications occurred including a right hemothorax and a small hemopericardium, which were managed by covered stent placement across the perforated SVC.
Conclusion Sharp central venous recanalization using the transseptal needle is feasible technique in patients who failed standard recanalization procedures. The potential high risk of complications necessitates thorough awareness of anatomy and proper technical preparedness.

Keywords Sharp central venous recanalization · Hemodialysis · Chronic occlusion

Introduction

The use of central venous catheters in the medical community is increasing with parallel increase in central venous complications such as thrombosis, stenosis and occlusion [1–3]. Of particular interest are hemodialysis patients who require long-term access and gradually exhaust their access points due to central venous occlusion [2, 3]. Patients with central venous occlusion often require alternative dialysis access via transfemoral, translumbar or transhepatic veins. This can be quality of life limiting, poorly tolerated and easily infected. Furthermore, occlusion of the iliac veins or inferior vena cava (IVC) complicates the surgical techniques of renal transplantation or may even preclude it [4, 5]. Therefore, repeated endovascular interventions are often required to maintain central venous patency and secure appropriate hemodialysis access. However, chronic central venous occlusion can be sometimes resistant to recanalization using standard techniques and may require either surgical reconstruction [6–9] or advanced endovascular procedures [10–23]. Different sharp central venous recanalization techniques have been described in previous literature with limited number of cases [10–23]. We report our institutional experience in the

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safety and effectiveness of this advanced technique in patients who failed standard recanalization procedures.

Materials and Methods

The institutional ethics and research committee approved this retrospective study, and informed consent was waived.

Patients' Characteristics

Since January 2014, a series of seven consecutive patients (four males and three females), mean age 35 years (18–65), underwent sharp central venous recanalization. Indications included obtaining hemodialysis access ($n = 6$) and restoration of superior vena cava (SVC) patency to alleviate occlusion symptoms and restore fistula function ($n = 1$, Table 1). All patients had failed at least one attempt of central venous recanalization and were undergoing dialysis through transfemoral catheter ($n = 4$) and transhepatic ($n = 2$) and temporary dialysis line due to poorly functioning fistula ($n = 1$). Occlusion characteristics for each patient are displayed in Table 2.

Procedural Protocol and Technique

A CT angiography/venography of the thorax is performed prior to procedure to assess the vascular anatomy. The transseptal needle (BRK™-1, 71 cm; St Jude Medical, MN, USA) was used in six of the seven successful cases. This needle is 18 gauge that accepts 0.018″ wire and is provided with a special pre-curved 8.5Fr sheath. The 45° curve at the distal tip of the needle allows steering the needle toward the target vein. Furthermore, the needle shaft is flexible and the curve can be adjusted according to the projected course through the mediastinum (Fig. 1). The procedure consists of right upper arm and femoral venous accesses followed by simultaneous venography to determine the exact length of the occluded segment and pathway in the mediastinum. The run is carried through the arterial phase to outline the course of the great vessels. Considering the anatomical relationship between the right brachiocephalic vein and subclavian artery, it is essential to direct the tip of the needle always anteriorly to avoid arterial injury (Fig. 1). This is achieved by obtaining multiple oblique projections while advancing the needle toward the target 10-mm Amplatz gooseneck snare (ev3, Plymouth, MN, USA) in the BCV. Access may be done under biplanar imaging or cone-beam CT guidance if available. Sharp recanalization using the transseptal needle was performed from the femoral access toward the BCV. This presumably minimizes the risk of bleeding if several punctures are made, since blood flow will be away form the puncture sites as opposed to performing the puncture from the arm access in the direction of blood flow. This would be of greater importance in cases of recanalizing the side of the fistula that tends to have higher venous pressures. Once the occluded segment is successfully crossed, a through-and-through access is gained using V-18™ Control Wire (Boston Scientific, Natick, MA, USA) or Transend® 0.014 (Stryker Neurovascular, Fremont, CA, USA). Sequential balloon dilation is performed using high-pressure balloons with repeated venographic evaluation to assess potential extravasation or arterial communication (Table 1). Covered stent placement was reserved to the cases of perforation or when venous patency is required for fistula function.

In one case, the transseptal needle could not be introduced into the SVC due to chronic total occlusion of the IVC that could not be recanalized. In this case, transmediastinal SVC access was performed using a 22G 15-cm Chiba needle that was inserted through a 4Fr sheath after

Table 1 Patients' demographic data and recanalization techniques

Case	Gender	Age	Recanalized occlusion length (cm)	Side	Tool	Stent	Created access	F/U mon	Complication
1	M	47	2.7	RT	BRK1	12-mm V12/12-mm nitinol	Lt IJV perm cath/Rt AVF	14	–
2	F	27	1.2	RT	BRK1	–	Rt IJV	12	–
3	M	18	2.6	RT	22G Chiba	–	Neck collateral	9	–
4	M	26	1.2	RT	BRK1	12-mm V12	Neck collateral	9	Hemothorax
5	M	23	3.2	RT	BRK1	10-mm V12	Rt SCV	3	–
6	F	65	9	RT	BRK1	–	Rt SCV	1	–
7	F	40	3.3	SVC	BRK1	12-mm V12	Left arm fistula	2	Small hemopericardium and transient hypotension

SCV subclavian vein, *IJV* internal jugular vein, *AVF* arteriovenous fistula

Table 2 Central venous occlusion characteristics

Case	SCV	BCV	SVC		IVC	Hepatic	Iliac	Femoral
			Infra-azygos	Supra-azygos				
1	−	Bil	−	+	−	+	Unilateral	Unilateral
2	−	Bil	−	+	−	−	Unilateral	Unilateral
3	−	Bil	−	+	+	−	Unilateral	Unilateral
4	−	–	−	+	−	−	–	–
5	−	Bil	−	+	−	−	–	–
6	+	Bil	+	+	−	−	–	–
7	−	–	+	−	−	−	–	–

SCV subclavian vein, *BCV* brachiocephalic vein, *IVC* inferior vena cava, *Bil* bilateral

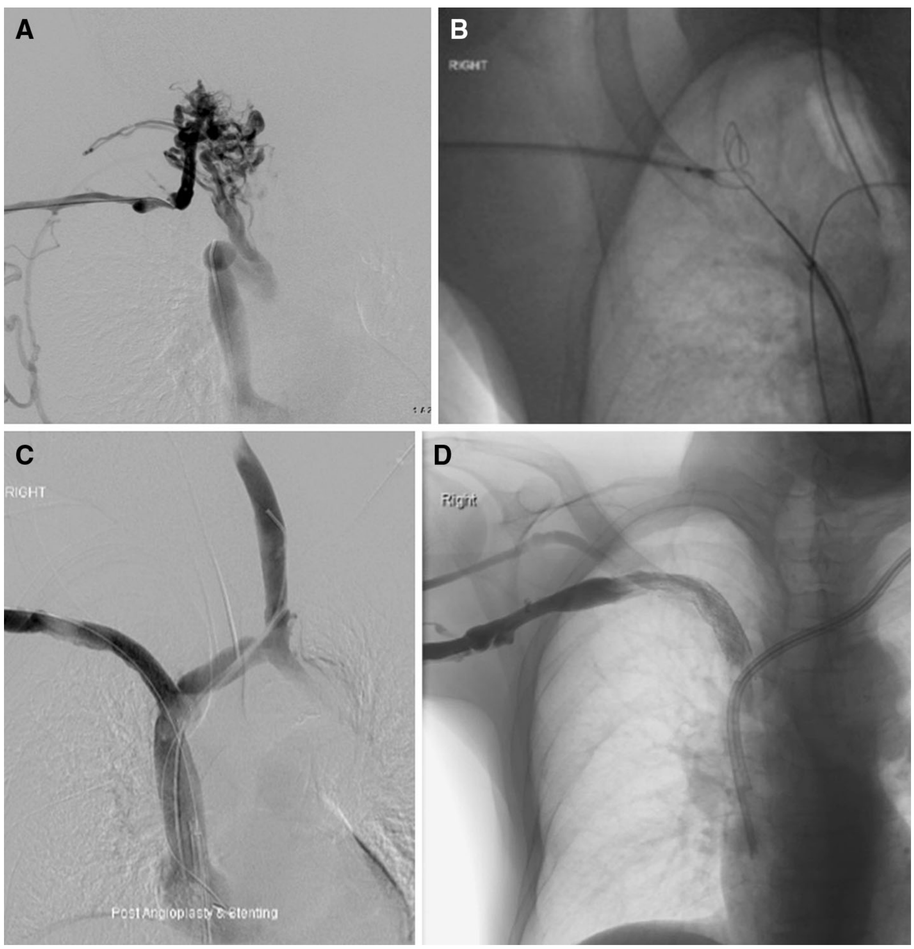

Fig. 1 A 47-year-old man who had chronic central venous occlusion that failed conventional recanalization. The patient remained on transhepatic dialysis catheter for 7 years, which was complicated by hepatic veins occlusion and chronic Budd–Chiari. **A** Right subclavian venography shows a 2.7-cm occluded segment involving the right BCV and SVC with extensive collaterals diverting flow to the SVC through the azygos vein. **B** Left anterior oblique projection shows the transseptal needle oriented anteriorly toward the clavicle and the snare in the right BCV. A 0.018″ V-18 wire (Boston Scientific, Natick, MA) was advanced through the needle into the BCV to gain through-and-through access. **C** Final venography following sharp recanalization and stenting of the right BCV and standard recanalization of the left BCV. **D** Right upper limb venography at 1 month shows patent stents and a dialysis catheter inserted from the left internal jugular access. The patient underwent fistula creation on the right side after 3 months, which remains patent at 14 months following the initial procedure

cannulating a small neck collateral to approach the SVC (Fig. 2). The second case of total SVC occlusion, the infra-azygos segment was crossed using standard techniques, and the sheath could be advanced above the azygos to provide needle access toward the snare in the BCV (Fig. 3). In the symptomatic patient with infra-azygos SVC

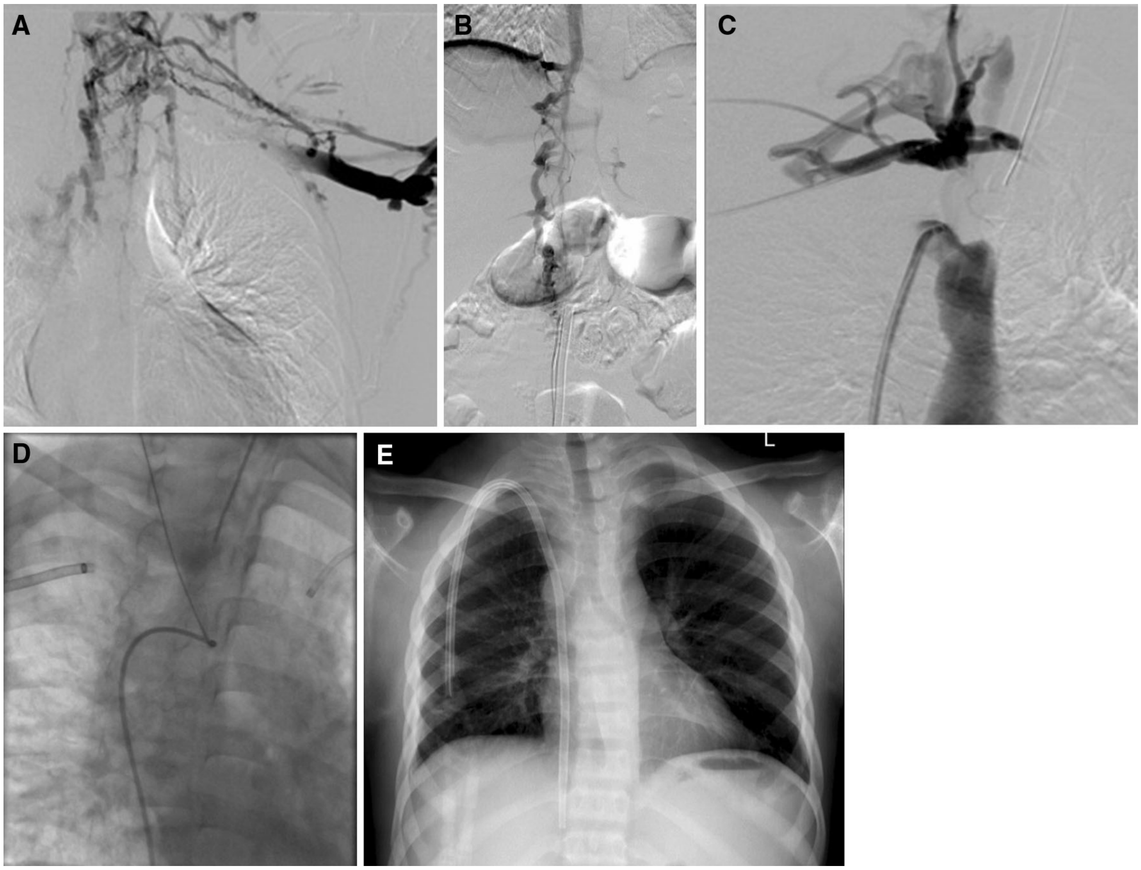

Fig. 2 A 18-year-old man with chronic central venous occlusion presented for exchange of dysfunction of right femoral dialysis catheter. **A** Left upper limb venography shows long segment of occlusion involving the left BCV. **B** Digital subtraction venography through the existing femoral dialysis catheter shows total occlusion of the IVC with prominent lumbar collaterals draining into the azygos vein. The occluded infra-renal IVC could not be crossed from the femoral access, and no retrograde access could be obtained due to the central occlusion. **C** Simultaneous right subclavian and SVC venography shows occlusion of the right brachiocephalic and supra-azygos SVC. Note the tip of the catheter in the azygos injecting contrast toward the SVC. **D** Right anterior oblique projection shows the tip of the 22G Chiba needle that was introduced from a neck collateral toward the tip of the catheter that was advanced through the azygos into the SVC. The tract was dilated up to 3 mm to allow passage of the peel-away sheath. Since the aim of this procedure was to place the dialysis catheter and not to restore patency, neither further dilatation was done nor stent was deployed. **E** Follow-up chest radiograph following placement of the dialysis catheter

occlusion, the transseptal needle was advanced directly from the right atrium into the supra-azygos SVC.

Technical success was defined as successful placement of a dialysis catheter or restoration of venous patency at the conclusion of procedure.

Results

Technical success was achieved in all patients with successful placement of dialysis catheters on the recanalized side in five cases and successful stenting of the occluded segment in the last two cases. Six procedures were performed toward the right BCV and one involved only recanalization of the infra-azygos SVC. The mean recanalized segment was 3.3 cm (1.2–9 cm). In two cases, we were able to recanalize the left side using standard techniques during the same session (Fig. 1).

One patient underwent fistula creation on the recanalized side 3 months following the procedure and it remained patent at 14 months. One functional catheter was removed at 2 months prior to renal transplant. The symptomatic patient remained free of symptoms with patent SVC stent and functional fistula at 2-month follow-up fistulogram. The remaining four catheters remained functional at median follow-up time of 9 months.

One procedure was complicated by intraprocedural hemothorax that occurred immediately after the initial balloon dilatation. This was successfully managed by placement a 12 mm $\times$ 59 mm Atrium Advanta V12 balloon-expandable covered stent (MAQUET Holding, Germany; Fig. 4). The patient received intraprocedural fluid

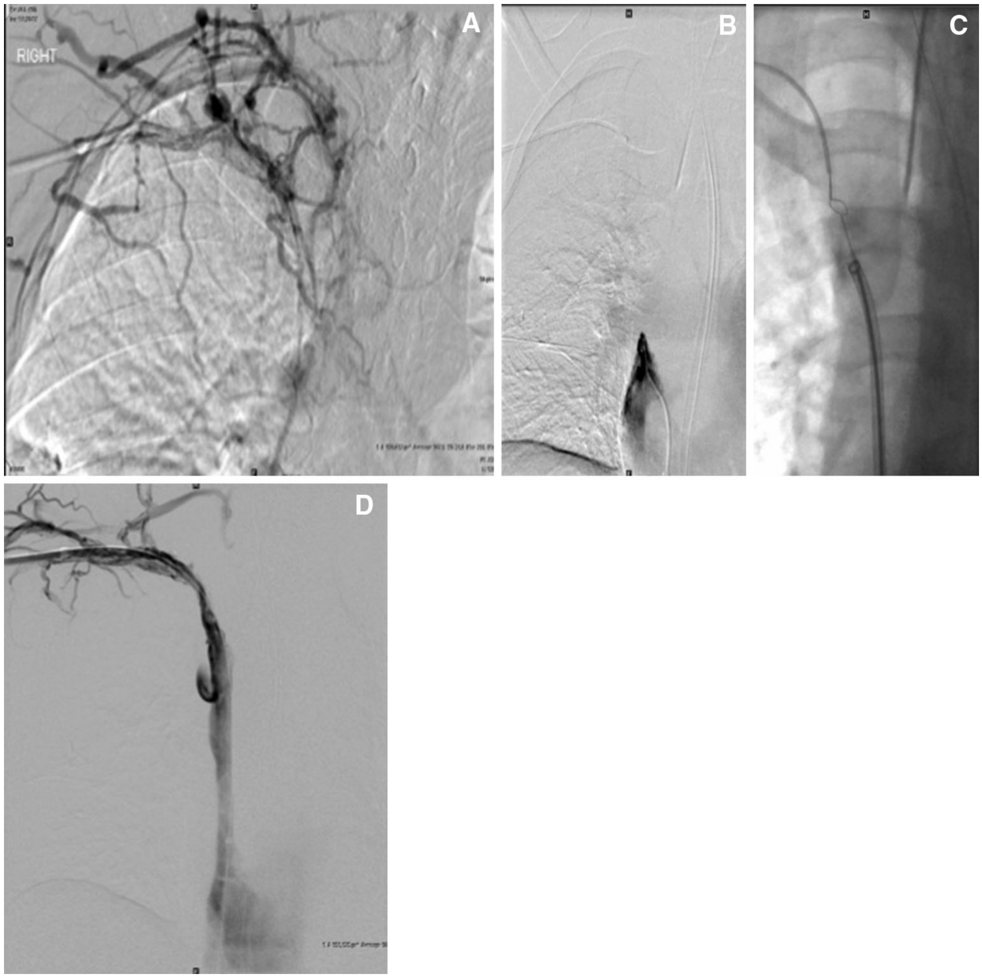

Fig. 3 A 65-year-old woman who has femoral dialysis catheter due to chronic central veins and SVC occlusion. **A** Right axillary venography shows total occlusion of the right subclavian, BCV and SVC with extensive collaterals. **B** Right atrial venography shows occlusion of the SVC at the cavoatrial junction. There was retrograde filling of the azygos following successful conventional recanalization of the infra-azygos SVC (not shown). However, the occlusion could not be crossed into the right BCV using conventional methods. **C** Left anterior oblique projection shows the transseptal needle pointing anteriorly toward the snare in the right BCV. **D** Final venography after balloon dilatation using 12-mm high-pressure balloon

resuscitation. Later, he received blood transfusion and chest tube placement with no further consequences. In this particular case, the patient had heart failure with ejection fraction of 25 %. The elevated central venous pressure may have increased the risk of intraprocedural bleeding. Another SVC perforation occurred in the symptomatic patient with dysfunctional fistula during recanalization of infra-azygos SVC, which resulted in small hemopericardium and transient hypotension immediately after initial balloon dilatation. This was successfully managed by placement of a 12 mm × 38 mm Atrium-covered stent (MAQUET Holding). The patient was observed in intensive care unit for 24 h and discharged home with a functional fistula with resolution of the facial and left upper extremity swelling.

Discussion

Benign central venous occlusion secondary to chronic use of central venous catheters is increasingly encountered in daily practice varying between 7 and 40 % depending on the caliber of the dwelling catheter, site of insertion and duration of catheter placement [2, 3, 24]. Preservation of central venous patency in patients on hemodialysis is of particular importance due to the long-term need for venous access or arteriovenous fistula.

Several endovascular techniques including thrombolysis, percutaneous transluminal angioplasty (PTA), bare and covered metallic stents have played pivotal roles in maintaining venous patency in these patients with variable success rates and long-term outcomes [2]. However, there

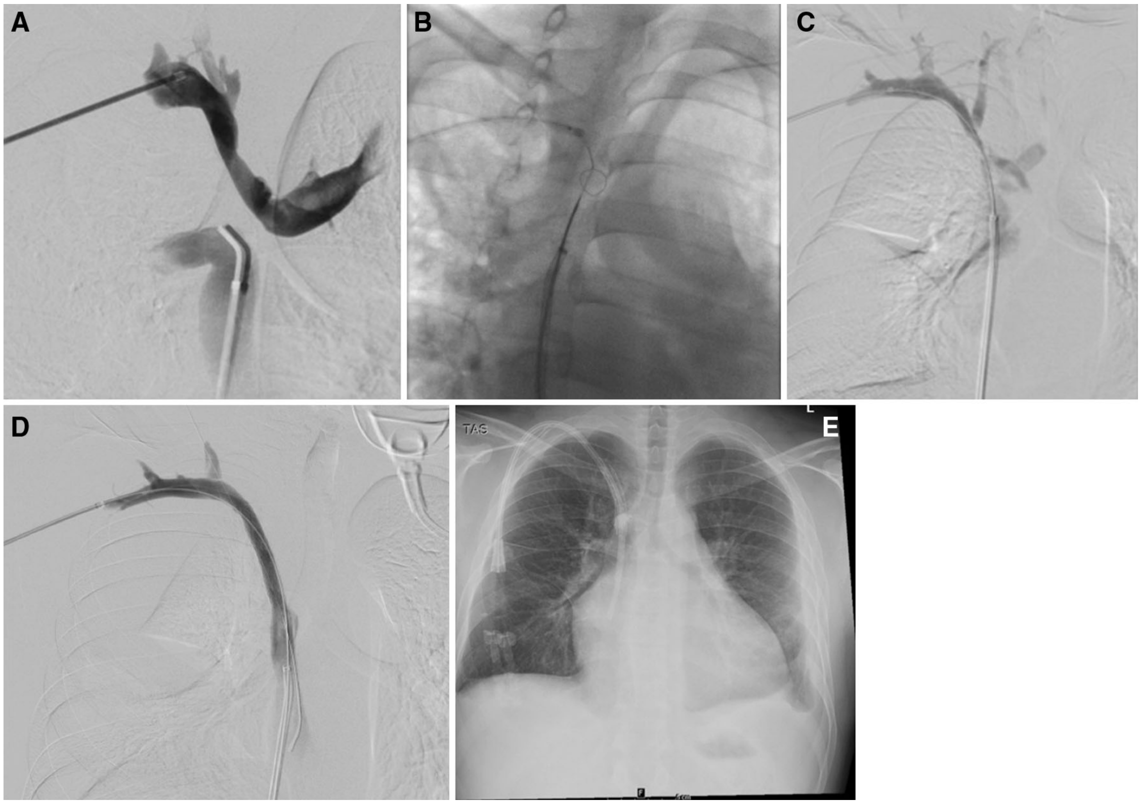

Fig. 4 A 26-year-old man with heart failure and SVC occlusion. **A** Simultaneous right subclavian and SVC venography shows a 1.2 cm occluded segment above the azygos. **B** Right anterior oblique projection shows the transseptal needle targeting the snare in the right BCV. **C** Venography following SVC dilatation using a 12-mm high-pressure balloon shows active extravasation from the recanalized segment with a large right hemothorax. **D** Repeat venography after deployment of a 12 mm × 59 mm Atrium Advanta V12 balloon-expandable covered stent shows no extravasation. **E** Chest radiograph few weeks after the procedure and right chest drainage shows properly positioned dialysis catheter and resolution of the right hemothorax

remain a small percentage of patients who fail all standard recanalization techniques and get traditionally shifted to alternative accesses such as transfemoral, transhepatic or translumbar. Alternatively, these patients may be referred to complex surgical procedures to restore venous access, such as axillary to brachiocephalic or jugular bypass [6], subclavian to atrial appendage bypass [8] or SVC conduits [25]. Recently, sharp recanalization procedures have been reported using different methods and tools to cross the chronically occluded segments. The initial description of sharp recanalization was by Ferral et al. [14] who reported the use of a gooseneck snare or a guidewire as a target to puncture the occluded venous segment and gain access for placement of central venous catheter in six patients. Later, sharp direct recanalization of chronically occluded right subclavian vein was reported using Rösch-Uchida needle (William Cook Europe, Sandet, Denmark) [23, 26] and direct needle puncture [16] targeting a centrally placed balloon. In a series of 33 cases of sharp subclavian and brachiocephalic recanalization using the Rösch-Uchida needle, the success rate was 93.3 % with no major complications [26]. The primary and secondary patency rates at mean follow-up period of 17.3 months were 8 and 56 %, respectively [26]. While successful use of TIPS needle was reported by several previous reports of sharp recanalization [13, 17, 22, 23, 26], we preferred the transseptal needle due to smaller gauge and the ability to adjust the angle of needle according to the transmediastinal course. In addition, we felt that introducing the transseptal needle through transfemoral approach to target a snare in the brachiocephalic vein makes it easier to steer and navigate the needle through the occlusion, as opposed to introducing the needle through arm or subclavian access as described in previous reports [23, 26]. Brountzos et al. [11] reported the use of reentry device to perform recanalization of occluded subclavian veins in a similar fashion to the subintimal recanalization technique. However, the limited range of the reentry needle makes it not suitable for long segments of occlusion such as in our cases [11, 27]. Lately, radiofrequency (RF; PowerWire, Baylis Medical Company Inc, Montreal, QC, Canada) was used in recanalization of central venous occlusions. This wire appears to be of particular value in long segments resistant to standard recanalization techniques in malignant [12] and non-malignant occlusions [15, 18, 28, 29].

Guimaraes et al. [15] reported 100 % success rate in crossing 43 central occlusions (six subclavian, 29 brachiocephalic and eight SVC) ranging between 1.5 and 10 cm. They reported a single major complication of pericardial tamponade attributed to balloon angioplasty and probably wire perforation. Another study reported successful crossing of 9 out of 12 long occlusions with mean of 29.8 ± 29.3 mm [28]. However, there was one death as a result of tracheal perforation by the RF wire.

Regardless of the sharp recanalization technique, operators should have thorough understanding of the patient's vascular anatomy prior to crossing the occluded segment to avoid major complications. Normally, the pericardial sac encases the cavoatrial junction and SVC below the azygos. Therefore, recanalizing the infra-azygos SVC increases the likelihood of pericardial tamponade [19]. In our series, we used the azygos–SVC junction as a landmark to stratify patients and anticipate the level potential complications.

Athreya et al. [10] reported one case of upper mediastinal extravasation at the central brachiocephalic which was managed by stent graft. Also, injury of the azygos vein after recanalization may result in hemothorax [19]. The two complications encountered in our series occurred immediately following balloon dilatation not after crossing the occlusion and establishing a through-and-through access. Both perforations were successfully managed by placement of a covered stent.

Our study is inherently limited by its retrospective nature and small sample size. However, it supports the existing evidence of the feasibility of sharp recanalization techniques in restoring venous access in patients on chronic hemodialysis. The potential high risk of complications necessitates thorough awareness of anatomy and proper technical preparedness.

Compliance with Ethical Standards

Conflict of interest Drs. Mohammad Arabi, Ishtiaq Ahmed, Abdulaziz Al-Mat'hami, Dildar Ahmed and Naveed Aslam have nothing to disclose.

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