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Management of Complications during Below-the-Knee Endovascular Treatment: A Technical Note

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We retrospectively reviewed the cases in which complications occurred during below-the-knee (BTK) endovascular treatments that were performed at our hospital from 2005 to 2014. Several interesting cases have been described herein. All the patients had diabetes and non-healing wounds on their feet and/or rest pain in their foot or leg, and therefore, endovascular treatment was performed for the BTK arteries of the affected lower extremity. The complications that occurred during the procedure were classified into six categories—vascular spasm, flow limiting dissection, perforation, broken guidewire, distal thromboembolism, and unusual puncture site bleeding. Each complication has its own solutions and management. We discuss these different classes of complications and describe how cases of each type were managed.

Keywords: *Diabetes; Angioplasty; Complication*

INTRODUCTION

Critical limb ischemia (CLI) is defined as the presence of ischemic rest pain, non-healing ulcers, or gangrene (1-6). It often occurs in conjunction with diabetes, chronic renal insufficiency, and other co-morbidities (1-6). Particularly, typical below-the-knee (BTK) arterial disease in patients with diabetes is characterized by a long, multilevel disease involving the anterior tibial artery (ATA), posterior tibial artery (PTA), peroneal artery, or all three of these BTK vessels. The impairment of peripheral perfusion in specific areas can lead to necrosis of diabetic foot ulcers, which can ultimately necessitate an amputation (1-6). Hence, successful treatment of the vascular lesions is very important.

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In recent years, endovascular therapy has become the treatment of choice for BTK arterial diseases, especially in patients at a high risk of or contraindications for surgical treatment (4-7). Therefore, endovascular revascularization is becoming increasingly recognized as the most appropriate treatment for BTK arterial diseases to improve wound healing and to relieve rest pain in patients with diabetes (4-8). However, since the BTK vessels are very small (< 5 mm) and usually have multifocal or long-segment steno-occlusive lesions, BTK endovascular treatments is technically difficult (5, 6). Therefore, many interventionists use various devices such as dedicated 0.018-inch or 0.014-inch guidewires, support catheters, and guiding sheaths (4-6). Moreover, various treatment strategies have been introduced for antegrade access in addition to retrograde transmetatarsal or transplantar arch accesses (8-11). Although these strategies have contributed to an increase in the technical success rate of BTK endovascular treatment, the procedure is still associated with many technical difficulties, which may result in various complications during the procedure (8-11). In previous studies, complications during BTK endovascular treatment have been reported in 2–10% of cases (1, 5, 6), and the frequency of complications varied among the studies. The most frequently reported complications were vessel occlusion

(due to dissection or a thrombotic event), vessel spasm, puncture site hematomas, and access site bleeding (1, 5, 6).

In this report, we preferentially reviewed the cases of complications that occurred during BTK endovascular treatment. Accordingly, the complications that could occur during BTK endovascular treatment were classified, and we herein describe the management of each of these complications.

Patients and Procedures

We retrospectively reviewed the all cases of complications that occurred during BTK endovascular treatment at the authors' hospital from 2005 to 2014. We have performed a large number of endovascular treatments for the lower extremity arteries, including the BTK vessels. From these cases, we included those in which complications occurred during the procedure. All the patients who underwent BTK endovascular treatment had diabetes and non-healing wounds on their feet and/or rest pain in the foot or leg.

All patients underwent a CT angiography to detect the BTK lesions before the interventional procedure. Endovascular procedures were performed under local anesthesia by interventional radiologists in an interventional radiology suite. The vital signs of the patients were monitored throughout the procedure. In most of the cases, the common femoral artery (CFA) was punctured using a Micropuncture Set (Cook Medical, Bloomington, IN, USA) under ultrasound guidance and sheath insertion was performed. Angiography using non-ionic contrast medium or carbon dioxide (for patients with poor renal function) and digital subtraction angiography were performed through the sheath to evaluate entire lower extremity arteries. In addition to those with only BTK artery lesions, some patients had lesions in the ilio-femoro-popliteal arteries. Although all affected arteries were treated in these patients, this report only investigated the treatment of BTK arteries. The steno-occlusive lesions of the BTK arteries were crossed using dedicated 0.018-inch (V18, Boston Scientific Inc., Marlborough, MA, USA) or 0.014-inch (Command ES, Abbott, Santa Clara CA, USA) guidewires. A support catheter (TrailBlazer support catheter, Medtronic, Minneapolis, MN, USA) and a guiding sheath (4-Fr Ansel Guiding Sheath, Cook Medical) were used to provide better support.

We initially attempted an antegrade approach by puncturing the CFA. In cases with restricted or no access through the CFA, we attempted retrograde access via the distal BTK vessels. In some cases, a pedal or plantar artery approach was also attempted. The BTK lesion was passed using these approaches and balloon angioplasty was then performed. During the procedure, complications were detected with a follow-up angiogram and appropriately managed. At the end of the procedure, we confirmed the establishment of blood flow in at least one BTK artery to ensure perfusion to the patient's foot.

Classification of Complications

Vascular Spasm

The first complication to develop is vascular spasm, which may occur after balloon angioplasty in stenotic or occluded vessels (1, 5-7). Moreover, spasms may be caused in the healthy blood vessels located in front of and behind the lesion during guidewire or balloon manipulation. Prevention of vasospasm requires careful manipulation of the guidewire as it passes through the normal vessel, and ensuring that unnecessary segments are not included in the balloon angioplasty. Vascular spasm is managed by intra-arterial injection of nitroglycerin or prostaglandin E1 into the affected blood vessels to induce vessel dilatation. Usually, vascular spasm improves over time, but these vasodilators may be administered to enable differential diagnosis of the residual stenosis concomitantly with the treatment. Another solution is the inflation of the angioplasty balloon for 5 to 15 minutes. The following case report summarizes several cases of vascular spasm and their management.

A 60-year-old male patient with diabetes had an ulcer on the right foot and chronic rest pain in the left foot that developed 2 years ago. Angiography results showed a long-segment steno-occlusive lesions in his right ATA and PTA (Fig. 1A). We performed BTK endovascular angioplasty using a balloon of 12 cm length and 2.5 mm diameter (Amphirion Deep, Medtronic) in the occlusive long segment of the distal PTA (Fig. 1B). Subsequently, a short-segment flow defect was observed in the distal PTA and vascular spasm was suspected, including in a segment that appeared normal on angiograms acquired before the balloon angioplasty (Fig. 1C). After intra-arterial injection of nitroglycerin (Nitroglycerin Diluted, Unipharm Korea, Seoul, Korea; 200 μg/mL; 3 mL) and prostaglandin (Alprostadil, Mitsubishi Tanabe Pharma Korea Co., Ltd., Hwaseong, Korea; 5 μg/mL; 1 mL) through a microcatheter, the spasm improved (Fig. 1D). Separate nitroglycerin (3 mL) and prostaglandin (1

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mL) injections were administered at the same time.

The second patient was a 72-year-old male with diabetes who had been experiencing chronic rest pain in his left foot for a few years. The pain had worsened recently and discoloration occurred after acupuncture. Angiography results showed multifocal, long-segment occlusive lesions in the femoropopliteal artery and the BTK arteries. During the procedure, mid to distal PTA flow was not observed and vascular spasm occurred (Fig. 2A). Intra-arterial nitroglycerin (200 μg/mL; 3 mL) and prostaglandin (5 μg/mL; 1 mL) injections were administered through a 5-Fr sheath. However, there was no response. Subsequently, a 2 mm x 15 cm balloon inflation (Amphirion Deep) was performed for 2 minutes, and then for 5 minutes, but a residual flow defect occurred in the distal PTA (Fig. 2B, C). This lesion recovered completely after an additional 10 minutes of inflation with the same balloon (Fig. 2D).

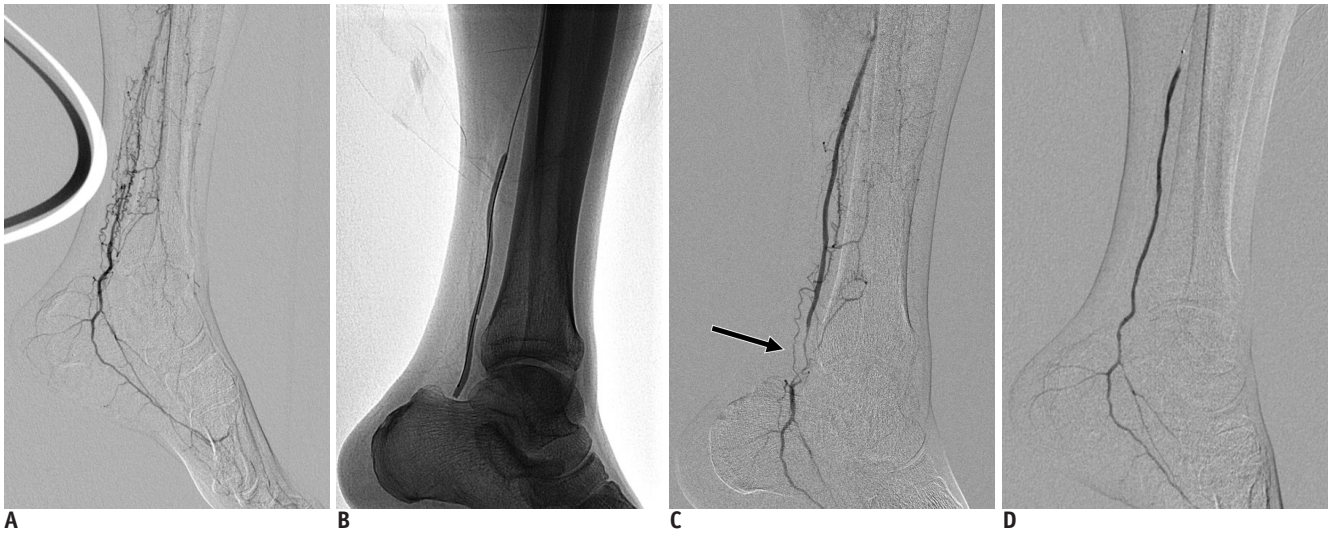

Fig. 1. 60-year-old male patient with underlying diabetes had ulcer on right foot and chronic rest pain in left foot.
A. Angiography showed long-segment steno-occlusive lesions in his right ATA and PTA. **B.** We performed BTK endovascular angioplasty using balloon of 12-cm length and 2.5-mm diameter (Amphirion Deep, Medtronic) in occlusive long segment of distal PTA. **C.** Subsequently, short-segment flow defect (arrow) was observed in distal PTA and vascular spasm was suspected, including in portion that appeared normal on angiography performed before balloon angioplasty. **D.** Spasm improved after intra-arterial injection of nitroglycerin (200 μg/cc; 3 cc) and prostaglandin (5 μg/cc; 1 cc). ATA = anterior tibial artery, BTK = below-the-knee, PTA = posterior tibial artery

Fig. 2. Patient was 72-year-old male with diabetes who had been experiencing chronic rest pain in his left foot for few years.
A. During endovascular treatment procedure, mid to distal PTA flow was not observed and vascular spasm occurred. **B, C.** 2 mm x 15 cm balloon inflation (Amphirion Deep) was performed for 2 minutes, and then for 5 minutes, but residual flow defect was detected in distal PTA. **D.** This lesion recovered completely after additional 10 minutes of inflation with same balloon.

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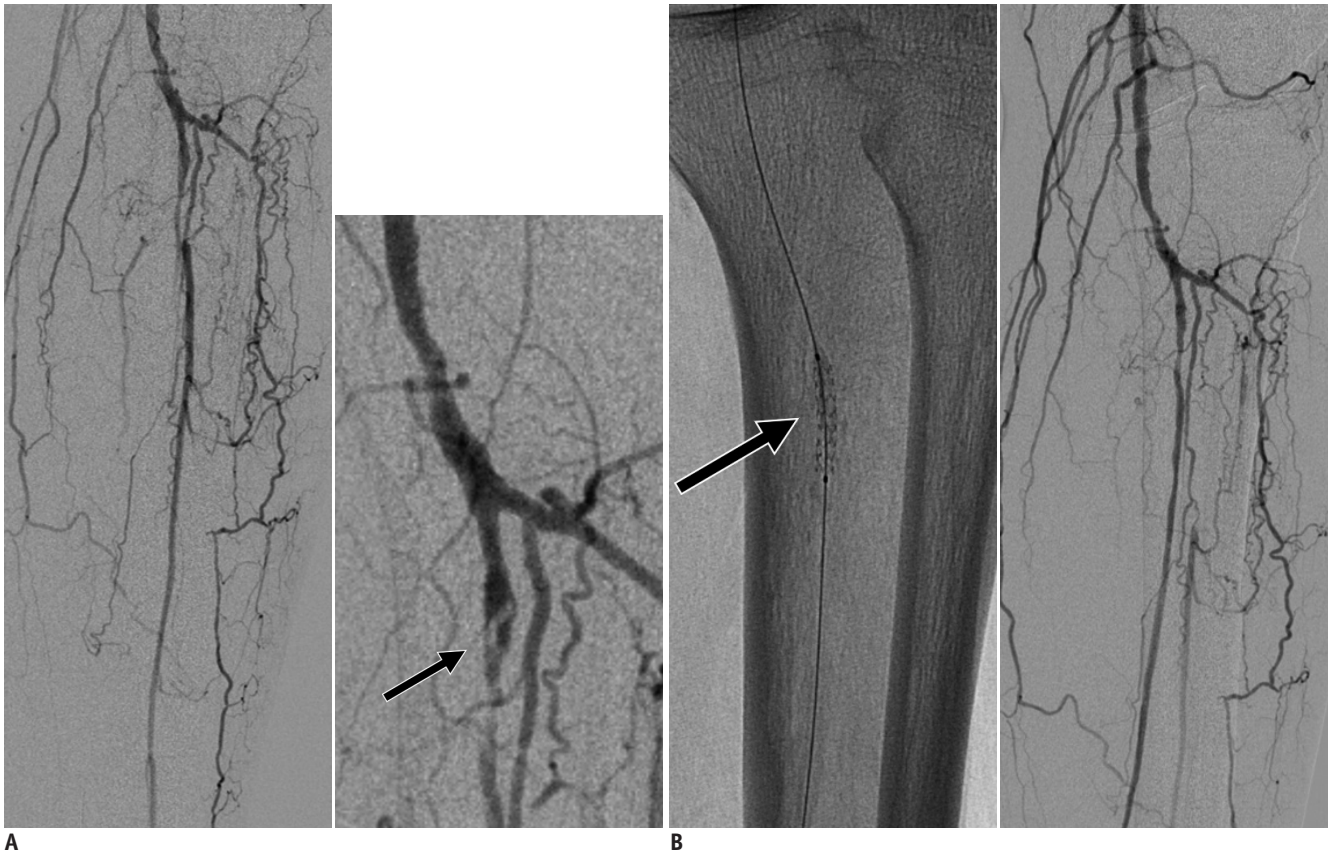
Flow-Limiting Dissection

Vessel dissection is a common complication after balloon angioplasty (1, 5-7). It frequently occurs after balloon angioplasty of heavily calcified vessels. Vessel dissection can also occur in cases when an oversized balloon is used in comparison to the vessel diameter, or in angioplasty procedures conducted in segments with chronic occlusion. Most cases of vessel dissection, with the exception of flow-limiting dissections, do not require additional treatment. Flow-limiting dissections can be resolved by stent placement. However, there are no adequate small-caliber stents that can be used in the BTK vessels, unlike in the femoropopliteal artery. The alternative that can be used in such situations is a coronary stent. The following report summarizes a case of flow-limiting dissection and its management.

A 69-year-old male patient with diabetes and hypertension was admitted with the primary symptoms of rest pain and coldness in his left foot. Angioplasty was performed for a long-segment occlusion of the PTA with a 2.5 mm x 12 cm balloon (Amphirion Deep). After 15 minutes of inflation, a follow-up angiography showed no flow below the proximal PTA and dissection in the proximal PTA (Fig. 3A). A 3 mm x 18 mm drug-eluting coronary stent (Cypher Select, Cordis, Miami Lakes, FL, USA) was deployed on the lesion and the flow was restored (Fig. 3B). Doppler ultrasonography scan at 14-month follow-up revealed that the stent patency was well maintained.

Perforation

Perforation usually occurs during guidewire manipulation rather than during balloon angioplasty. It can occur in the main arteries as well as in the branch vessels. During guidewire manipulation, the main artery or branch may be directly injured by the guidewire, and the guidewire end tip may inadvertently injure the distal vessel as the balloon is advanced and removed along the guidewire. The risk of vessel perforation during guidewire passage is decreased



A B

Fig. 3. 69-year-old male patient with diabetes and hypertension was admitted with primary symptoms of rest pain and coldness in his left foot.

A. Angioplasty was performed for long-segment occlusion of PTA with 2.5 mm x 12 cm balloon (Amphirion Deep). After 15 minutes of inflation, follow-up angiography showed no flow below proximal PTA and dissection (arrow) in proximal PTA. **B.** 3 mm x 18 mm drug-eluting coronary stent (arrow; Cypher Select, Cordis) was deployed on lesion and flow was restored.

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by subintimal passage of the guidewire, which can be confirmed by looping the end of the guidewire with a real-time fluoroscopy system. During the procedure, the tip of the guidewire must be thoroughly checked. To prevent BTK vessel injury when treating femoropopliteal artery lesions, it is advisable to replace the guidewire with J-tip (Rosen wire guide, Cook Medical) after passage through the lesion. In most cases of perforation, the amount of bleeding is not significant. However, unrecognized vascular injury or perforation may cause massive bleeding or compartment syndrome of the affected lower extremity. Therefore, the angiography findings must be carefully studies during the procedure, particularly those of the vessels through which the guidewire has passed.

If the amount of bleeding resulting from the perforation is small, external compression of the bleeding site is enough to resolve the issue. If the perforated vessel is undergoing angioplasty, a balloon tamponade can be performed using the balloon catheter in use, and embolization can be performed for branch vessels that can be selected by a microcatheter. Possible embolic materials include gelatin foam particles, n-butyl cyanoacrylate glue, and coils. We have typically employed gelatin foam particles because it is easy and safe to use. Additionally, the injection of a heparin antagonist may be helpful. In contrast, the usefulness of a stent graft in these cases is controversial. Below, we describe three perforation cases that were managed using different solutions.

BTK endovascular treatment was performed in a 54-year-old male diabetic patient who had an ulcer on his right big toe. Vessel perforation occurred during subintimal passage of the guidewire through the occlusive segment of the right PTA (Fig. 4). After confirming contrast leakage on angiogram, we retracted the guidewire to a site proximal to the perforation and advanced the guidewire into another subintimal channel (Fig. 4). When balloon angioplasty was performed through this new subintimal channel, it induced a balloon tamponade effect on the perforated site and

Fig. 4. 54-year-old male diabetic patient had ulcer on his right big toe. During subintimal passage of guidewire through occlusive segment of right PTA, vessel perforation occurred. After confirming contrast leakage on angiogram, we retracted guidewire to site proximal to perforation and advanced guidewire in another subintimal channel. When balloon angioplasty was performed through this new subintimal channel, it induced balloon tamponade effect on perforated site and bleeding was resolved.

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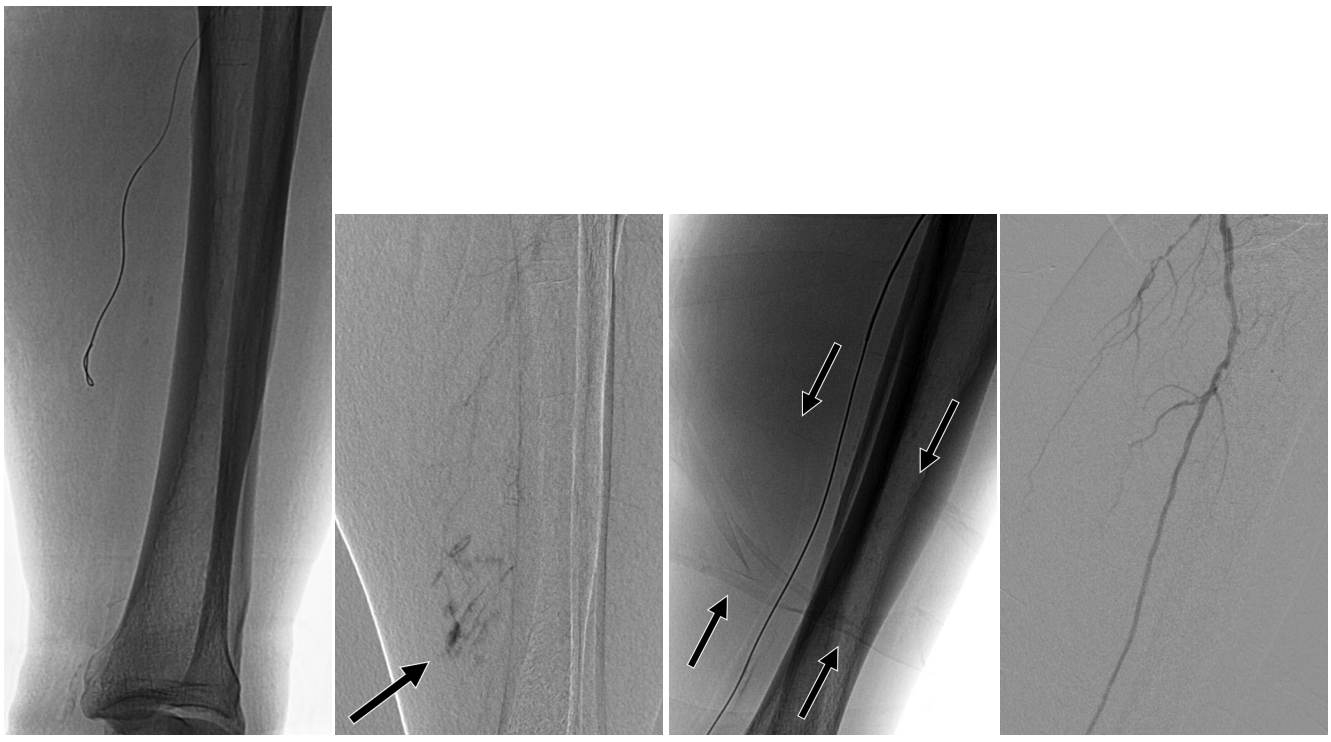

A B

Fig. 5. 70-year-old male diabetic patient had long-segment steno-occlusive lesions in his bilateral BTK vessels.
A. Perforation occurred (arrow) at branch of mid-PTA during guidewire advancement. **B.** Bleeding was resolved after external compression of calf with elastic bandage (arrows) for 10 minutes.

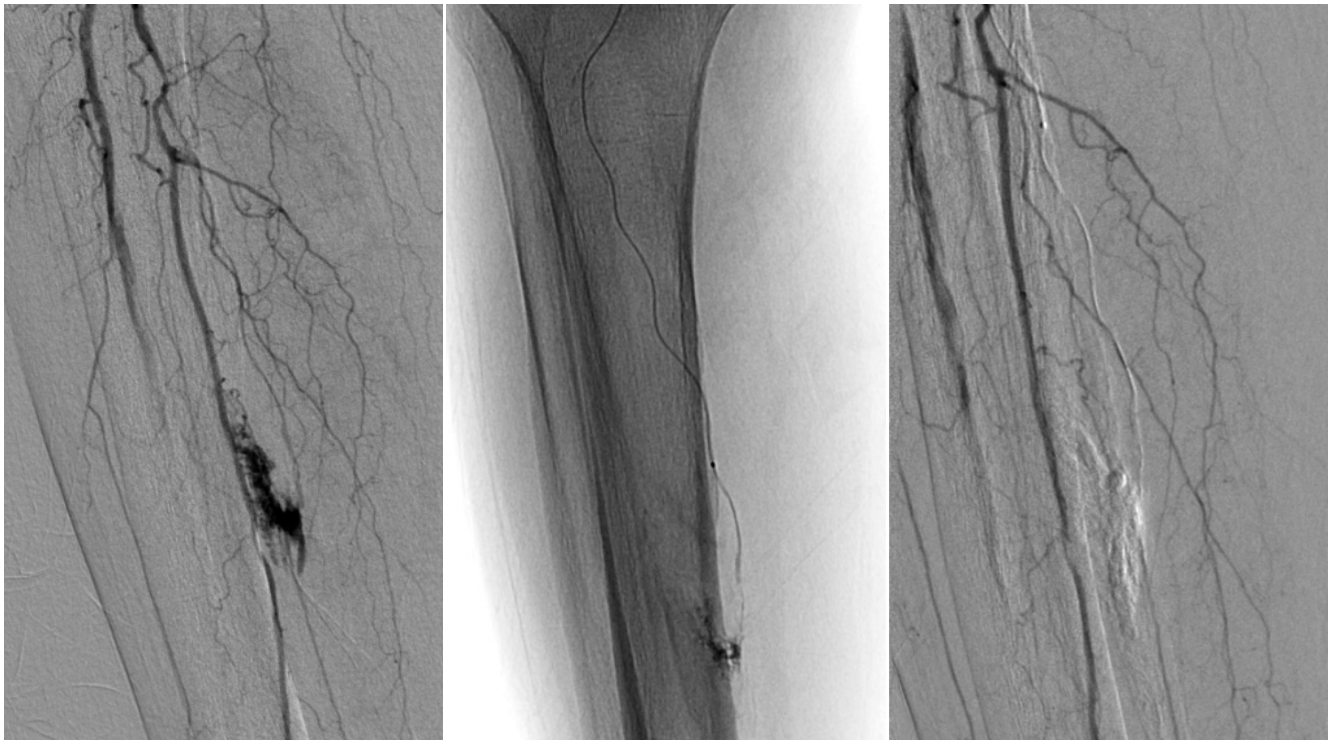

Fig. 6. 88-year-old male diabetic patient with rest pain in left foot had segment occlusive lesions in his left ATA and PTA, as well as severe stenosis in ipsilateral superficial femoral artery. Perforation of peroneal artery occurred during this procedure because non-J tip guidewire was used. Since perforated vessel diameter was large enough for microcatheter selection, direct embolization was performed using 350–560-μm gelatin foam particles (Cali-Gel, Alicon).

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bleeding was resolved (Fig. 4). Usually, balloon tamponade is performed for 3–5 minutes. However, since the contrast leakage was persistent in the follow-up angiogram in this case, tamponade was necessary for an additional few minutes.

In another case, angiography of a 70-year-old male diabetic patient revealed long-segment steno-occlusive lesions in the bilateral BTK vessels. Perforation occurred at the branch of the mid-PTA during guidewire advancement (Fig. 5A). The bleeding was resolved after external compression of the calf with an elastic bandage for 10 minutes (Fig. 5B).

An 88-year-old male diabetic patient with rest pain in the left foot had segment occlusive lesions in his left ATA and PTA, as well as severe stenosis in the ipsilateral superficial femoral artery (SFA). For treatment of the SFA lesion, a 0.035-inch guidewire was advanced below the popliteal artery. Perforation of the peroneal artery occurred during this procedure because a non-J tip guidewire was used (Fig. 6). Since the perforated vessel diameter was large enough for microcatheter selection, a direct embolization was performed using 350–560-μm gelatin foam particles (Cali-Gel, Alicon, Zhejiang, China) (Fig. 6). The targeted vessel was well embolized, preventing further bleeding.

Broken Guidewire

This complication occurs primarily while using a micro-guidewire (such as a 0.016-inch or 0.014-inch guidewire), which has an increased risk of breakage during excessive guidewire manipulation in long-segment occlusions or

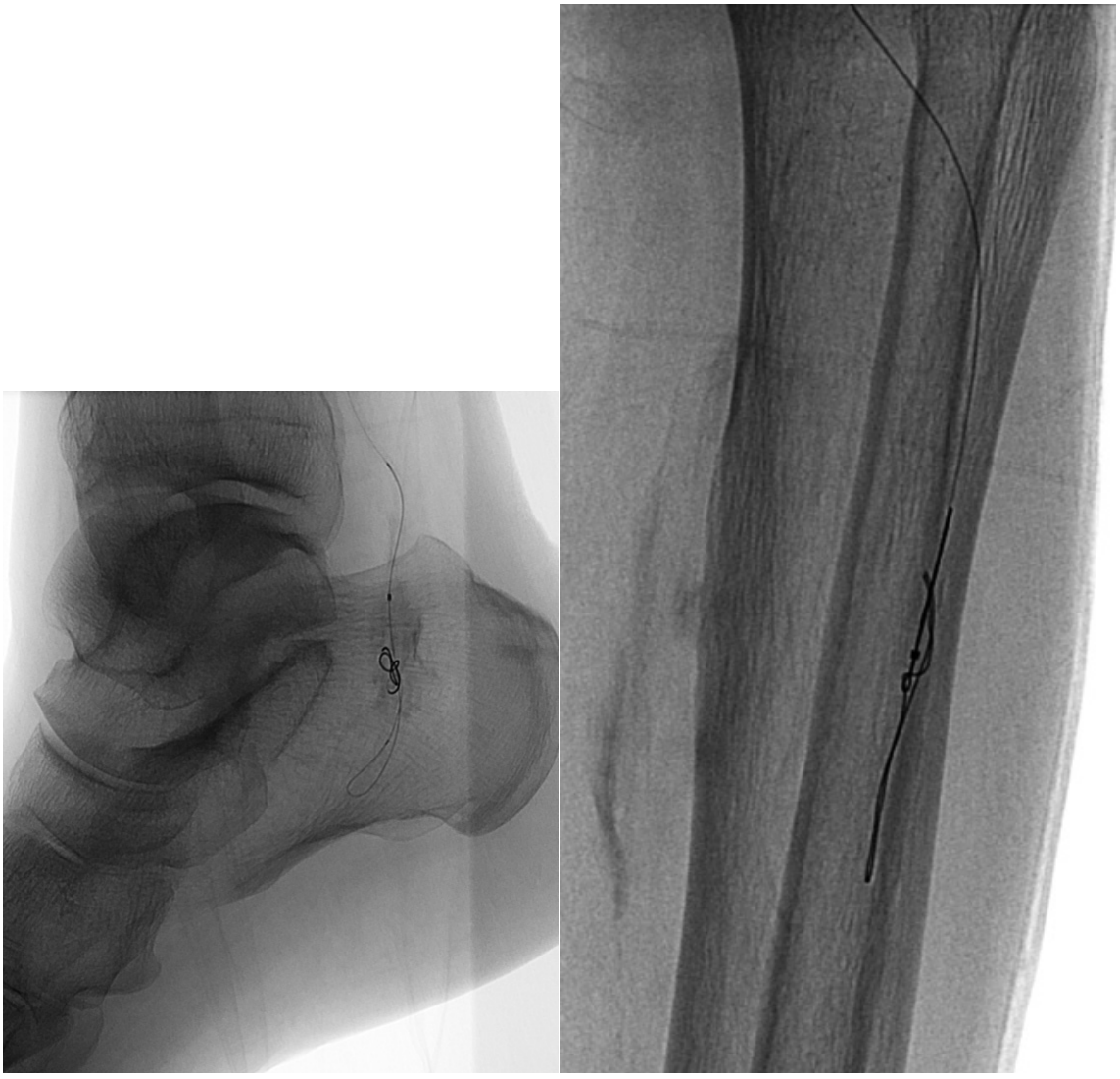

Fig. 7. 79-year-old female diabetic patient had ulcers on both of her feet. 0.016-inch guidewire used (Fathom, Boston Scientific Inc.) broke during subintimal passage through right PTA. Fortunately, fragment could be removed using snare (Amplatz Goose neck snare, Medtronic).

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heavily calcified lesions. The guidewire fragment can sometimes be removed using a foreign body retrieval device such as a snare. In some cases, the broken fragment cannot be removed and remains intact, but it rarely causes major problems. We have described instances of this complication in the following case reports.

A 79-year-old female diabetic patient had ulcers on both of her feet. A 0.016-inch guidewire (Fathom, Boston Scientific Inc.) broke during subintimal passage through the right PTA (Fig. 7). Fortunately, the fragment was removed using a snare (Amplatz Goose neck snare, Medtronic) (Fig. 7).

A 59-year-old male patient had rest pain in both of his feet. Breakage of a 0.016-inch guidewire (Fathom) occurred during subintimal passage through the occlusive segment of his left ATA (Fig. 8). This fragment could not be removed using any method. Therefore, we successfully recanalized the posterior tibial and the lateral plantar arteries instead of the ATA (Fig. 8). We decided to perform a follow-up observation and finished the procedure. Blood circulation in both feet and the wound healing improved postoperatively, without complaints of any particular symptom.

Distal Thromboembolism

Distal thromboembolism is a complication that may occur during the treatment of any arterial occlusive lesions. Distal thromboembolism in BTK arteries may occur during the endovascular treatment of the upper level artery—the ilio-femoro-popliteal artery. A high risk of a thrombotic event is associated with acute thrombotic lesions or performance of atherectomy. In such cases, the development of distal protection devices is necessary to prevent thromboembolism. However, in cases when only BTK endovascular treatment is performed, the incidence of distal thromboembolism is very low and the plaque load is small. Therefore, major problems are not observed in most cases. Distal thromboembolisms can be treated with aspiration thrombectomy using a 5-Fr Envoy guiding catheter (Codman & Shurtleff, Inc., Raynham, MA, USA) or by intra-arterial infusion of thrombolytic agents. Accurate evaluation for the presence of a superimposed acute thrombus on a chronic occlusion is of utmost importance before the treatment of arterial occlusive lesions. Precautions must be taken to prevent the occurrence of distal embolism during the procedure. New filling defects or flow defects should be

Fig. 8. 59-year-old male patient had rest pain in both of his feet. Breakage of 0.016-inch guidewire (Fathom) occurred during subintimal passage through occlusive segment of his left ATA. We performed successful recanalization of posterior tibial and lateral plantar arteries instead of ATA.

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assessed in the follow-up angiogram and complain of sudden leg pain should be promptly addressed. One case report of distal thromboembolism is discussed below.

A 79-year-old male diabetic patient had ulcers on both of his feet. A focal embolism was detected in the distal ATA during an angioplasty for total occlusion of the ATA with a 2.5 mm x 12 cm balloon (Fig. 9). The embolism was resolved after aspiration thrombectomy using a 5-Fr Envoy guiding catheter (Fig. 9).

Puncture Site Bleeding from Retrograde Access

Puncture site bleeding can occur when retrograde puncture is performed. A micropuncture needle is used to puncture distal BTK vessels such as the dorsalis pedis artery, lateral plantar artery, and transmetatarsal artery, under ultrasound or fluoroscopy guidance (9-11). Bleeding may occur in these punctured vessels or in any vessels in the puncture pathway. The more the number of punctures attempted and the thicker the needle, the higher the risk of bleeding. However, bleeding can be resolved by external compression because most punctures are performed by selecting the superficial arteries of the calf and foot. Manual compression is often applied during the procedure and elastic bandages are applied postoperatively. In some cases, balloon tamponade may be useful, whereas in others, postoperative monitoring alone is sufficient. The nature of the intervention required depends upon the amount of bleeding and the location of the damaged blood vessel. We describe a case of puncture site bleeding below.

A 77-year-old male diabetic patient presented with primary symptoms of rest pain and coldness in the right foot. The right distal PTA showed relatively good flow, but occlusion was present at the origin of the PTA without a proximal stump. A retrograde puncture was performed using a Micropuncture Set (Cook Medical) on the distal PTA at the ankle level (Fig. 10A). Angioplasty was successfully

Fig. 9. 79-year-old male diabetic patient had ulcers on both of his feet. Focal embolism (arrow) was detected in distal ATA during angioplasty for total occlusion of ATA with 2.5 mm x 12 cm balloon. Embolism was resolved after aspiration thrombectomy using 5-Fr Envoy guiding catheter (Codman & Shurtleff, Inc.).

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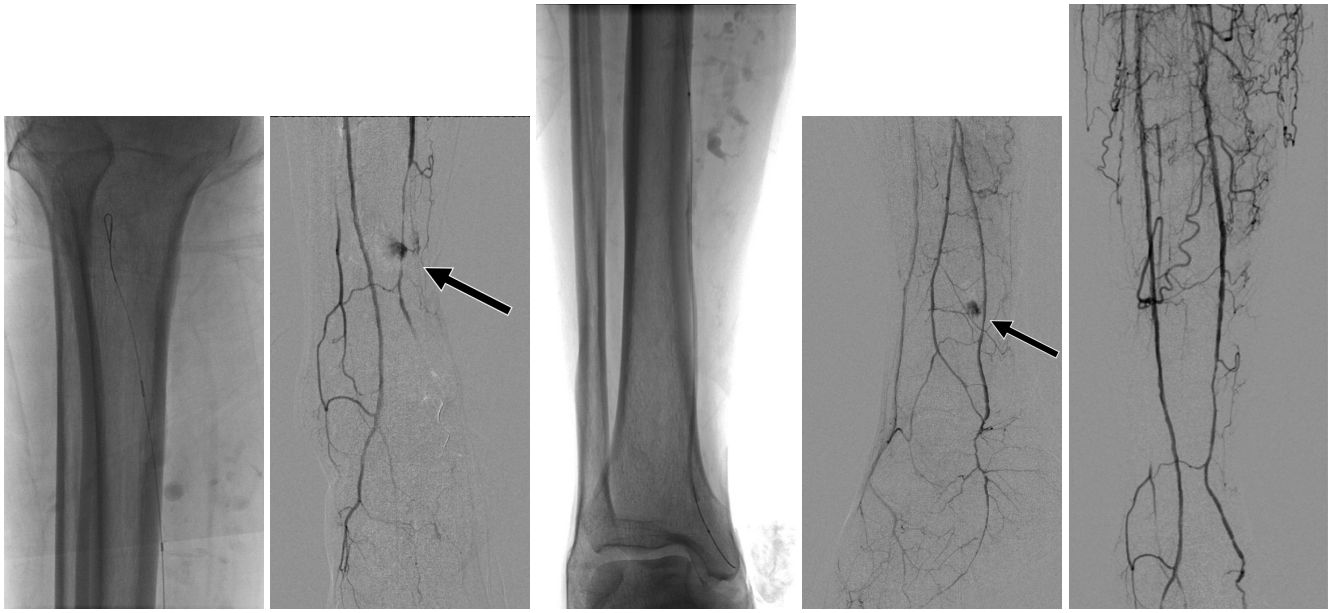

Fig. 10. 77-year-old male diabetic patient presented with primary symptoms of rest pain and coldness in right foot.
A. Retrograde puncture was performed using Micropuncture Set (Cook Medical) on distal PTA at ankle level. **B.** However, contrast leakage (arrow) was observed on follow-up angiography at anterior aspect of ankle. **C, D.** This was considered to be due to retrograde puncture site bleeding. Balloon tamponade using 2.5 mm x 22 cm balloon was performed for 15 minutes, but small amount of bleeding persisted (arrow). **E.** After manual external compression of patient's ankle for 10 minutes, bleeding stopped completely.

performed after passage of the guidewire through the entire PTA. However, contrast leakage was observed on follow-up angiography at the anterior aspect of the ankle (Fig. 10B), presumably due to a retrograde puncture site bleeding. Balloon tamponade was performed using a 2.5 mm x 22 cm balloon for 15 minutes, but a small amount of bleeding persisted (Fig. 10C, D). After manual external compression of the patient's ankle for 10 minutes, the bleeding stopped completely (Fig. 10E). These finding suggests that the bleeding was not from the punctured vessel itself, but from a small branch along the pathway of the puncture route.

CONCLUSION

The present report describes six type of complications that can occur during BTK endovascular treatment, and their management. Complications that arise during BTK endovascular treatment cannot be classified as common or rare. Occasionally, these complications might be difficult to manage and embarrassing to deal with. They may also interfere with the active BTK endovascular treatment as the interventionist has to manage them during the procedure. However, it is important to recognize that most of these complications can be completely resolved. Therefore, we have described the complications that have occurred during our clinical experience and described their management. Familiarity with the complications that may occur during BTK endovascular treatment and the management of these complications should be helpful for surgeons treating patients with CLI. Successful BTK endovascular treatment reduces ischemic rest pain of the limbs, helps wound healing in patients with CLI, and enables operators to salvage the affected limb.

Conflicts of Interest

The authors have no potential conflicts of interest to disclose.

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