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Original research article

JVA The Journal of Vascular Access

The Journal of Vascular Access
1–8
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DOI: 10.1177/11297298261435742
journals.sagepub.com/home/jva
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Management of hemodialysis catheter-induced cavoatrial junction lesion by VBX stent-graft

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Abstract

Background: Hemodialysis catheter-induced cavoatrial junction (CAJ) stenosis or occlusion is a potentially severe condition. It not only leads to severe symptoms of superior vena cava (SVC) syndrome but also limits the establishment of vascular access in the upper extremities of hemodialysis patients. Endovascular therapy is the first-line treatment but has a high restenosis rate and potential fatal risks such as SVC rupture, cardiac tamponade, and stent malposition or migration during the procedure. Few studies focusing on CAJ management have been reported.

Objective: We evaluated the technical and clinical outcomes of Viabahn VBX stent grafts used for reconstructing the CAJ lesion in hemodialysis patients with SVC syndrome.

Methods: We retrospectively analyzed 12 patients with catheter-induced CAJ lesions who were treated with VBX stent grafts. Demographic data, clinical signs and symptoms, technical details, and clinical outcomes were recorded.

Results: The study included 8 females and 4 males, with a mean age of 48.3 ± 12.3 years (age range: 28–62 years). High-grade stenosis of the CAJ was detected in five cases, while occlusion was observed in seven cases, and among them, one case had an indwelling tunneled central catheter (TCC). The technical success rate was 100%, without any complications. After stent deployment, symptoms were alleviated in all cases. During the follow-up period (mean follow-up time of 18.9 ± 6.0 months), the primary patency rate of the target lesion at the CAJ reached 100%.

Conclusions: Using a VBX stent-graft is a safe and effective method to treat CAJ lesion avoiding major fatal complication.

Keywords

Dialysis access, central venous stenosis, balloon expandable stent, superior vena cava syndrome, cavoatrial junction

Date received: 28 December 2025; accepted: 8 March 2026

Central venous stenosis or obstruction (CVD) remains a challenge among hemodialysis patients. The hemodialysis catheter is the main cause of CVD, and the incidence of CVD associated with central venous catheters (CVCs) is estimated to be as high as 20%–40%.[1–3] Multiple catheter placements, longer durations, placement in the subclavian vein, and placement on the left side appear to increase the predisposition to the development of CVD.[4] The pathophysiology of CVD is mainly attributed to direct vessel wall injury caused by CVCs, which triggers an inflammatory response, thrombus formation, and fibrin accumulation, ultimately leading to stenosis formation.[5]

Cavoatrial junction (CAJ) stenosis or occlusion is one of the common sites affected because of the location of the tip of the hemodialysis tunneled cuffed catheter (TCC). Compared with central venous lesions at other sites, CAJ lesions impact all the venous return of the head, neck, chest, and both upper extremities. This restricts the options for subsequent upper extremity vascular access and can result in superior vena cava (SVC) syndrome. Severe

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symptoms are especially likely to occur when there is a high-flow arteriovenous fistula and the collateral circulation cannot compensate. In addition to swelling of the face, neck, chest, and arms, oropharyngeal dysphagia may cause dyspnea, stridor, cough, or dysphagia. Cerebral edema may lead to headache, confusion, and, in the most severe cases, death due to cerebral herniation. Rarely, proximal esophageal varices may be observed and cause gastrointestinal bleeding.[6,7]

Endovascular therapy with percutaneous transluminal angioplasty (PTA) is the first-line to treat CVD but has a high rates of restenosis which need reintervention.[8] Stenting is only indicated in cases of elastic central vein stenosis or recurrent stenosis within 3 months[9] because it didn't improve the patency compared to PTA and had disadvantages of intrastent neointimal hyperplasia, stent migration, and stent fractures.[10] Although covered stents have improved patency, a lower risk of restenosis, and fewer reinterventions,[11] but they are limited by its disadvantage of covering another major reflux vein.

Compared to other central venous lesions, endovascular management of CAJ lesion has a higher fatal risk of SVC rupture, malignant arrhythmia, cardiac tamponade, hemopericardium, hemothorax due to the sharp recanalization or large size balloon dilation, and stent malposition, migration which might lead to the life-threatening sequelae, which include cardiac conduction abnormalities, valvular damage, endocarditis, cardiac tamponade, and cardiac perforation.[12–15] Therefore, extreme caution must be applied while planning an endovascular treatment of the CAJ and it is necessary to explore a safe and effective endovascular therapy that can not only ensure a good patency rate but also avoid fatal complications. There are few reports in the literature focusing on CAJ management. In this study, we retrospectively present our experience regarding the technical and clinical outcomes of Viabahn VBX stent grafts (W.L. Gore & Associates, Flagstaff, AZ, USA) for reconstructing CAJ lesions. These are balloon-expandable graft stents that can be precisely deployed, have the capacity to variably expand the stent diameter to better conform to the vessel wall, form a funnel shape through post-dilation, reduce the risk of stent migration, eliminate concerns about vessel rupture, and potentially have a better patency rate.

Material and methods

Patients

A retrospective analysis of the clinical characteristics, endovascular procedures, complications, and outcomes was performed for twelve patients with catheter-induced CAJ lesions who were treated with VBX stent grafts from 25 October 2022 to 9 September 2024. All CAJ high-grade stenosis or occlusion lesions accompanied by the opening of the azygos vein were confirmed by digital subtraction angiography (DSA). Written informed consent was obtained from all patients, and the procedures adhered to the Declaration of Helsinki and its subsequent revisions. The research was approved by the Institutional Review Board (2026LCSY035).

Endovascular procedure

The CAJ lesions were verified by venography. Under local anesthesia, the common femoral vein, designated as the main access for introducing the balloon and stents, was accessed under sonographic guidance, and an 8Fr vascular access sheath was inserted. Another access, such as fistula access or jugular vein access, was also established to introduce the working guidewire, perform the crossing step, and carry out the post-dilate procedure.

In patients with an indwelling TCC, a 0.035" guidewire (Terumo, Japan) was inserted through the TCC across the CAJ lesion into the right atrium. Subsequently, the TCC was withdrawn, and an 8Fr sheath was introduced, with the tip of the guidewire confirmed to be in the right atrium.

In other cases, with the aid of an MPA (Multipurpose A, Cordis, USA) or vertebral catheter, the guidewire traversed the lesion via the dialysis access under fluoroscopic guidance. In some occlusion lesions, sharp recanalization was achieved using the back end of the glide wire, needle recanalization, etc. The wire advanced through the inferior vena cava to the iliac vein. With the assistance of the MPA catheter, the wire passed into the 8 Fr femoral sheath and was then pulled out of the femoral sheath. The other end of the wire was retained to establish a through-and-through circuit.

In occlusion cases, the lesion was predilated with a 6–8 mm high-pressure balloon (Mustang, Boston Scientific, Boston, MA, USA). Venography was performed to assess the effect and detect complications such as bleeding during predilation. Subsequently, in all cases, an 11 mm × 59 mm VBX Balloon Expandable Endoprosthesis (VBX, WL Gore, Flagstaff, AZ, USA) was implanted, with two-thirds of the stent positioned above the CAJ. A 14–16 mm balloon (Atlas, BD Peripheral Vascular, USA) was inserted through either the dialysis access or the jugular access to post-dilate the upper part of the stent to a diameter of 14–16 mm (depending on the diameter of the SVC). Simultaneously, a 12–14 mm balloon (Atlas, BD Peripheral Vascular, USA) was used to dilate the other side of the stent via the femoral access, firmly holding the stent to prevent its migration during the dilation process. Alternatively, another guidewire with a balloon was advanced through the femoral approach (Figure 1). The stent was reshaped into a funnel shape through post-dilation (Figure 2). Venography was performed again to

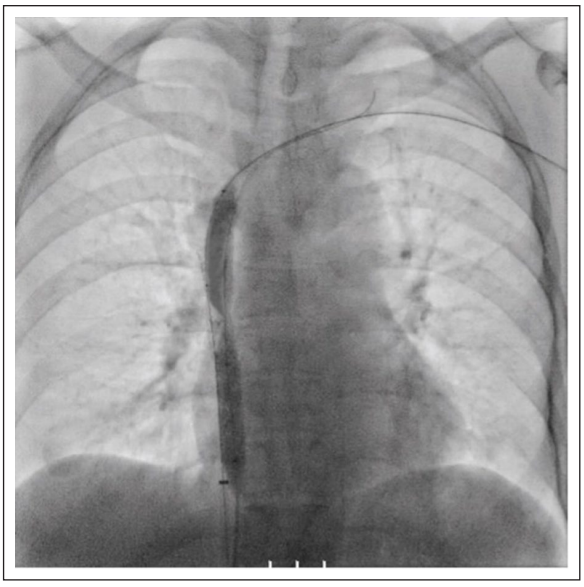


Figure 1. The proximal segment of the stent was post-dilated to a diameter of 14 mm. Simultaneously, a 12 mm balloon, introduced via femoral access, was inflated at the distal end of the stent to provide counter-traction and prevent stent migration.

confirm successful recanalization without complications such as bleeding or stent migration. All patients were administered 2000 U of heparin intravenously prior to PTA and received prophylactic antibiotics.

Statistical analysis and definition

A software package for SPSS version 20.0 was employed for statistical analysis. For data with a normal distribution, continuous variables were presented as means ± standard deviations. The Kaplan–Meier method was utilized for survival curve analysis. Access circuit primary patency (ACPP) was defined as the time interval from stent implantation to reintervention in the access circuit. Target lesion primary patency (TLPP) was defined as the time interval from stent implantation to reintervention in the target lesions.

Results

There were 8 females and 4 males, with a mean age of 48.3 ± .3 years (age range: 28–62 years). All cases were catheter-induced superior vena cava (SVC) syndrome. They had right internal jugular (RIJ) TCC for 1–8 years, and one case was accompanied by catheter infection. There were six cases of left forearm brachio-basilic loop arteriovenous graft (AVG), two cases of left wrist radiocephalic arteriovenous fistula (RCAVF), and one case each of left forearm RCAVF, right wrist RCAVF, and right proximal radio-median cubital arteriovenous fistula (AVF). Only in one case was the RIJ TCC still used without any other arteriovenous (AV) access.

Clinical symptoms included facial edema and chest swelling in all cases. Unilateral extremity swelling with the vascular access was observed in nine cases. In four cases, symptoms of intracranial hypertension, such as dizziness, head heaviness, and blurred vision, were present.

The CAJ lesion was diagnosed by DSA in all cases, accompanied by the opening of the azygos vein. High-grade stenosis was detected in five cases, and occlusion was found in seven cases. All lesions were short segments, with a length range of 1–3 cm.

Besides the CAJ lesions, DSA showed right brachiocephalic vein occlusion with compensatory collaterals in one case (Figure 3(a)), venous anastomotic stenosis in four cases, cephalic arch stenosis in one case, and juxta-anastomosis stenosis of the AVF in one case. Femoral vein occlusion in one case was reopened by PTA for the deployment of an 8 Fr vascular access sheath.

Among the seven CAJ occlusion cases, two were sharply recanalized using the sharp back end of a 0.035" or 0.014" glide wire. The technical success rate reached 100% without any complications, such as stent malposition, migration, bleeding, or cardiac tamponade. In the case of indwelling TCC, an AVG with an early cannulation graft was created, and the TCC was removed after VBX deployment. Symptoms were alleviated in all cases following stent deployment (Figures 3 and 4). During a mean follow-up period of 18.9 ± 6.0 months (range: 10–33 months), no restenosis of the CAJ occurred in any case (Figures 3 and 4). The target lesion patency rate (TLPP) of the CAJ was 100%. Concomitant lesions were treated in six cases. In one case, thrombosis of the AVG occurred due to dissection of the early cannulation graft, and a new AVG was established. The assisted cumulative patency probability (ACPP) at 6 and 12 months was 81.8% and 54.5% respectively (Figure 5). Table 1 details the treatment and outcomes of each patient.

Discussion

CAJ lesions affect the venous return of the upper body, including the intracranial veins. This not only leads to severe symptoms of SVC syndrome but also restricts the establishment of the dialysis access in the upper body of hemodialysis patients. Endovascular therapy, which involves PTA either alone or in combination with a stent, serves as the first-line treatment for CVD. This approach is less invasive than surgical bypass and is associated with lower perioperative mortality but still need reinterventions.[8,9,16] Compared to other central venous lesions, endovascular procedure of CAJ lesion has a higher fatal risk. It is necessary to explore effective and safe treatment

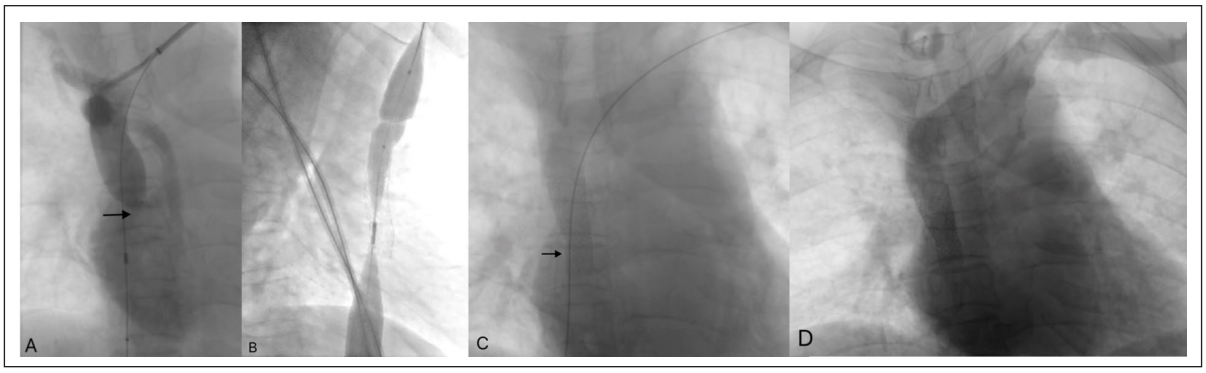


Figure 2. A 43-year-old female. (a) Venography showed occlusion of CAJ (↑) with azygos collaterals. (b) Post-dilation of the VBX stent using balloon angioplasty. (c) The stent was remodeled as funnel-shape by post-dilation. (d) Follow-up venography at 26 months post-implantation confirmed stent patency without evidence of edge stenosis.

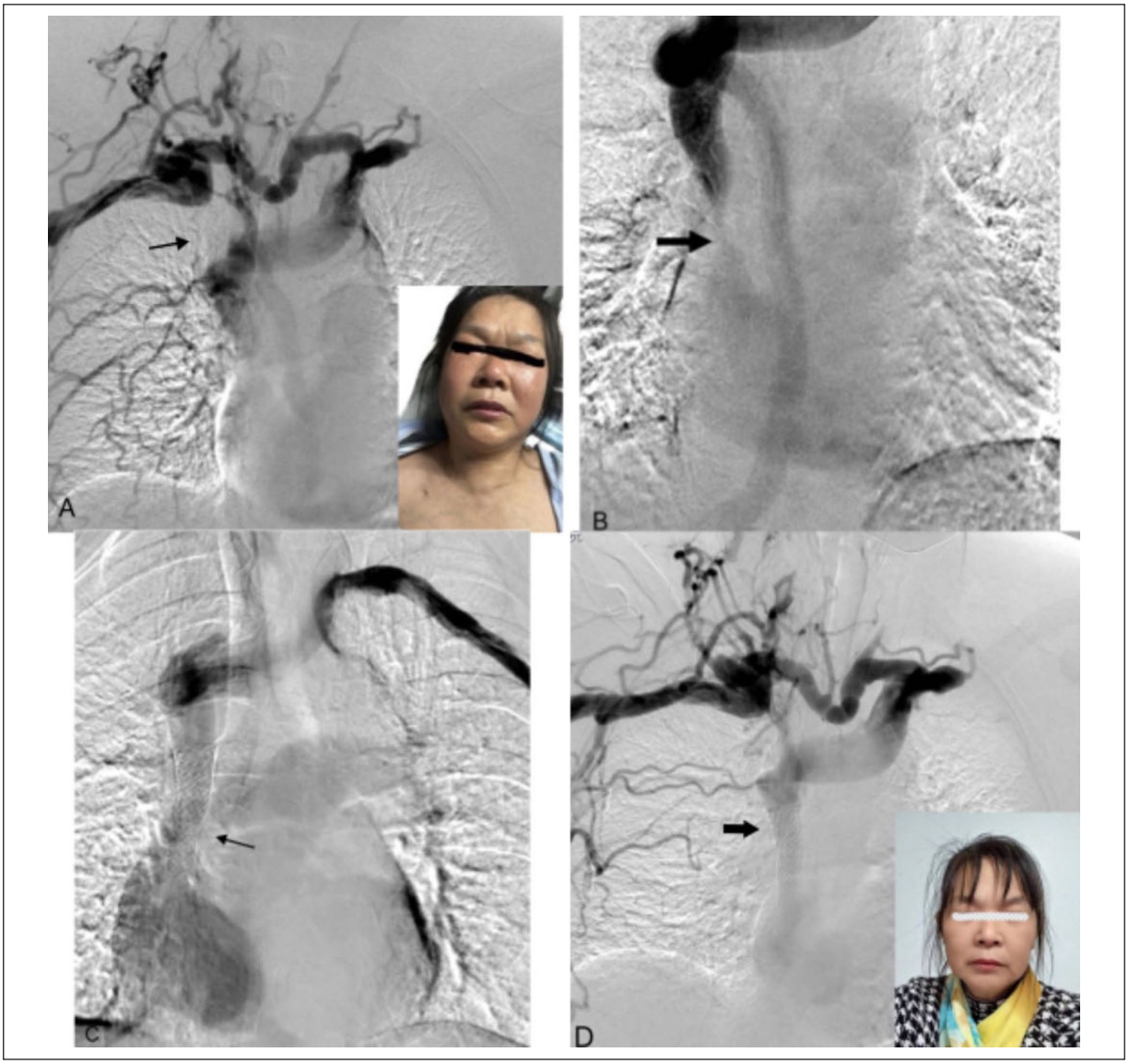


Figure 3. A 54-year-old female. (a) Venography showed occlusion of right brachiocephalic vein (↑) and severe stenosis of CAJ. The symptoms included facial edema and chest swelling with collaterals pre-operation. (b) 90% stenosis of CAJ (↑) with azygos collateral. (c) VBX stent implantation (↑). (d) Follow-up at 19-month post-operation, stent was still patent without restenosis (↑) and symptoms relieved without recurrence.

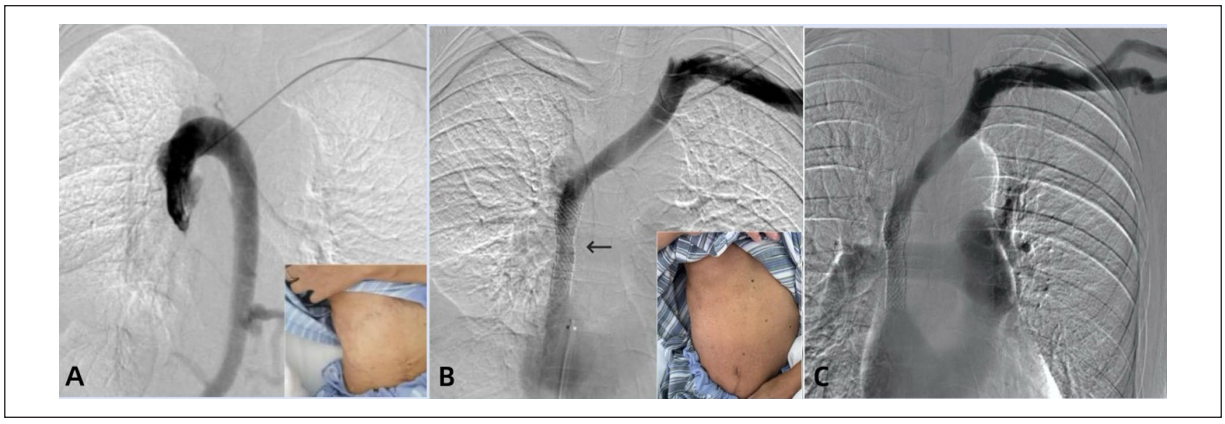


Figure 4. A 50-year-old female with left arteriovenous graft. (a) Venography showed occlusion of the CAJ and numerous collateral branches on the abdominal wall. (b) VBX stent implantation (↑) was performed, and the abdominal collaterals disappeared. (c) During the 10-month follow-up after the operation, the stent remained patent without restenosis.

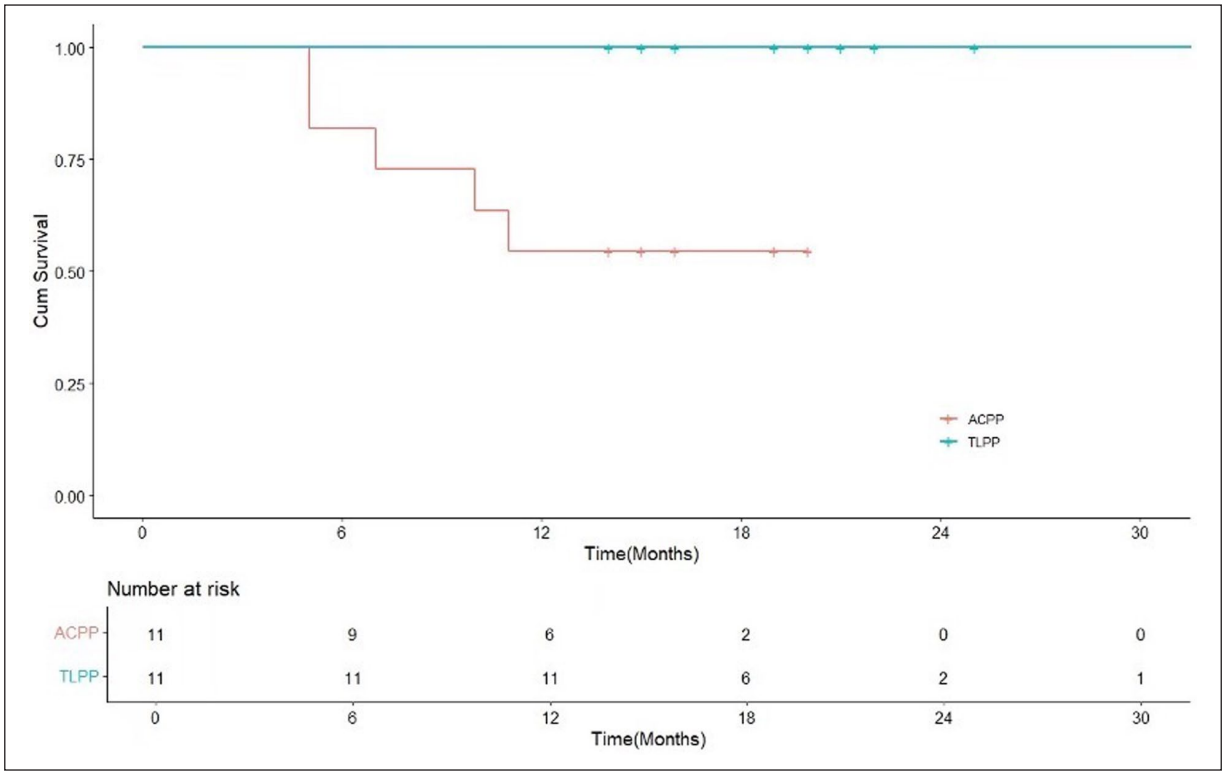


Figure 5. Kaplan–Meier curve of TLPP of CAJ and ACPP.

methods to increase the primary patency time, reduce the number of re-interventions, and avoid the occurrence of life-threatening complications during each intervention. To our knowledge, the literature contains few reports that focus on CAJ management.

In the present study, we chose the balloon expandable graft stent (Viabahn VBX stent grafts) to reconstruct CAJ lesion. The reasons for our selection of VBX stent grafts included achieving a higher primary patency rate, reducing the rupture-related risk and the need for bailout procedures, enabling precise deployment during continuous heart contractions to avoid stent malposition and migration, and having the ability to perform post-dilation to prevent late stent migration. Although the sample was only 12 cases, but the results were encouraging. During the follow-up period, which ranged from 10 to 33 months (mean follow-up time: 18.9 ± 6.0 months), 100% of target lesion primary patency (TLPP) was achieved, which was higher

Table 1. Details of patient characteristics and outcomes following intervention.

Patient	Age	Sex	Etiology	Dialysis access	CAJ lesion	Other lesion	Follow-up time (months)	CAJ TLPP (months)	ACPP (months)
1	Female	43	4 years RIJ TCC	Left forearm BBAVG	Occlusion	Venous anastomotic stenosis	33	33	5
2	Feamle	35	3 years RIJ TCC	Left forearm BBAVG	80% stenosis	No	25	25	11
3	Female	55	1 year RIJ NTC + TCC	Left wrist RCAVF	Occlusion	Cephalic arch stenosis	22	22	5
4	Male	61	2 years RIJ TCC	Left forearm BBAVG	90% stenosis	Venous anastomotic stenosis	21	21	7
5	Male	61	5 years RIJ TCC	Right TCC, and left AVG creation after recanalization of SVC	Occlusion	Right BCV stenosis	20	20	20
6	Female	54	8 years RIJ TCC	Right elbow proximal radial-median cubital AVF	90% stenosis	Right BCV occlusion with compensated collaterals	19	19	19
7	Male	57	3 years RIJ TCC	Right wrist RCAVF	Occlusion	No	16	16	16
8	Female	44	2 years RIJ TCC	Left forearm BBAVG	80% stenosis	Venous anastomotic stenosis	16	16	10
9	Female	28	3 years RIJ TCC	Left forearm BBAVG	90% stenosis	No	16	16	16
10	Female	29	4 years RIJ TCC	Left wrist RCAVF	Occlusion	AVF stenosis	15	15	15
11	Male	62	2 years RIJ TCC	Left forearm RCAVF	Occlusion	No	14	14	14
12	Female	50	5 years RIJ TCC	Left forearm BBAVG	Occlusion	Venous anastomotic stenosis	10	10	6

CAJ: cavoatrial junction; RIJ: right internal jugular vein; BCV: brachiocephalic vein; TLPP: target lesion primary patency; ACPP: access circuit primary patency; BBAVG: brachial artery-basilic vein AVG; RCAVF: radiocephalic AVF.

than most previous reports, and there was no restenosis or complications.

During the follow-up, 100% of TLPP was achieved without edge stenosis. The result is higher than most of the previous study with the endovascular therapy. The primary patency of PTA alone was less than 50% and that of bare metal stent (BMS) ranged from 16%–70% at 12 months.[9] Tan et al.[17] reported the highest primary patency of BMS, finding a 94.4% primary patency rate at 12 months in 20 patients using a dedicated nitinol venous stent (Vici, Veniti, Boston Scientific, Marlborough, MA, USA). Covered stents provide mechanical support and a barrier to the surrounding fibrotic recoil of the vein and intimal hyperplasia, thereby enhancing patency. The primary patency ranged from 56% to 88.3% at 12 months.[18–22] Chen et al.[22] reported the highest 1-year TLPP of 88.3% using the Gore Excluder abdominal aortic aneurysm leg endoprosthesis.

Besides achieving high primary patency, another reason for choosing a covered stent is to reduce the rupture-related risk and the need for bailout procedures. When sharp recanalization is used for occlusive lesions, it may lead to bleeding, especially cardiac tamponade. Moreover, superior vena cava (SVC) rupture may occur during large-sized balloon dilation. SVC rupture and cardiac tamponade are associated with up to 1.8% of interventional procedures.[23] Sometimes, these complications can be fatal, and a covered stent may be useful for saving lives. Moreover, covered stents provide a distinct advantage over BMS by enabling direct apposition to and coverage of thrombus at the lesion site.

Preventing stent malposition and migration is also crucial. The stent should be accurately implanted to ensure complete coverage of the lesion, while avoiding extension across the azygos vein or excessive protrusion into the atrium. This can be accomplished using a balloon-expandable stent. The main drawback of balloon-expandable stent grafts is their vulnerability to external compression and subsequent deformation. However, CAJ lesions are less likely to be subjected to external compression. SVC stents are especially prone to migration due to their large size and the diameter changes associated with variations in venous return. They can migrate into the innominate vein, right atrium, right ventricle,[24] and pulmonary artery, with an incidence of 2%–3%.[25] Such migration may result in life-threatening complications. It occurred during the deployment or postoperatively. Pennetta et al.[26] reported two

cases of using VBX for treatment of CAJ lesions. There are similarities between our stent deployment and this report. Stent-graft should be released with approximately 1/3 of the stent inside the atrium and oversizing was not necessary. According to the diameter of the superior vena cava after relieving the stenotic lesion of the CAJ, we post-dilate the upper two-thirds of the stent to 14–16 mm, basically maintaining an equal size to the SVC. The difference lies in that in order to prevent the stent from postoperative migration, we make full use of the variable diameter characteristic of VBX. The stent is post-dilated into a funnel shape. During the post-dilation process, to prevent the stent from shifting, when a 14 or 16 mm balloon is inflated at the upper two-thirds of the stent, another 12 mm balloon was inflated at the other end simultaneously to hold the stent in place. Compared to other balloon-expandable covered stents, the VBX stent is shaped like a funnel, with its upper end expanding to 16 mm in diameter. This larger diameter offers better compatibility with the superior vena cava while also preventing later displacement. As all patients had upper limb arteriovenous fistulas and underwent regular dialysis 2–3 times a week, with heparin used for anticoagulation during each dialysis session, no additional antiplatelet medications or anticoagulants were administered for stent implantation after the operation for these patients.

Limitations: In this study, we only included CAJ lesions complicated with upper extremity arteriovenous fistulas or graft, while CAJ lesions with continuous use of hemodialysis catheters were not included. Therefore, the sample size in this study was small. Larger-scale studies with long-term follow-up outcomes are needed for confirmation. High blood flow is associated with CVS. However, in this study, the blood flow of hemodialysis access was not measured.

In conclusion, using VBX stent-graft is a safe and effective method to treat CAJ lesion. Making full use of the characteristics of this stent can effectively prevent life-threatening complications such as bleeding, stent malposition and migration. Our experience showed a 100% TLPP during the follow-up period (ranging from 10 to 33 months) without any reinterventions. For patients who do not have upper limb arteriovenous fistulas and rely solely on catheters for dialysis, whether antiplatelet or anticoagulant drugs should be used in combination to maintain stent patency remains to be further explored.

Author contributions

Conception and design: YS and DL. Analysis and interpretation: HY, XB, and YS. Data collection: HY and XB. Writing the article: HY and YS. Critical revision of the article: YS and DL. Final approval of the article: YS and DL. Statistical analysis: HY and XB. Obtained funding: Not applicable. Overall responsibility: YS.

Declaration of conflicting interests

The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Funding

The authors received no financial support for the research, authorship, and/or publication of this article.

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