Transarterial Interventional Therapy for Non-functioning Hemodialysis Access

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Abstract

Transarterial vascular access interventional therapy (VAIVT) for non-functioning hemodialysis access has advantages over the venous approach because natural venous outflow through the fistula as well as the stump at the fistula site in total occlusion can be observed, and most strictures and/or occlusions can be treated via one access route. The brachial arterial approach is essential, but the radial arterial approach at the wrist is also necessary for certain patients. The transarterial approach can be applied to all VAIVTs; however, additional venous access is necessary in cases requiring a large device and those with unsuccessful traversal of the occluded segment via the arterial route. The high origin of the radial artery is a disadvantage of the trans-brachial approach, and local hematomas are the most frequent complications.

Key words: Vascular access interventional therapy, transarterial approach, thrombotic occlusion, non-thrombotic occlusion

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Introduction

Vascular access interventional therapy (VAIVT) for non-functioning hemodialysis access, such as pharmacomechanical thrombolysis, mechanical thromboaspiration, and percutaneous transluminal angioplasty (PTA), have become acceptable alternatives to surgical repair [1, 2]. For VAIVT, retrograde venous puncture has been proposed as a standard approach [1, 2]. However, this approach has drawbacks, because it is often difficult to visualize the arterial and venous vascular trees. Additionally, multiple venous punctures are sometimes necessary to restore the non-functioning hemodialysis fistula due to underlying multifocal stenotic lesions downstream of the venous puncture site [3].

The transarterial approach for non-functioning hemodialysis access has some advantages over the venous approach, although the use of large devices has a risk of arterial injury or spasm. Arterial injection of contrast material can reveal natural venous outflow through the fistula and aid the detection of the stump at the fistula site in patients with total occlusion. Furthermore, most strictures and/or occlusions in both arterial and venous segments can be treated via one access route (**Figs. 1** and **2**) (**Table 1**) [4]. With advances in angioplasty balloon catheter technologies, almost all VAIVTs can be performed through a 4-F sheath, and this can increase the safety and technical success of transarterial VAIVT for non-functioning hemodialysis access. In this paper, we describe our transarterial VAIVT techniques.

Indication for transarterial VAIVT

The transarterial approach provides a clear view of the fistula and collateral flow and simplifies the VAIVT procedure; therefore, it can be applied to all VAIVTs, including total fistula occlusion. However, in cases requiring a rela-

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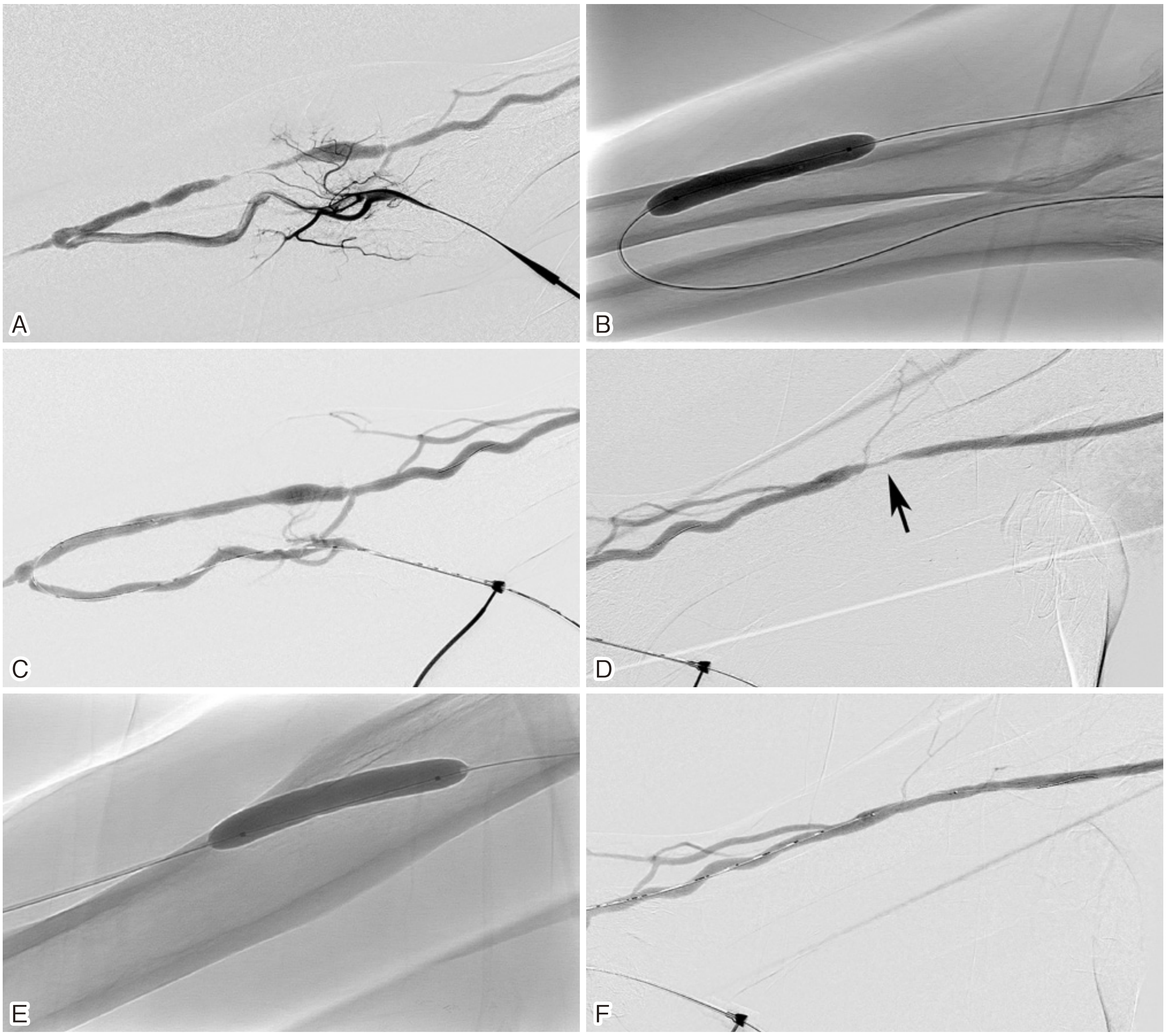

Figure 1. Transbrachial VAIVT for multifocal stenotic lesions between the forearm and upper arm.
A: Initial brachial arteriography showed multiple stenoses in the forearm venous segment of a hemodialysis fistula anastomosed at an acute angle. B: A guidewire and balloon catheter could be passed through the anastomosis, and PTA was performed. C: Arteriography performed after PTA showed dilatation of the stenosed lesions. D: Another stenosis in the cephalic vein of the upper arm was observed (arrow). E: Additional PTA was performed. F: Final arteriography showed an improvement of the stricture.

tively large device, such as a thromboaspiration catheter, ultra-high-pressure or large (≥ 8 mm in diameter) angioplasty balloon catheter, cutting balloon catheter, and metallic stent, and those with unsuccessful traversal of the occluded segment via the arterial route, an additional venous puncture is required (**Figs. 3-5**) [5]. It has been reported that the transradial approach is more useful than the transbrachial approach in reducing hemorrhagic complications at the puncture [6, 7]; however, PTA for lesions bridging the anastomosis and VAIVT for hemodialysis grafts are impossible through this route. Therefore, the brachial arterial approach is essential for VAIVT, and 92% of native non-functioning hemodialysis fistulas can be restored [4, 8]. The transbrachial approach can also be applied to an occluded hemodialysis graft (**Fig. 6**).

Arterial puncture technique

After local anesthesia, an antegrade puncture of the brachial artery is performed with a 22-gauge (G) needle followed by angiography. After the confirmation of stenosed or occluded lesions, an antegrade insertion of a 3-cm-long 4-F sheath into the brachial artery is performed. If a long segment occlusion, a sharp angle at the anastomosis site, and/or

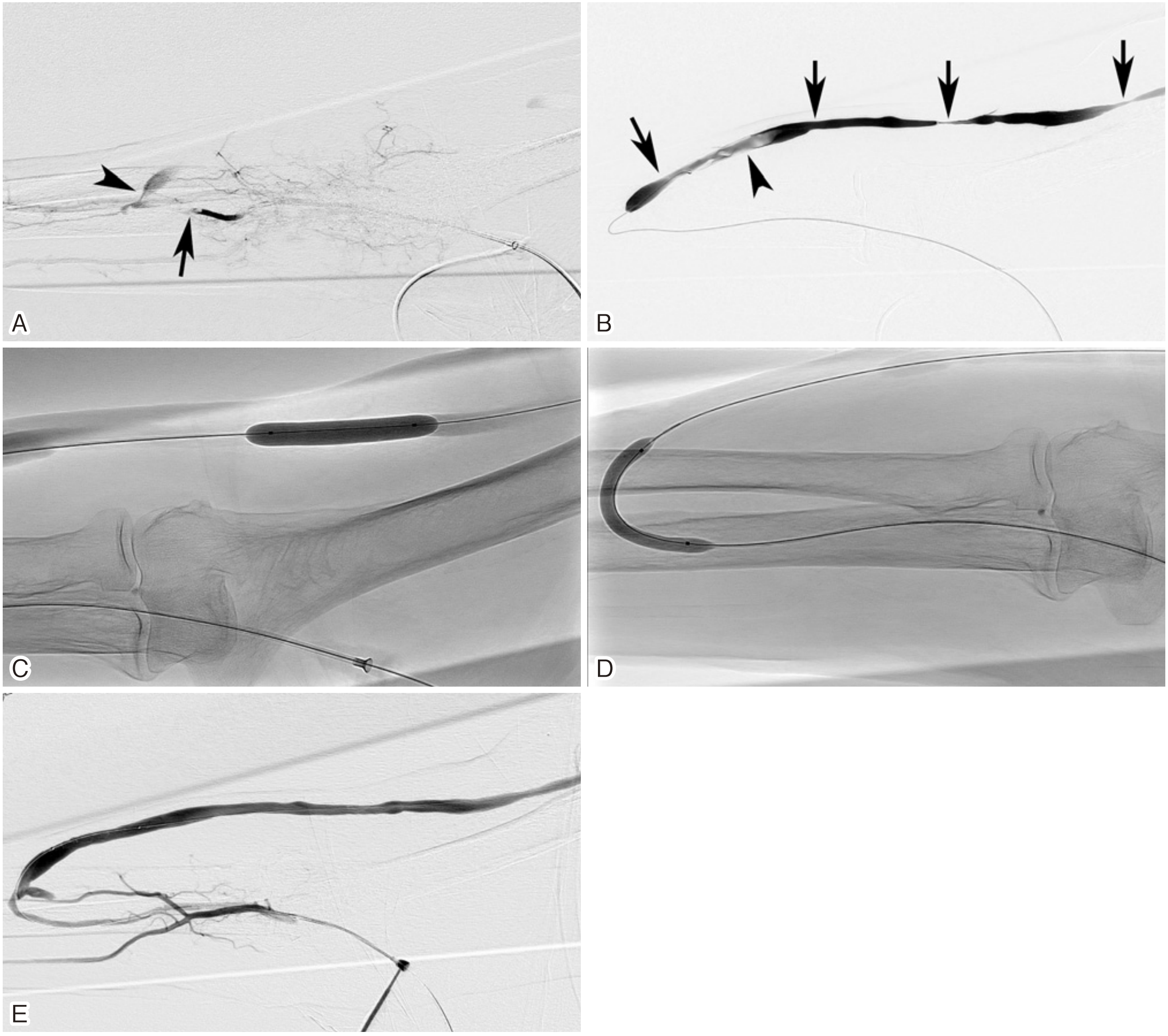

Figure 2. Transbrachial VAIVT for both the arterial and venous lesions.
A: Initial brachial arteriography showed total occlusion of the radial artery (arrow) and severe stenosis just above the anastomosis (arrowhead). B: Venography performed through a microcatheter crossing the occluded segment showed a small thrombus (arrowhead) and multifocal stenoses (arrows). C: The venous stenotic lesions were dilated with a straight balloon catheter. D: The anastomosis stricture and radial arterial occlusion were dilated together using a curved balloon catheter. E: Final arteriography showed the restoration of the fistula.

a tortuous radial artery connecting the fistula is demonstrated on an arteriogram, the sheath is not placed in the brachial artery. In such a case, a retrograde puncture of the radial artery is performed with a 22-G needle at the wrist, and a 4-F sheath is placed to facilitate the traversal of the stenosed or occluded segment along a straight pass (**Fig. 7**). If the radial artery is not palpable, it can be punctured under sonographic or fluoroscopic guidance while the radial artery is opacified using contrast material injected through the outer cannula of the 22-G needle placed in the brachial artery (**Fig. 8**). The outer cannula in the brachial artery is left in place until the end of the procedure to check the blood flow of the fistula (**Fig. 7**). After the insertion of the sheath, 3,000 U of heparin is intravenously administered and 1,000 U is added every hour.

Techniques of transarterial VAIVT

A 4-F angioplasty balloon catheter is inserted into the sheath and navigated by a 0.018-inch guidewire. If the guidewire can cross the stenosed or occluded segment, the balloon catheter is advanced and PTA is performed. During the procedure, contrast material can be injected through the sidearm of the sheath to check the vascular anatomy and blood flow through the fistula. A curved balloon catheter is useful for dilating the stricture bridging the anastomosis or

Table 1. Advantages and disadvantages of each approach route

Approach route	Advantage	Disadvantage
Transvenous	・Low incidence of hemorrhagic complications ・Use of large-sized device ・Easy advancement of devices along the straight way	・Difficulty in depicting both arterial and venous vascular trees ・Difficulty in depicting the stump of totally occluded fistulas ・Difficulty in evaluating natural fistula flow ・Frequent multiple punctures to treat multifocal lesions
Transbrachial	・Depiction of both arterial and venous vascular trees ・Depiction of the stump of totally occluded fistulas ・Easy evaluation of natural fistula flow ・One access treatment for lesions in both arterial and venous segments	・Risk of hemorrhagic complication ・Risk of arterial injury and spasm ・Difficulty in using large-sized devices ・Difficulty in advancing devices via sharp angled or tortuous routes ・Multiple punctures in cases with arterial anomaly
Tranradial	・Low incidence of hemorrhagic complications ・Depiction of both arterial and venous vascular trees ・Depiction of the stump of totally occluded fistulas ・Easy evaluation of natural fistula flow ・Use of large-sized device ・Easy advancement of devices along the straight way ・One access treatment for lesions in both arterial and venous segments expect for the anastomosis site	・Difficulty in puncture ・Risk of arterial injury and spasm ・Impossibility of the treatment for lesions at the anastomosis ・Impossibility of the treatment for non-functioning hemodialysis grafts

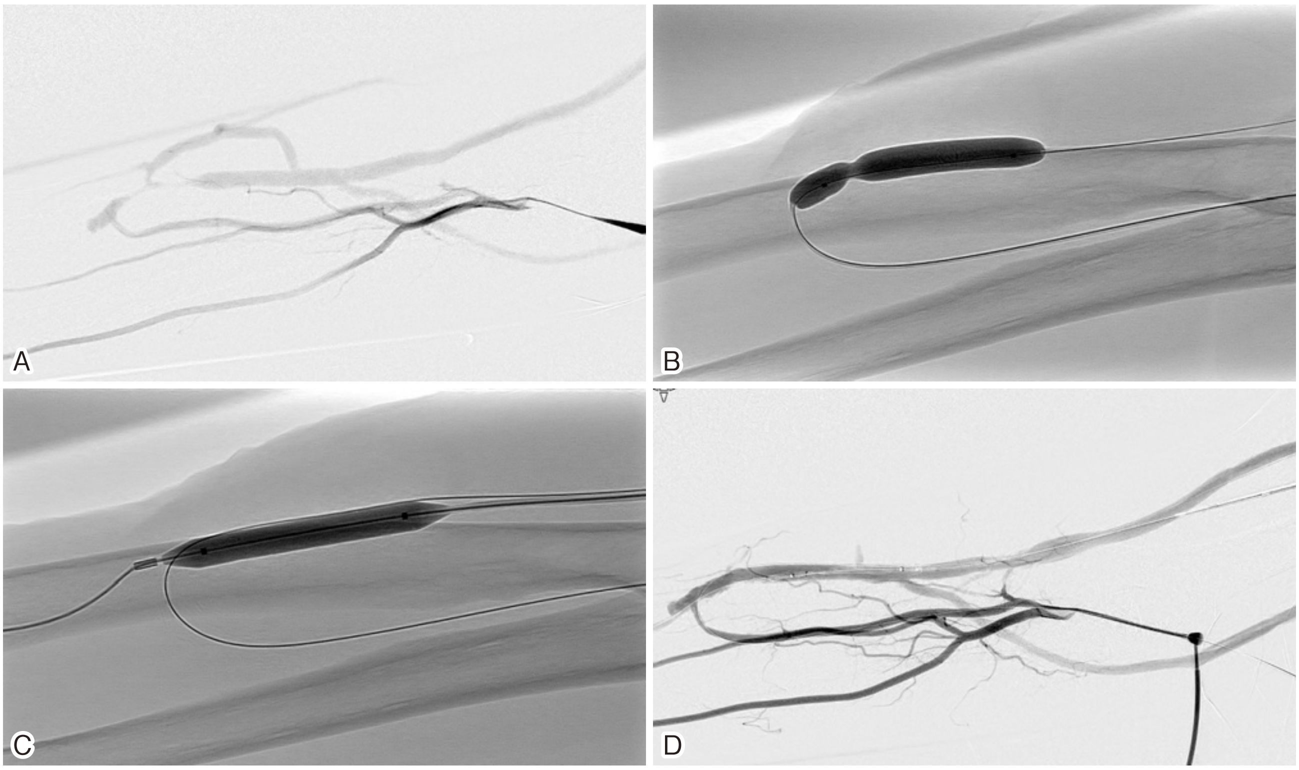

Figure 3. Additional venous puncture for using an ultra-high-pressure balloon catheter.
A: Initial brachial arteriography showed a severe stricture in the venous segment just above the anastomosis. B: Transarterial VAIVT was performed. The waist of a 5-mm balloon catheter remained despite stepwise expansions of up to 22 atm. C: A 5.5-F sheath was retrogradely inserted into the outflow vein, and PTA was performed for up to 30 atm using a 5-mm ultra-high-pressure balloon catheter (Conquest; Bard, Tempe, AZ, USA). The parallel wire technique was also used, and the waist of the balloon catheter disappeared. D: Final arteriography showed dilatation of the stricture.

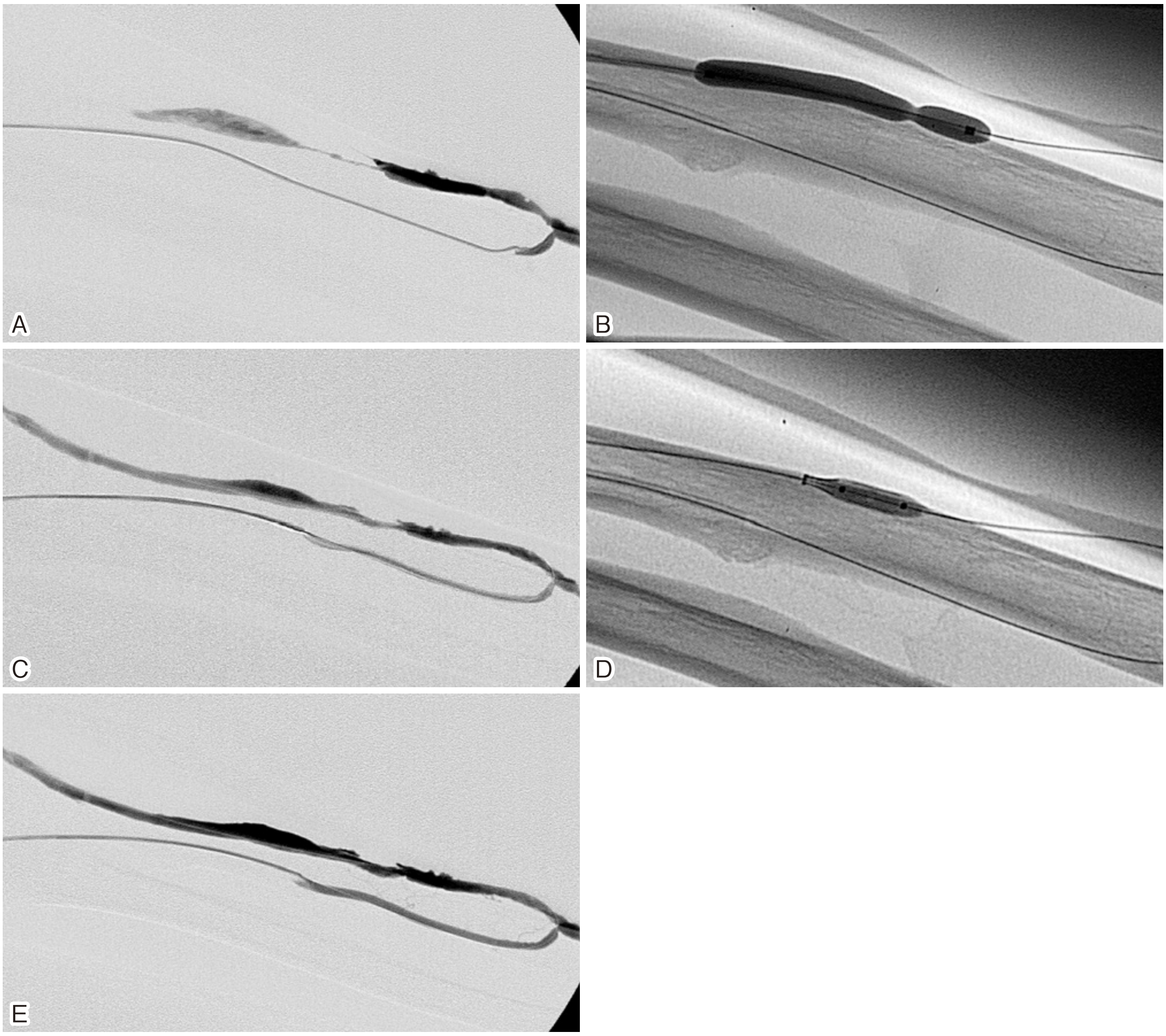

Figure 4. Additional venous puncture for using a cutting balloon catheter.
A: Initial brachial arteriography showed severe stenosis in the outflow vein. B: Transarterial VAIVT was performed. The waist of the balloon catheter remained despite stepwise dilations of up to 22 atm. C: Arteriography performed after PTA showed residual stenosis. D: A 7-F sheath was retrogradely inserted into the outflow vein, and PTA was performed at 6 atm using a cutting balloon catheter (Peripheral Cutting Balloon; Boston Scientific, Marlborough, MA, USA). E: Final arteriography showed an improvement of the stricture.

angulated vessel portion (**Figs. 2**, **5**, and **9**). PTA should be started from the distal to the proximal lesions because the penetration of a once inflated balloon catheter is reduced. However, in cases with a severe stricture or thrombus at the anastomosis, the anastomotic lesion should be dilated first to prevent clotting of the fistula during the procedure or the migration of the thrombus into the distal artery.

When the guidewire cannot cross the occlusion, the balloon catheter system is exchanged for a J-shaped 4.2-F catheter, and the traversal of the occluded segment is attempted with a 0.032-0.035-inch hydrophilic guidewire. If the catheter can be advanced across the occluded segment, it is exchanged for a balloon catheter over the 0.018-inch guidewire, and PTA is performed. If the attempt fails, a microcatheter system is coaxially used to traverse the occluded segment.

If the balloon catheter cannot pass through the anastomosis at an acute angle, bending its tip into a J-shape by steam heat is useful. Pushing the balloon catheter while applying external manual compression just distal to the anastomosis site is also helpful in advancing the balloon catheter along the guidewire.

If residual stenosis with flow delay is observed after PTA, additional dilation with a high-pressure or cutting balloon catheter via the venous approach is required. The cutting balloon catheter is mainly used for a short and straight stric-

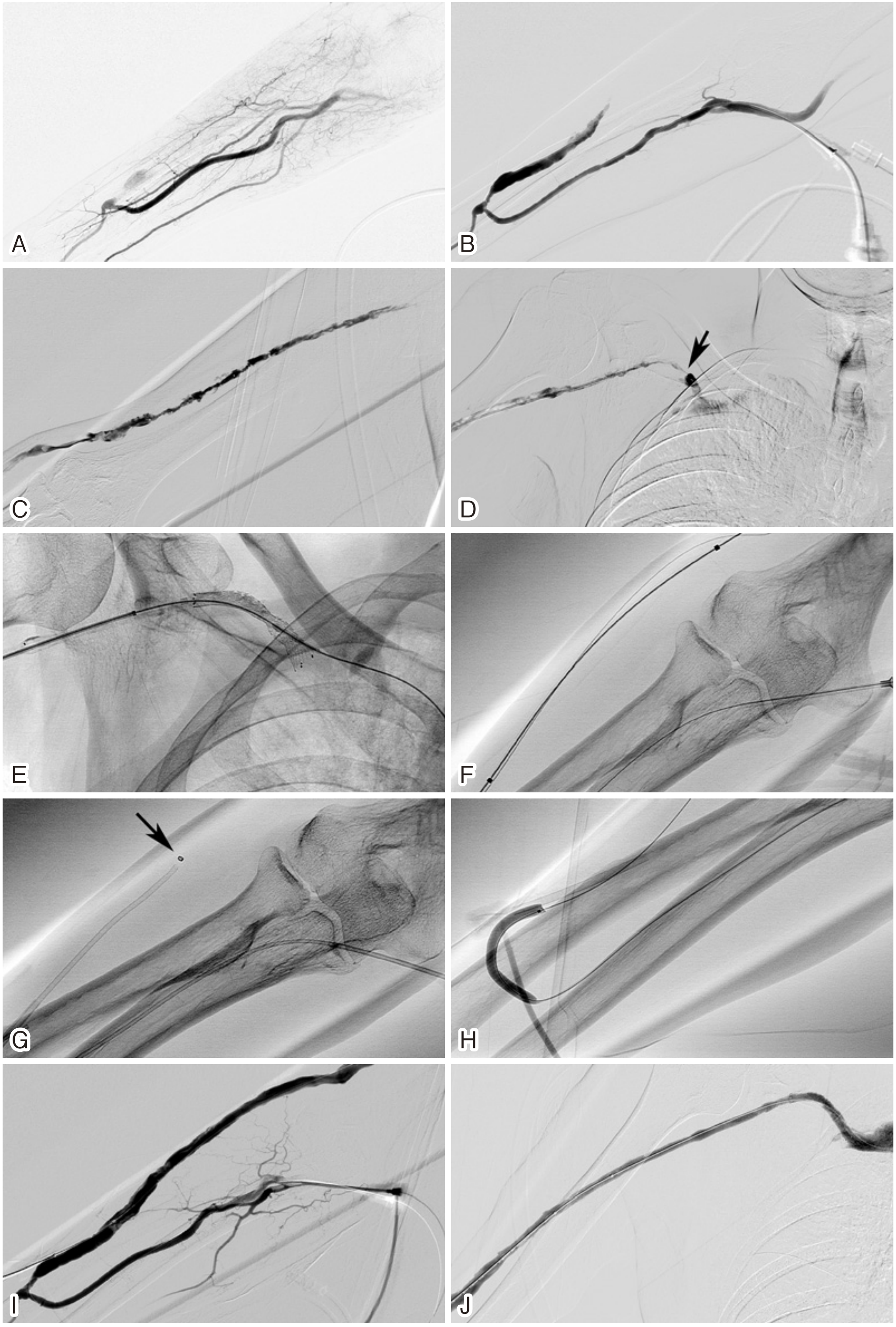

Figure 5. Additional venous puncture for using a metallic stent.

A: Initial brachial arteriography showed total occlusion of the outflow vein. B, C, D: Venography performed through the microcatheter showed multifocal stenoses and thrombi between the forearm and upper arm. The severe stricture of the arch of the cephalic vein was also observed (arrow in Fig. 5D). E: An antegrade puncture of the outflow vein was performed in the forearm, and a 6-F sheath was inserted. PTA was performed for the stricture of the arch of the cephalic vein, but vessel dissection developed (not shown). Subsequently, a metallic stent (SMART stent, Cordis, Cardinal Health) was placed. F: Infusion of 240,000 U of urokinase was performed using a pulse spray catheter. G: Manual thromboaspiration was also performed. The arrow indicates the tip of a thromboaspiration catheter. H: Finally, PTA was performed for the residual stenoses using a curved balloon catheter. I, J: Final arteriography showed the restoration of the fistula.

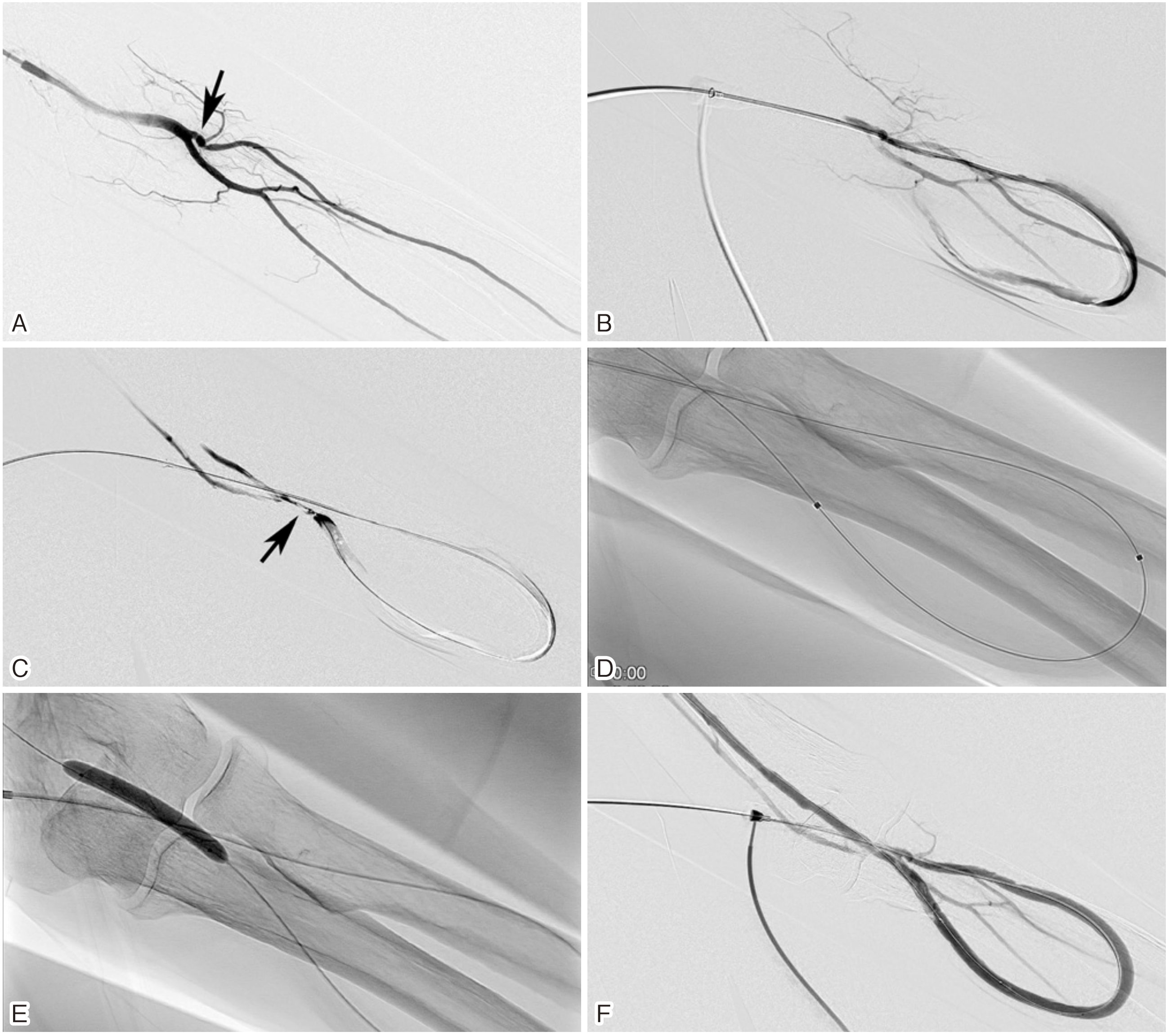

Figure 6. Transbrachial VAIVT for an occluded hemodialysis graft.
A: Initial brachial arteriography showed total occlusion of the hemodialysis graft. The arrow indicates the arterial anastomosis. B: A 4.2-F catheter was advanced into the occluded graft. C: Venography showed thrombi and a severe stricture at the venous anastomosis (arrow). D: Thrombolysis was performed using a pulse spray catheter. E: PTA was performed for the stricture. F: Final arteriography showed the restoration of the hemodialysis graft.

ture (**Fig. 4**).

VAIVT for massive thrombotic occlusion

In cases with a small thrombus, PTA is directly performed without thrombolysis (**Fig. 2**). If the fistula flow cannot be restored by intraluminal thrombus despite repeated PTA procedures, infusion of urokinase can also be performed using a 4-F pulse-spray catheter (Fountain, Merit Medical, Jordan, UT, USA) via the arterial approach.

However, direct PTA is not effective when large thrombi are demonstrated in the hypertrophied outflow vein. In such a case, the microcatheter is navigated using the guidewire until the non-affected vein can be observed. Thereafter, the non-affected venous segment is retrogradely punctured with a 22-G needle, and a 3-cm-long 6-F sheath is inserted. When the non-affected vein cannot be palpated, it is punctured under fluoroscopic guidance while the collapsed vein is opacified by injecting contrast material through the microcatheter. In cases with long and tortuous occluded segments, a pull-through guidewire technique is useful. First, the 0.016-inch guidewire is inserted through the microcatheter and navigated into the sheath placed in the vein. Subsequently, the guidewire and the venous sheath are grasped with surgical forceps and pulled out. Finally, the sheath is repositioned over the pulled-through guidewire (**Fig. 10**) [5]. A stainless-shaft guidewire should not be used for this technique because it is easily kinked at the anastomosis site. Af-

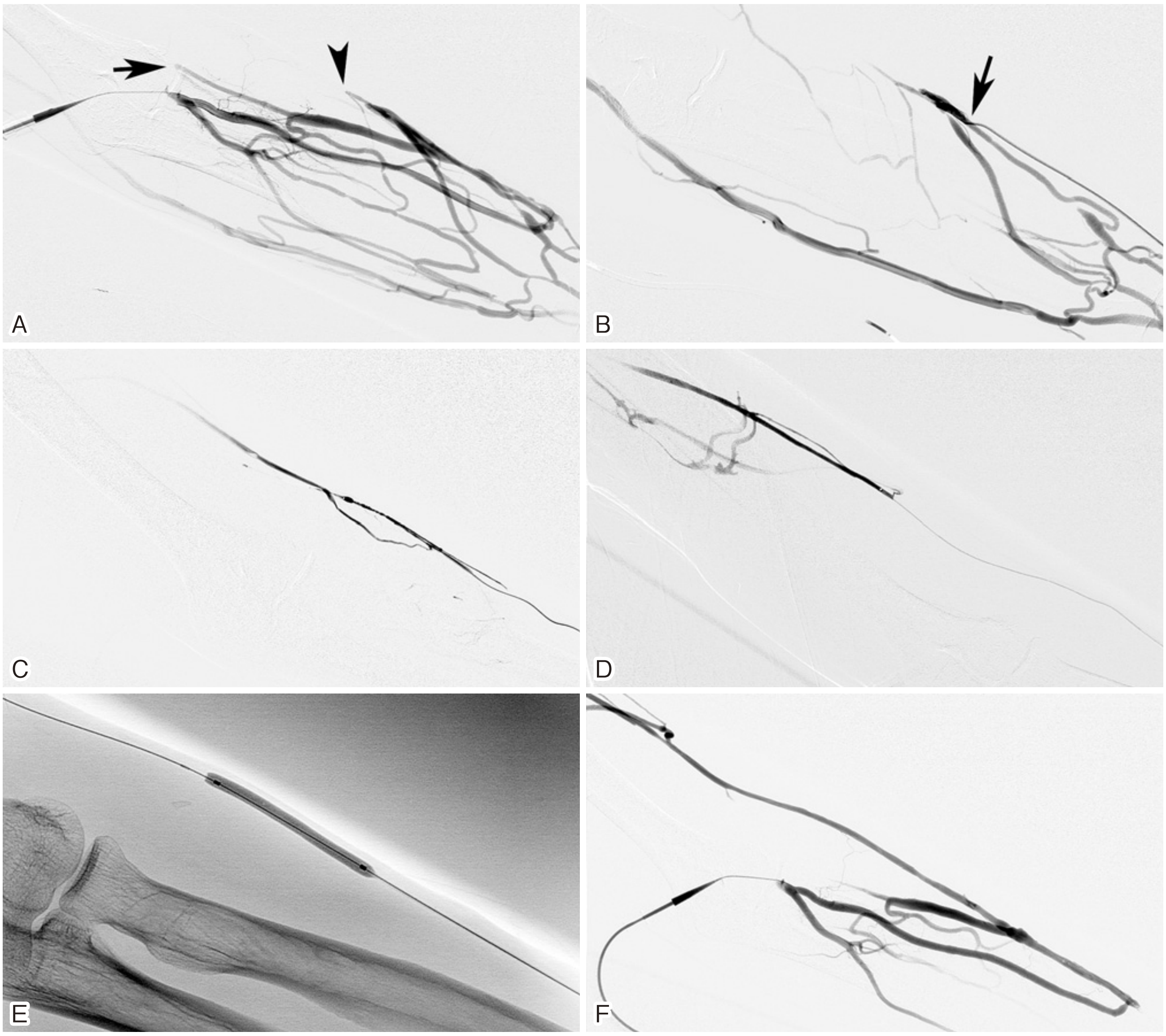

Figure 7. Transradial VAIVT for non-thrombotic occlusion of the non-mainstream venous route. A: Initial brachial arteriography showed total occlusion of the outflow vein (arrow). The non-mainstream vein was also occluded (arrowhead), and multifocal long segment occlusions were suspected. B: The cannula was left in place but the sheath was not placed in the brachial artery. Thereafter, a retrograde puncture of the radial artery was performed at the wrist and a 4-F sheath was inserted. Subsequently, a traversal of the main outflow vein was attempted, but it failed (not shown). Therefore, a 4.2-F catheter was advanced into the non-mainstream vein. The arrow indicates the tip of the catheter. C: Venography performed during the traversal of the occluded segment through a microcatheter showed non-thrombotic occlusion and the connection with the cephalic vein. D: The microcatheter could traverse the non-thrombotic occluded segment. E: PTA was performed at 16 atm. F: Final arteriography performed through the outer cannula of a 22-G needle in the brachial artery showed good blood flow through the non-mainstream venous route.

ter the establishment of the pulled-through guidewire, all VAIVTs can be performed via the venous access. Thrombolysis is usually performed first, followed by manual aspiration of the thrombus using a 6-F thromboaspiration catheter (Thrombuster, Kaneka Medix, Osaka, Japan; Vasplyser, Cordis, Cardinal Health, Dublin, OH, USA) for residual thrombi, if necessary (**Fig. 5**). Finally, PTA is performed on the residual stenoses. This order of treatment can reduce the risk of pulmonary embolism.

VAIVT for non-thrombotic occlusion

Non-thrombotic occlusion (NTO) is a condition characterized by a complete venous collapse without a thrombus. NTOs are also indications for VAIVT because their technical success rates are equal to those of thrombotic occlusions

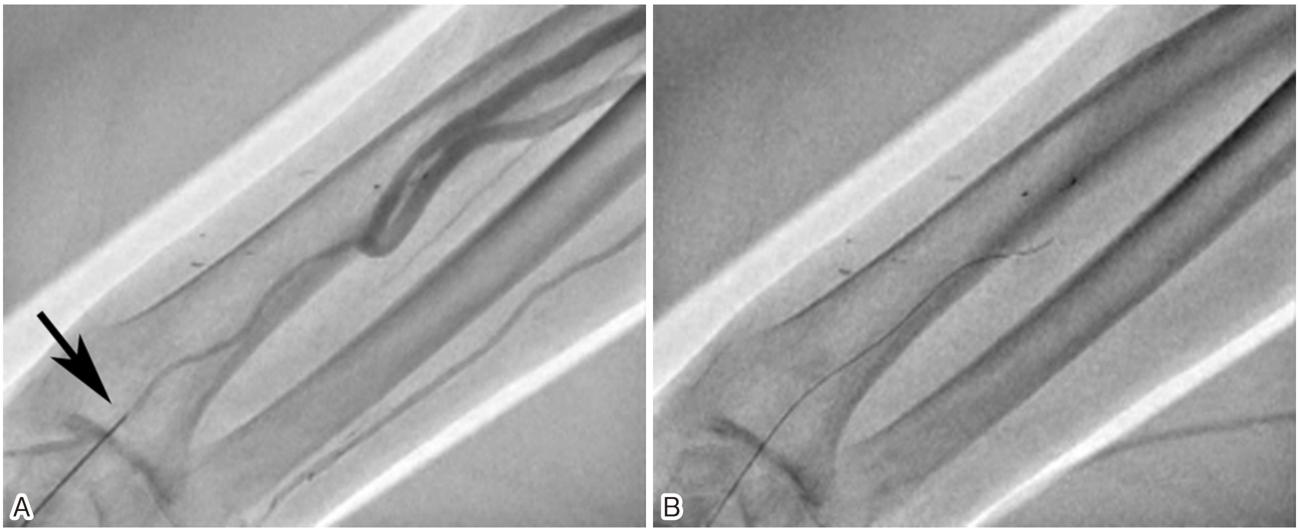

Figure 8. Puncture of the non-palpable radial artery under fluoroscopic guidance.
A: The radial artery was punctured with a 22-G needle while injecting contrast material through the outer cannula of a 22-G needle placed in the brachial artery. The arrow indicates the 22-G needle. B: A guidewire was inserted into the radial artery through the needle.

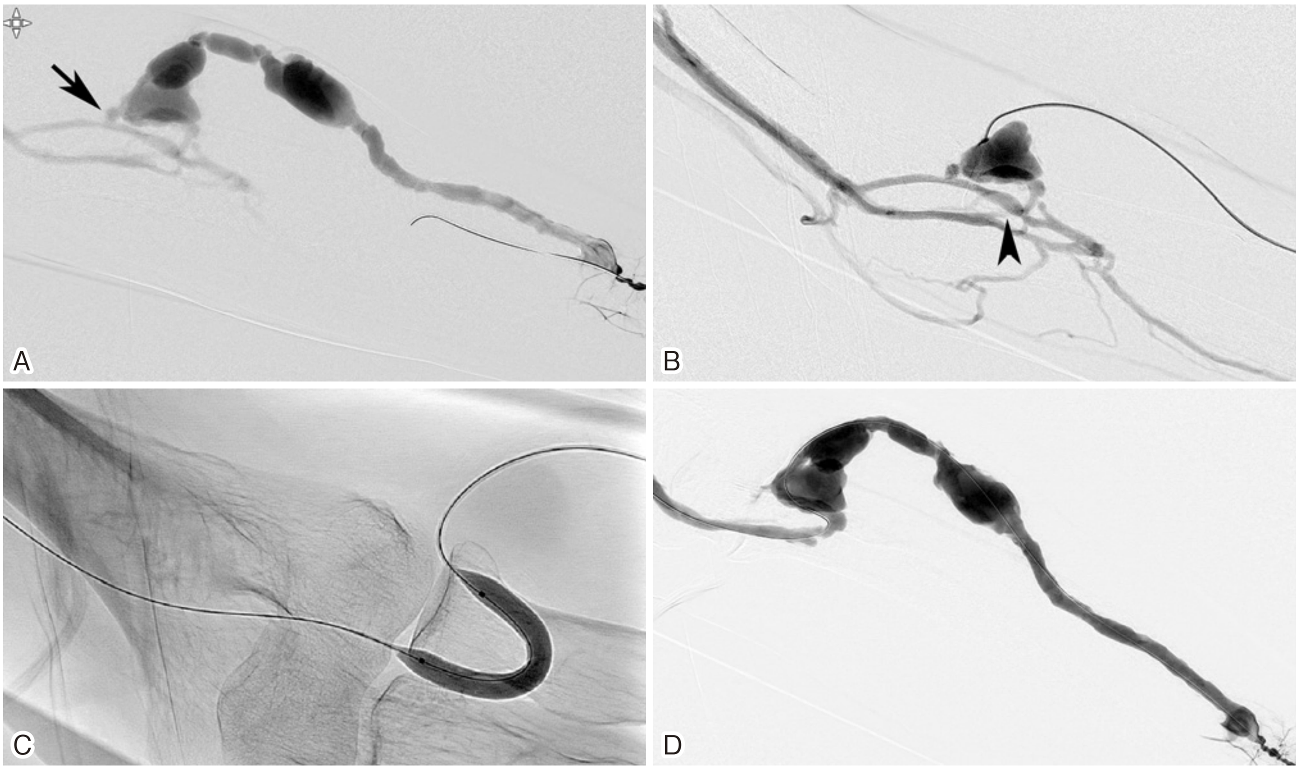

Figure 9. Transradial VAIVT for the non-mainstream venous route.
A: Initial radial arteriography showed total occlusion of the main outflow vein (arrow) and several collateral flows. B: The microcatheter could not traverse the main outflow vein, and one collateral vein (arrowhead) was selected for the creation of a new outflow route. C: PTA was performed using a curved balloon catheter. D: Arteriography performed 8 months after PTA showed that a previously dilated vein was hypertrophied and other collateral veins disappeared.

(**Figs. 7** and **11**) [8]. In cases of NTO, a traversal of the occluded segment is attempted, using a microcatheter-guidewire system, to check for vessel perforation. If perforation occurs, the microcatheter is pulled back until the opacification of the true lumen; the true lumen is subsequently secured by the guidewire. Manual compression of the perforated vein should also be performed, if necessary. When the traversal of the occluded segment is unsuccessful despite

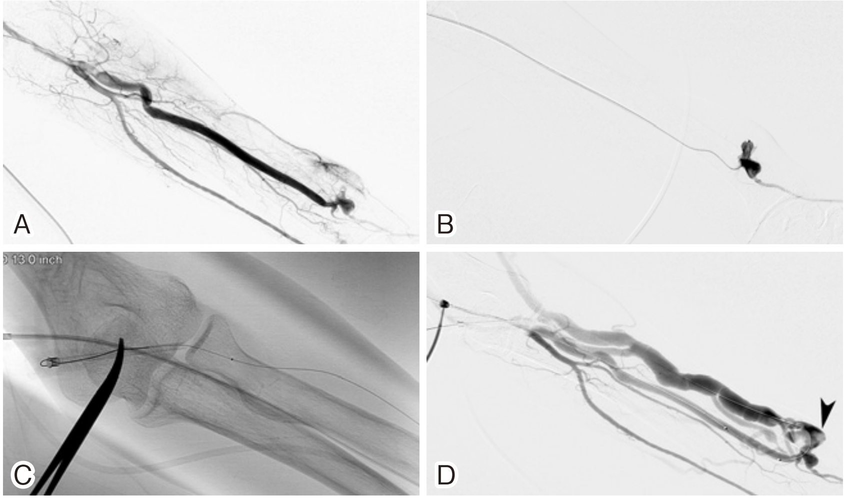

Figure 10. Pull-through technique for an occluded hemodialysis fistula.
A: Initial brachial arteriography showed total occlusion of the fistula at the anastomosis. B: A microcatheter system was advanced into the occluded segment through a 4.2-F catheter. C: The occluded segment was traversed using a microcatheter system. When the microcatheter was advanced until the non-affected vein, a retrograde placement of a 6-F sheath was performed in the non-affected vein. The 0.016-inch guidewire was navigated into the sheath, and it was pulled through with the sheath grasped by surgical forceps. The sheath was repositioned over the pulled-through guidewire. Thereafter, thrombolysis and PTA were performed via the venous route. D: Final arteriography showed the restoration of the fistula, although a small thrombus remained (arrowhead).

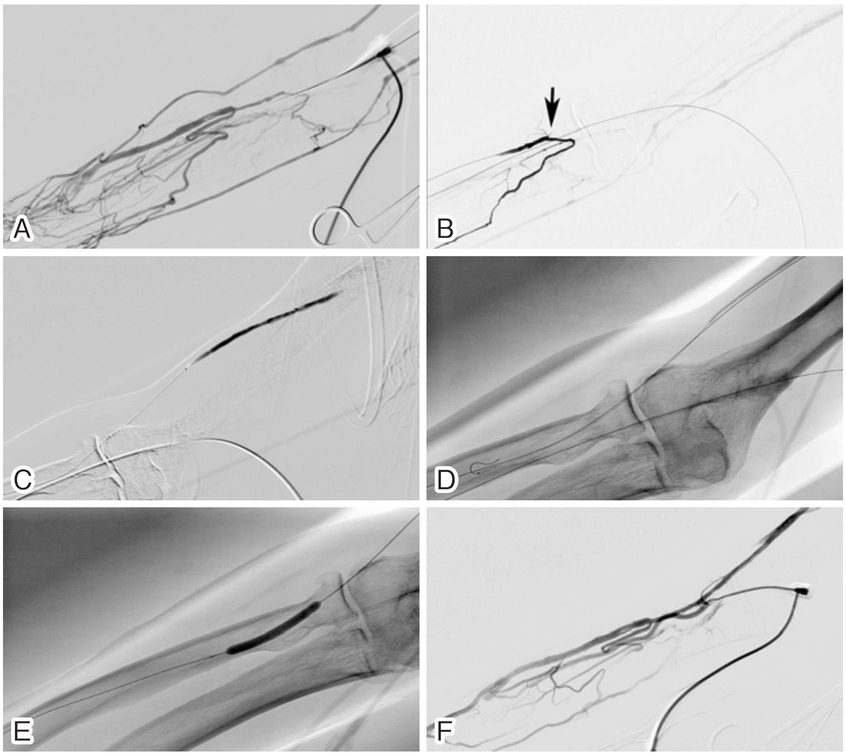

Figure 11. Transvenous VAIVT for non-thrombotic occlusion.
A: Initial brachial arteriography showed total occlusion of the main outflow vein and development of collateral flows. B: Venography performed through the microcatheter shows occlusion of the main outflow vein (arrow). C: The microcatheter could traverse the occluded segment. D: A balloon catheter could not be passed through. Therefore, a retrograde puncture of the cephalic vein was performed, and the microcatheter was advanced through the occluded segment. E: The balloon catheter could be passed through the occluded segment via the venous route, and PTA was performed. F: Final arteriography showed the recanalization of the occluded segment and a decrease in the collateral flows.

several attempts, the site downstream of the occluded segment is punctured and retrograde crossing should be attempted. Despite successful penetration of the microcatheter, the advancement of a balloon catheter through the NTO lesion may be sometimes difficult because of the complete vessel collapse. When the balloon catheter cannot be advanced through the occlusion via the brachial arterial approach, the transradial or venous approach facilitates the advancement of a balloon catheter along the straight pass (**Fig. 11**). A low-profile balloon catheter (Saber, Cordis, Cardinal Health) also facilitates crossing the tight lesions.

VAIVT for a non-mainstream venous route

PTA for a non-mainstream venous route is a skill for restoring the non-functioning hemodialysis fistula when a mainstream outflow vein cannot be identified or traversed (**Figs. 7** and **9**). The transarterial approach makes it easier to complete this procedure because it can provide an overview of collateral flows [9]. First, a non-mainstream vein that branches near the occluded venous segment and connects to a large proximal vein is selected. The relatively straight route should be chosen for a new outflow route. Based on the direction of the non-mainstream venous route, another 4-F sheath is placed, if necessary. The microcatheter is advanced into the large proximal vein through the non-mainstream vein, and the route is dilated using a balloon catheter. A pull-through guidewire technique is also used to advance the balloon catheter if the route is tortuous. PTA for immature veins carries a risk of venous dissection and rupture; therefore, the use of a small balloon catheter (e.g. ≤ 5 mm) is recommended [9].

Figure 12. Axillary origin of the radial artery (arrow).

Indication for stent placement

The placement of a metallic stent should only be considered when the fistula flow cannot be maintained due to residual stenosis, repeated re-stenosis within 3 months, or vessel injury (**Fig. 5**) [2]. A self-expandable uncovered stent is recommended because it is flexible, and it is not destructed by external forces. A covered stent can also salvage pseudoaneurysms. However, the venous approach is usually required to deploy a stent because it is mounted in the large catheter.

Pitfalls of arterial approach via the brachial artery

An axillary origin of the radial artery has been reported in 1.2-5% of cases in addition to the reported high origin of the radial artery from the brachial artery in 10-19.2% of cases (**Fig. 12**) [10]. In these cases, multiple arterial punctures, as well as ultrasound examination of the upper limb, may be required (**Fig. 13**). Changes in radial artery palpation under manual compression of the brachial artery is useful for surmising this anomaly.

Complications

Complications, such as local hematomas and pseudoaneurysms, mainly occur at the arterial puncture site due to in-

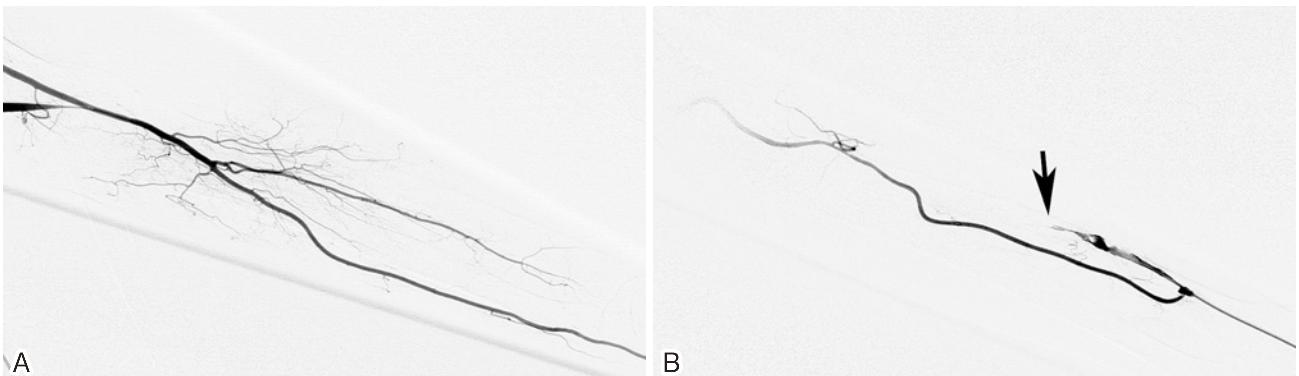

Figure 13. High origin of the radial artery.
A: Brachial arteriography showed no fistulas. Additionally, the radial artery was not demonstrated.
B: The radial artery was punctured at the wrist and arteriography showed an occluded hemodialysis fistula (arrow).

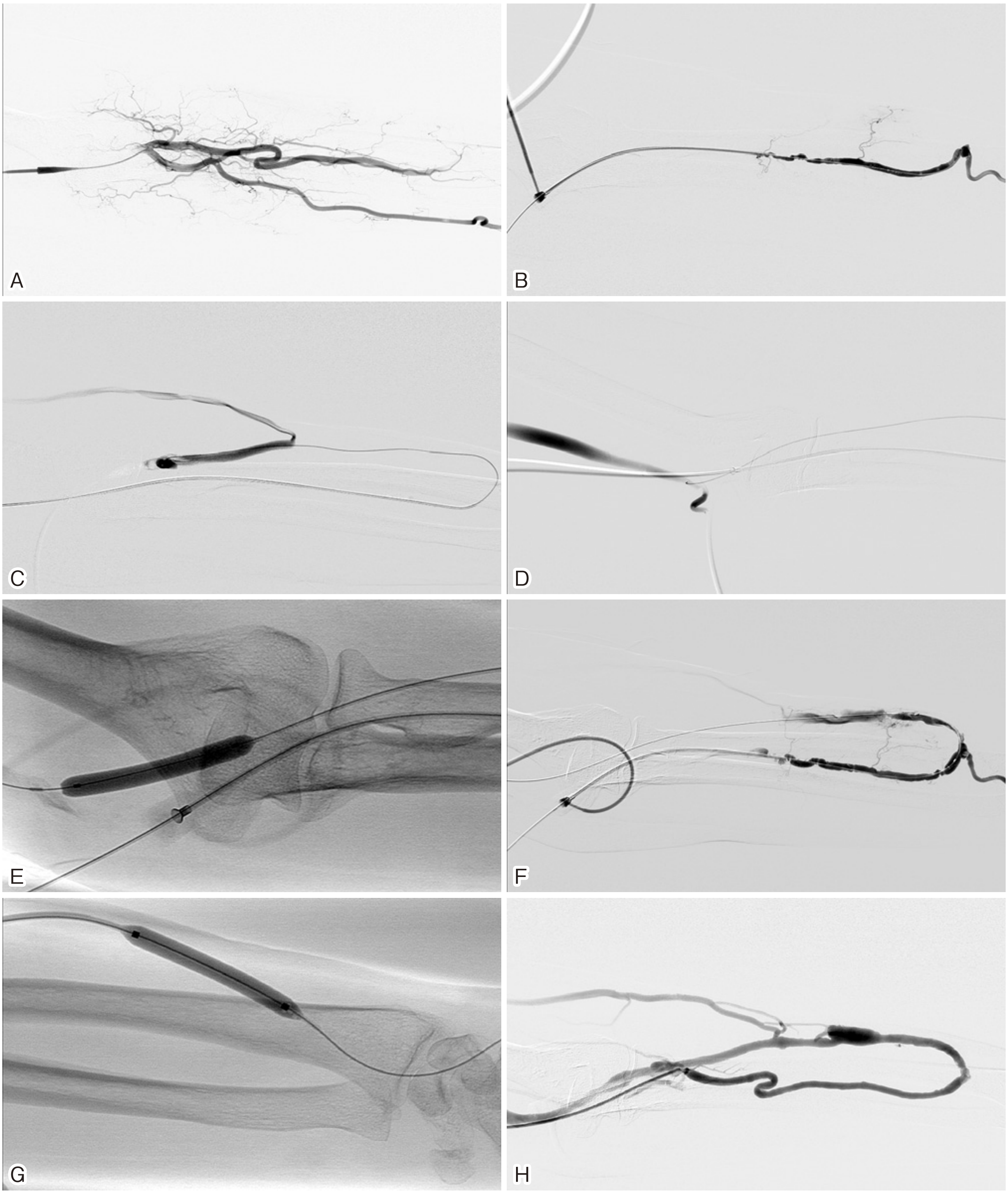

Figure 14. Decrease in radial arterial flow due to vessel stretching and spasm during transbrachial VAIVT.
A: Initial brachial arteriography showed total occlusion of the fistula at the anastomosis. The radial artery was also very tortuous. B: A 4.2-F catheter was distally advanced, and the radial artery was stretched by the catheter. C, D: The occluded segment was traversed by a microcatheter. E: PTA was performed. F: Arteriography performed immediately after PTA showed the stasis of blood flow due to vessel stretching and spasm. Therefore, a retrograde puncture of the non-affected outflow vein was performed and the balloon catheter in the radial artery was withdrawn. G: PTA was repeated via the venous route. H: Final arteriography showed the restoration of the fistula and the disappearance of the stretching of the radial artery.

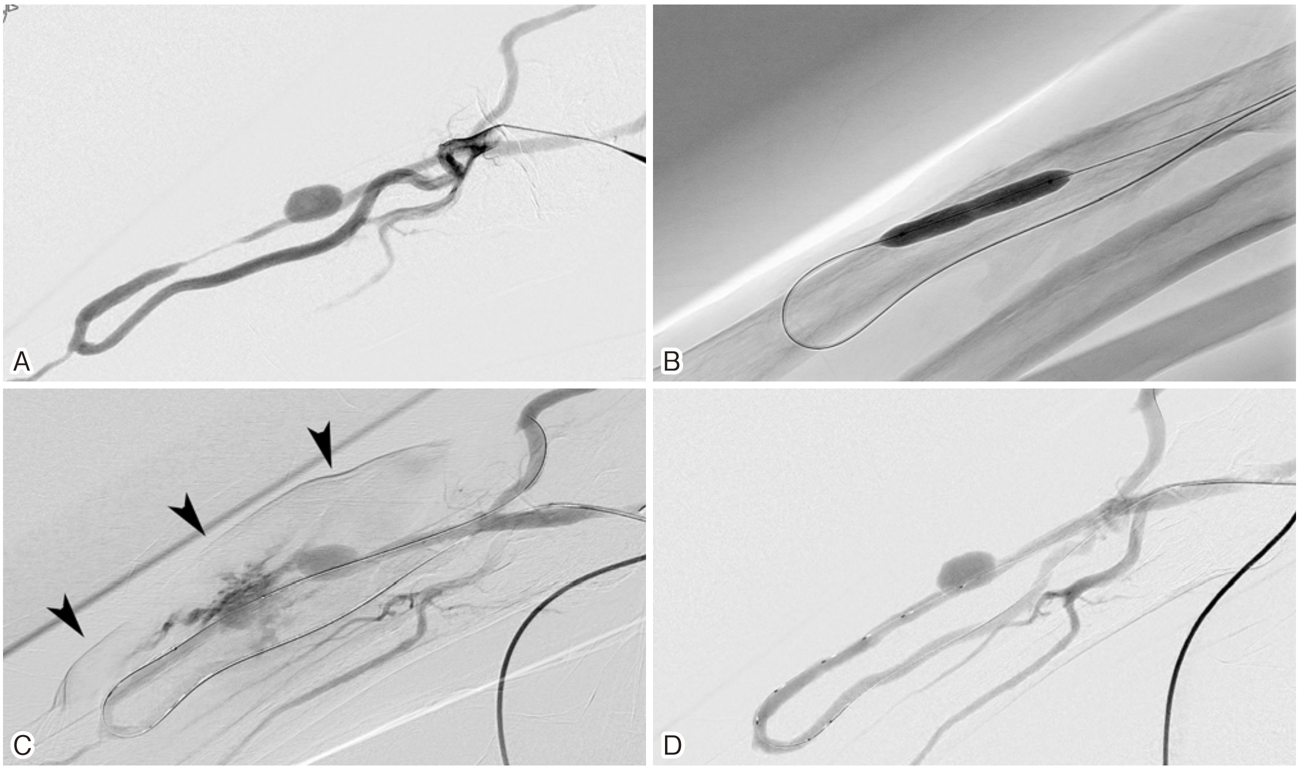

Figure 15. Vessel rupture during VAIVT.
A: Initial brachial arteriography showed severe stenosis in the venous segment. B: PTA was performed at 14 atm. C: Arteriography performed immediately after PTA showed extravasation of contrast material and hematoma (arrowheads) due to vessel rupture. D: Final arteriography performed after manual external compression and intermittent balloon inflation at 4 atm in the ruptured vein for 45 minutes (3×10 minutes and 3×5 minutes) showed the disappearance of extravasation and improvement of the stricture.

sufficient manual compression. The reported incidence of hemorrhagic complications was 4% in patients with a 4-F sheath [4] and 12% in patients with a 5- or 6-F sheath [3]. The rate of major complications requiring surgical intervention, such as persistent bleeding and pseudoaneurysms, was 4% in patients with a 5- or 6-F sheath [3]. In cases with a tortuous radial artery, a catheter in the radial artery stalls the arterial flow due to vessel stretching and spasm. In such a situation, another approach route should be created to withdraw the device from the radial artery (**Fig. 14**). Intraarterial injection of 1-2 mg of nitroglycerin is also required for vascular spasm with arterial flow delay. The migration of a thrombus into the distal artery during the pulling back of the balloon catheter can also develop. When ischemic symptoms occur, the injection of urokinase or thromboaspiration should be performed. Moreover, other complications related to VAIVT may develop, which included vessel rupture and/or acute occlusion of the dilated vein, especially following the use of an over-sized balloon catheter and/or dilatation with excessively high pressure. If vessel rupture occurs, prolonged inflation of the balloon catheter for 5-10 minutes at 4-8 atm at the rupture point and external manual compression should be performed (**Fig. 15**). The procedure should be repeated until the extravasation of contrast material ceases. Pulmonary embolism, even paradoxical cerebral embolism, is the most severe complication of VAIVT for thrombotic occlusion, and the use of urokinase before PTA can reduce the risk [6].

Conclusion

Transarterial VAIVT is a safe and effective procedure for non-functioning hemodialysis access. It can simplify the VAIVT procedure with high success rates, and radiologists should be familiar with the techniques.

Conflict of interest: The authors declare that they have no conflicts of interest to report.

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