Percutaneous Transluminal Angioplasty of a Dysfunctional Central Vein Caused by a Tunnel-cuffed Catheter

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Research Article

Keywords: percutaneous transluminal angioplasty, central vein stenosis, tunnel-cuffed catheter, hemodialysis access, digital subtraction angiography

Posted Date: September 8th, 2022

DOI: https://doi.org/10.21203/rs.3.rs-2021041/v1

Abstract

Background: For patients without arteriovenous fistula and with dysfunctional central veins caused by long indwelling tunnel-cuffed catheter (TCC), no consensus on how to achieve functional hemodialysis access has been reached. This study investigated the value of percutaneous transluminal angioplasty (PTA) of a dysfunctional central vein caused by a TCC under digital subtraction angiography (DSA) guidance.

Methods: In total, thirteen patients with indwellingTCC-related complications were admitted to our institution. The TCC indwelling duration was 35.2 months (range, 6 to 70 months). The failed TCCs were removed under the support of a stiff guide wire,and an angiogram showed central vein stenosis (CVS) or occlusion. PTA was performed to recanalize the central vein, and new TCCs were placed *in situ* or in another central vein under DSA guidance.

Results: TCCs were successfully removed in twelve patients. TCC removal failed in one patient due to severe adhesion of the TCC and the left innominate vein 4 years after implantation. PTA of central veins, including the right internal jugular vein, innominate vein, superior vena cava, and right iliac vein, was performed, and new TCCs were successfully placed in all patients. No stents were implanted in any patients. The mean follow-up was 12.9 months (range, 3 to 36 months). The new TCCs functioned well in all patients.

Conclusions: Under DSA guidance, recanalization of TCC-related CVS or occlusion by PTA and implantation of anew TCC catheter *in situ*or another central vein can establish dialysis access for patients with poorly functioning TCCs successfully.

Background

Central vein stenosis (CVS) or occlusion is a common complication in patients undergoing hemodialysis and affects the function of vascular access and the quality of dialysis.[1] Central vein catheterization is one reason for CVS or occlusion and negatively affects the duration of catheterization.[2] A tunnel-cuffed catheter (TCC) is the only effective device for dialysis access in patients requiring long-term hemodialysis and in patients whose native or prosthetic arteriovenous fistulas cannot be established. However, long-term indwelling TCCs will result in hyperplasia of the vascular intima, the formation of fibrous sheaths, and CVS or occlusion leading to incarceration, adhesion, and blockage of the catheter.[3] In addition, CVS or occlusion results in failed TCC implantation and loss of hemodialysis access.

Percutaneous transluminal angioplasty (PTA) has been used to treat CVS or occlusion,[4] and stent implantation is considered for central veins with > 50% elastic retraction or restenosis within three months in patients undergoing arteriovenous fistula hemodialysis.[5] For patients without arteriovenous fistula and with dysfunctional central veins caused by long indwelling TCCs, no consensus on how to achieve functional hemodialysis access has been reached. In this study, we performed PTA to recanalize the central vein, implanted new TCCs *in situ* or in any central vein after removal of the dysfunctional TCC, and evaluated the safety and efficiency of the strategy.

Methods

Patients

We collected 66 patients with indwelling TCC catheters under regular dialysis at our institution between July 2018 and July 2021, and according to the inclusion and discharge criteria, a total of thirteen patients were included in the study. Inclusion criteria: (1) a dysfunctional TCC and a pump-controlled flow rate less than 200 ml/min during dialysis after thrombolysis with urokinase; (2) a need for TCC replacement loss of the polyester cuff; and (3) an inability to establish a native or prosthetic arteriovenous fistula, as confirmed by preoperative duplex venous mapping. The exclusion criteria were as follows: (1) severe cardiopulmonary insufficiency and an inability to tolerate surgery; (2) allergy to contrast; and (3) severe coagulation abnormalities.

These thirteen patients included two males and eleven females with an average age of 52.2 years (range, 31 to 84 years). Twelve patients had TCC dysfunction, and one patient had lost the polyester cuff of the TCC. The TCC indwelling duration was 35.2 months (range, 6 to 70 months). The locations of the TCCs were the left internal jugular vein in four patients and the right internal jugular vein in nine patients.

Procedure

All patients underwent PTA of CVS or occlusion and new implantation of TCCs *in situ* or in another new central vein under DSA guidance. Under local anesthesia, a small skin incision was made proximal to the polyester cuff. The TCC was exposed, isolated, and cut into two segments. The polyester cuff was separated, and the distal segment was removed. A stiff guide wire (Terumo Corporation, Shibuya-ku, Tokyo) was inserted into the proximal catheter to ensure that the subsequent operation was in the original channel (Fig. 1A), and the proximal segment was removed under the support of the guide wire. A 10-F sheath (Cook Medical, Bloomington, IN) was placed to stop bleeding, and central venous lesions were determined by angiography using a 10-F sheath (Fig. 1B). The stenosis or occluded lesion was dilatated sequentially from a small-diameter balloon (8 mm in diameter; Invatec, BS, Italy) to a large-diameter balloon (10 mm and 12 mm in diameter; Invatec, BS, Italy) (Fig. 1C, D). According to the nominal pressure of the balloon, the balloon was dilated for 2 min each time. Angiography was performed after dilation to determine whether the central vein stenosis or occlusion was relieved (Fig. 1E). New TCCs (Covidien llc, MA, USA) were implanted after CVS or occlusion was resolved and the location was confirmed under X-ray (Fig. 1F).

In situ implantation was preferred, and TCCs were implanted in other central veins after PTA in three patients. One patient underwent a new TCC implantation in the right internal jugular vein because of failed removal of the previous TCC in the left innominate vein (Fig. 2A). An angiogram showed stenosis of the right internal jugular vein with a previous history of dialysis catheter placement (Fig. 2B), and the jugular vein was dilated with the balloon (Fig. 2C). Then, an angiogram showed alleviation of CVS (Fig. 2D), and the new TCC was implanted in the right innominate vein and the superior vena cava by right internal jugular vein puncture under guide wire guidance (Fig. 2E, F).

Results

The TCC indwelling duration was 35.2 months (range, 6 to 70 months). TCCs were removed successfully under the support of the stiff guide wire in twleve patients. One TCC could not be removed in another institution because of severe adhesion of the TCC and the left innominate vein 4 years after implantation, with no support from a stiff guide wire. Intraoperative angiograms showed stenosis of the right internal jugular vein and left innominate vein in two patients, stenosis of the right innomate vein in five patients, stenosis of the left innominate vein and the superior vena cava in one patient, stenosis of the right internal jugular vein and the superior vena cava in three patients, occlusion of the superior vena cava in one patient, occlusion of bilateral innominate veins and stenosis of the right iliac vein in one patient (Table 1).

Table 1
Patient characteristics

Cases	Sex	Age, y	LD of TCCs (time)	CVS or occlusion	PTA	New TCC implantation	Follow-up (months)
1	F	45	Left IJV (12 m)	Right IJV, left IV	Right IJV	Right IJV	36
2	F	84	Left IJV (48 m)	Right IJV, left IV	Right IJV	Right IJV	6
3	F	31	Right IJV (36 m)	Right IV	Right IV	*In situ*	9
4	F	63	Left IJV (6 m)	Left IV, SVC	Left IV, SVC	*In situ*	36
5	M	52	Right IJV (18 m)	Right IV	Right IV	*In situ*	15
6	F	36	Right IJV (70 m)	Right IV	Right IV	*In situ*	11
7	M	42	Right IJV (60 m)	Right IV, SVC	Right IV, SVC	*In situ*	13
8	F	69	Right IJV (24 m)	Right IV	Right IV	*In situ*	12
9	F	58	Right IJV (27 m)	SVC	SVC	*In situ*	10
10	F	42	Left IJV (48 m)	Bilateral IV, RIV	RIV	RIV	9
11	F	50	Right IJV (28 m)	Right IV, SVC	Right IV, SVC	*In situ*	3
12	M	61	Right IJV (56 m)	Right IV, SVC	Right IV, SVC	*In situ*	3
13	M	46	Right IJV (24 m)	Right IV	Right IV	*In situ*	5

F, female; M, male; LD, location and duration; TCC, tunnel-cuffed catheter; CVS, central vein stenosis; PTA, percutaneous transluminal angioplasty; IJV, internal jugular vein; IV, innominate vein; SVC, superior vena cava; RIV, right iliac vein.

All patients underwent PTA of the central vein, and angiograms showed no extravasation of the contrast. TCC implantation in the central vein was achieved in all patients with a success rate of 100%. New TCCs were implanted *in situ* in ten patients and in another central vein in three patients. A new TCC was implanted in the right internal jugular vein because of complete occlusion of the entire left innominate vein due to the indwelling TCC (patient 1). Because of the anatomical relationship between the left innominate vein and the superior vena cava, the long-term patency rate of the left TCC is lower than that of the right. Therefore, this patient preferred TCC implantation in the right internal jugular vein after PTA. A new TCC was implanted in the right internal jugular vein because the previous TCC in the left innominate vein failed to be removed (patient 2). A new TCC implanted in the right iliac vein because of occlusion of bilateral innominate veins (patient 10).

The mean follow-up was 12.9 months (range, 3 to 36 months) after the operation. TCCs in all patients showed good function with a pump-controlled flow rate of 200–260 ml/min. Two patients, patients 2 and 4, died of cardiovascular disease 6 months and 3 years, respectively, after the operation.

Discussion

TCCs provide the only life-sustaining channel for patients who are unable to undergo permanent hemodialysis or peritoneal dialysis. However, CVS or occlusion after catheter insertion results in TCC dysfunction. In this study, we performed PTA to recanalize CVS or occlusion, implanted new TCCs, and established dialysis access with a success rate of 100% and no complications.

Prevention of catheter-related CVS or occlusion is important; once stenosis forms, restenosis is possible with any treatment, and the patient's dialysis lifeline cannot be sustained. To prevent CVS or occlusion, catheters and central vein devices should be implanted in as few patients with chronic kidney disease (CKD) and under dialysis as possible. In patients with stage 4 CKD, native or prosthetic arteriovenous fistulas should be established as soon as possible, and emergency central vein catheter dialysis is unnecessary. For patients requiring acute dialysis for whom the maturation time of the arteriovenous fistula is > 1 month, TCC implantation is recommended instead of a dialysis catheter with no tunnel or polyester cuff (NCC) to reduce damage to the central vein. However, long-term indwelling of TCCs results in CVS or occlusion, which affects the function of TCCs.

A poorly functioning central vein catheter, especially TCCs, is defined by the American Kidney Disease Outcomes Quality Initiative (KDOQI) by an effective dialysis blood flow of the catheter < 300 ml/min or an arterial pressure ≤ 250 mmHg when the blood pump flow rate reaches 200 ml/min.[6] The standard for a poorly functioning central vein catheter set by Chinese expert groups for Chinese patients is an effective dialysis blood flow of the catheter < 200 ml/min, an arterial pressure < 250 mmHg, a venous pressure > 250 mmHg when the blood pump flow rate reaches 200 ml/min, or catheter recirculation higher than 10%.[5] Long-term indwelling of a catheter in a central vein results in the formation of a thrombus and catheter fiber sheath, which are the main reasons for malfunction of central vein catheters.[3] Therefore, unfractionated heparin alone or combined with urokinase is routinely used after dialysis to prevent the formation of a thrombus and catheter fiber sheath. Regular urokinase infusion through the catheter is required to avoid repeated catheter dysfunction.[3] Implanting a new catheter in a central vein is recommended when the catheter is still ineffective under multiple thrombolysis attempts. CVS or occlusion is the main reason for poor catheter function, and stenosis occurs in any location of the central vein, including the jugular vein, innominate vein, superior vena cava, iliac vein, and inferior vena cava.[2,7]

In our study, urokinase infusion after TCC malfunction was not effective. DSA showed CVS or occlusion of the central vein in all patients. Therefore, TCC-related CVS or occlusion is a difficult problem for patients for whom vascular access cannot be established or whose vascular resources have been exhausted and often leads to failure of TCC extubation or reinsertion, as well as failed reestablishment of dialysis access.

Available treatments for the replacement of failed TCCs include replacement of the catheter *in situ* through the guide wire, implantation of the new catheter by changing the puncture site, and implantation of a new catheter after endovascular treatment.[3] Janne d'Othee et al. compared the technical success rate, complication rate, and durability of catheter function during a follow-up of 63 patients undergoing catheter replacement by three different techniques (over-the-wire catheter exchange, fibrin sheath stripping by a femoral vein approach, and over-the-wire catheter removal with balloon dilatation of the fibrin sheath followed by catheter replacement), and no significant difference was found.[8] Oliver et al. randomly assigned 33 patients with fiber sheath catheter replacement to either direct catheter exchange or exchange after PTA sheath disruption and found that disrupting sheaths by PTA resulted in durable catheter patency and modestly improved blood flow over the duration of catheter use.[9] The method advocated by the KDOQI guidelines is to disrupt the fibrin sheath with a balloon and place a new catheter.[6] DSA is the gold standard for diagnosing central vein diseases and can be simultaneously used for endovascular treatment. In the presence of fibrin sheath formation or CVS, endovascular treatment can be performed at the same time, and then central vein catheters such as TCCs can be replaced to improve the success rate of catheter replacement and the patency rate while maximizing protection of previous vascular resources.[10]

The current treatments for central vein diseases related to TCCs include vascular bypass and endovascular therapy. Vascular bypass is not preferred because of large trauma and a high risk of complications.[11, 12] With the development of vascular techniques, endovascular therapy, including PTA or stenting, has become the first-line treatment for CVS or occlusion due to minimal trauma, good maneuverability, excellent patient tolerance, significant immediate efficacy, and maximum preservation of vascular resources. The technical success rate of PTA in the treatment of central vein disease can be as high as 70–90%.[13] Due to elastic retraction of the central vein, the long-term patency rate after PTA treatment varies markedly among studies. At 12 months, the unassisted patency rate after PTA is 12–50%, and the cumulative patency rate is 13–100%.[14–17] As a result, repeated PTA is often required. Therefore, stent placement was the first choice for central vein diseases in some centers,[18–22] which can prevent restenosis caused by vein traction and prolong the patency duration. The consensus on vascular access for hemodialysis in China recommends stent implantation for patients with poor PTA performance (residual stenosis > 30%), repeated short-term restenosis lesions, anatomical compression lesions, and occlusive lesions.[5]

In our study, we performed PTA to dilate the narrow or occluded central vein and then inserted a new TCC without stent placement. During the follow-up, the dialysis flow rate reached 200–260 ml/min, and none of the patients required urokinase infusion. Therefore, the technical success rate and long-term patency rate of PTA are ideal, and this strategy allows the possibility of future reintervention. For patients with CVS or occlusion, repeated PTA can be performed, and the TCC can be replaced to maintain dialysis access and prolong the life of dialysis. Additionally, we used a large-diameter balloon (10 to 12 mm) to fully dilate the central vein to maintain the blood flow between the catheter and the central vein after TCC placement.

Conclusions

Under DSA guidance, recanalization of TCC-related CVS or occlusion by PTA and implantation of a new TCC catheter *in situ* or another central vein can establish dialysis access for patients with poorly functioning TCCs. This method is safe and effective with a high rate of success.

Declarations

Acknowledgement

Not applicable.

Ethics approval and consent to participate

This study was approved by the Ethics Committee of the Affiliated Hospital of Qingdao University (QYFY-WZLL-26866), and all patients signed the informed consent form before the operation and allowed their clinical data to be used for research purposes. All methods were carried out following relevant guidelines and the declaration of Helsinki.

Consent for publication

Not applicable

Availability of data and materials

The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request and all data generated or analysed during this study are included in this published article.

Competing interests

The authors declare that they have no competing interests.

Funding

This work was supported by grants from the National Natural Science Foundation of Shandong Province (ZR2020QH060), the National Natural Science Foundation of China (81770679, 81470973 and

81970582), Qingdao Key Health Discipline Development Fund and the “Clinical medicine + X” scientific research project of the Affiliated Hospital of Qingdao University (QDFY+X202101064).

Authors’ contributions

The study was designed by Y.W. and Y.X. Data collection and analysis was conducted by Q.B. The surgical procedures were performed by Y.W., L.N., Q.B., and Y.Z. The manuscript was written by H.L. All authors approved the final version of the manuscript.

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Figures

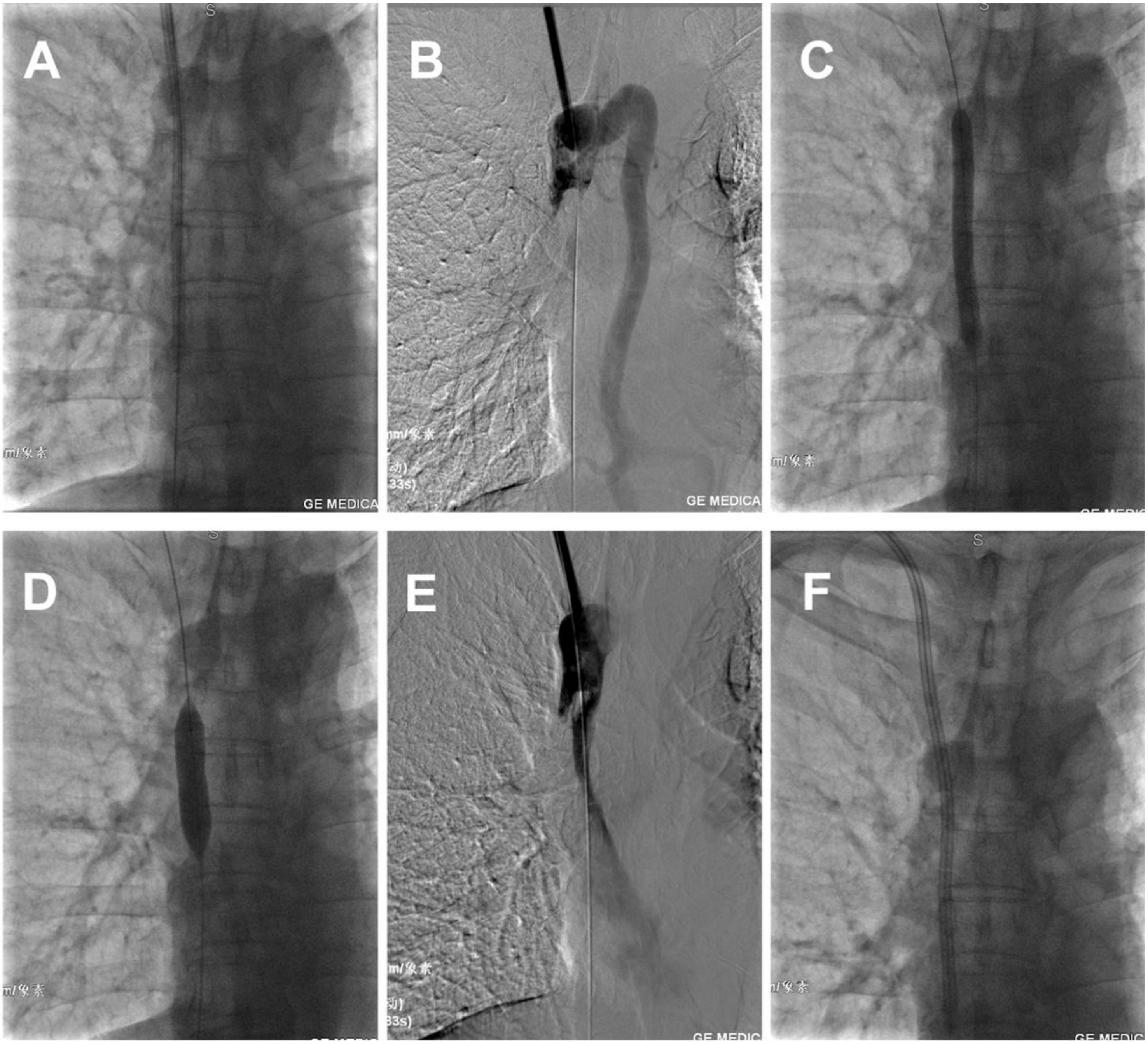

Figure 1

Percutaneous transluminal angioplasty (PTA) of central vein and implantation of the new TCC *in situ*. A. A stiff guide wire was inserted in the old TCC to ensure that the subsequent operation was in the original channel. B. Angiogram showing that the superior vena cava was occluded and the collateral vein was opened. C. PTA of the superior vena cava with a small balloon (8 mm in diameter). D. PTA of the superior vena cava with a large balloon (12 mm in diameter). E. Angiogram showing that the superior vena cava was patent and that the collateral vein had disappeared. F. The new TCC was implanted *in situ*.

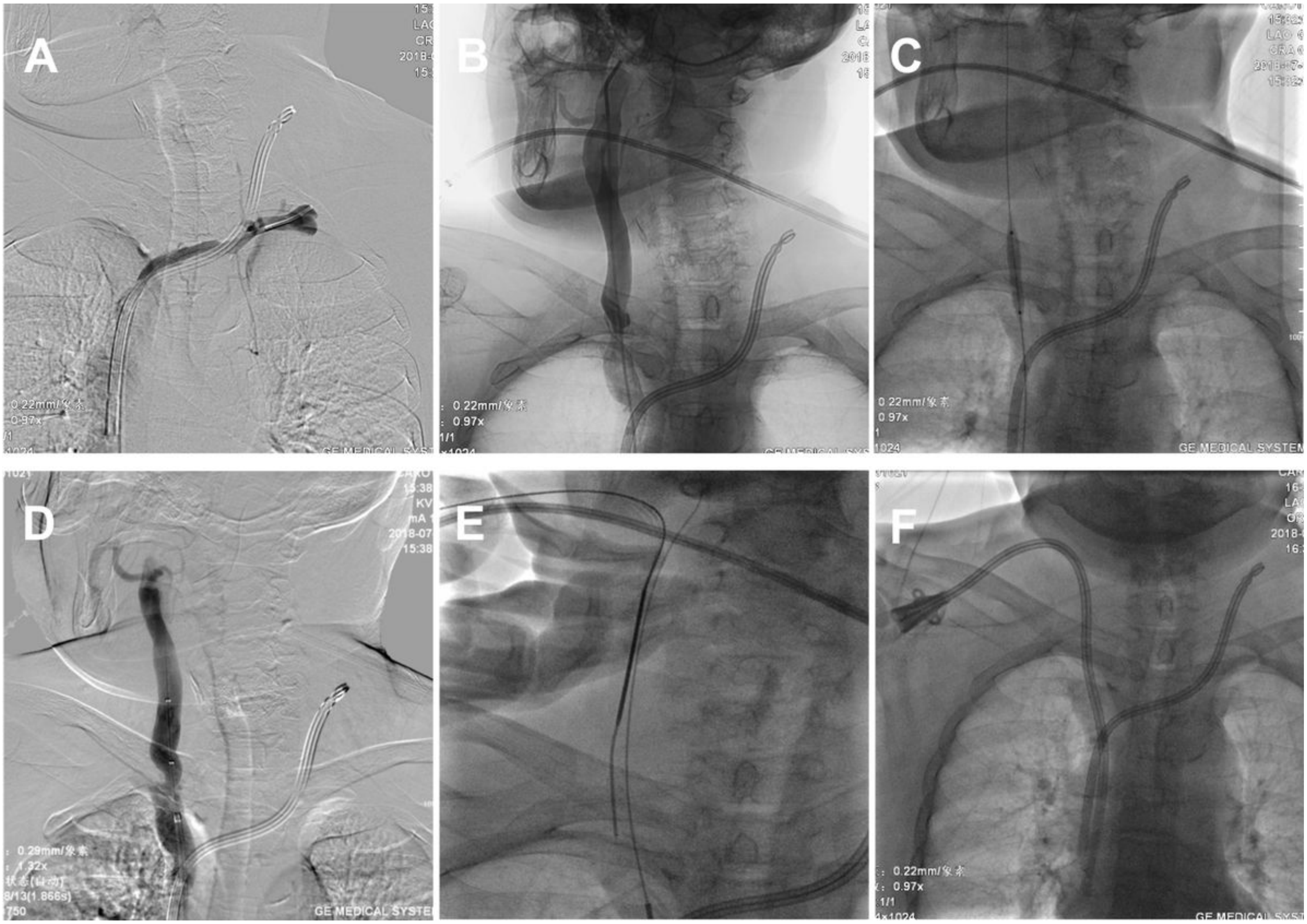

Figure 2

PTA of central vein stenosis and implantation of the new TCC in another central vein. A. The previous TCC could not be removed due to adhesion of the catheter, and an angiogram showed stenosis of the left innominate vein. B. Angiogram showing stenosis of the right internal jugular vein. C. PTA of the jugular vein with a balloon (8 mm in diameter). D. Angiogram showing alleviation of jugular vein stenosis. E. Right jugular vein puncture under guide wire guidance. F. Implantation of the new TCC in the right innominate vein and the superior vena cava.