Collateral artery bypass in the infrapopliteal segment

Ai Tochikubo, MD, Atsuhiro Koya, MD, Daiki Uchida, MD, PhD, Yuki Tada, MD, Shinsuke Kikuchi, MD, PhD, *and* Nobuyoshi Azuma, MD, PhD, *Hokkaido, Japan*

ABSTRACT

A 74-year-old man with diabetes and end-stage renal failure on regular dialysis required revascularization for gangrene of multiple toes and a heel ulcer on the right foot with chronic limb-threatening ischemia. However, the anterior tibial artery, posterior tibial artery, and peroneal artery, which are the usual targets below the knee, showed obstruction or calcification and were considered inappropriate bypass targets. Instead, a collateral artery developed along the area of the posterior tibial artery, and bypass surgery was performed with this artery. This is a case report showing successful collateral artery bypass grafting in the distal infrapopliteal segment. (J Vasc Surg Cases and Innovative Techniques 2021;7:30-4.)

Keywords: Infrapopliteal arterial lesions; Collateral bypass; Chronic limb-threatening ischemia

Chronic limb-threatening ischemia (CLTI) can be overcome through optimal revascularization and wound management. In particular, diabetes mellitus and end-stage renal disease are significantly associated with a poor prognosis and delayed wound healing.[1,2] Patients with CLTI with these comorbidities have a high incidence of severely calcified and atherosclerotic segments in the infrapopliteal arteries, resulting in difficulty with endovascular therapy and the requirement of bypass grafting to the arterial segment.[3-5] It is well known that the quality of life of these patients is poor.[6] The medial sural artery and descending genicular artery were previously reported as targets of collateral bypass grafting.[7,8] We describe a patient who experienced extensive gangrene involving the forefoot and a heel ulcer due to CLTI without a suitable recipient artery for anastomosis in the foot segment and required distal bypass to the collateral artery in the distal infrapopliteal segment. The patient provided consent at the time of discharge for information to be used for research and publication.

CASE REPORT

A 74-year-old man was admitted to our hospital for CLTI treatment. Ulcers had formed on multiple toes of his right foot 1 month prior, and extensive gangrene involving the forefoot had developed (Fig 1, *A*). Although he was ambulatory before the onset of CLTI, he used a wheelchair at the admission due to foot pain. He had end-stage renal disease and was on regular hemodialysis due to diabetic nephropathy. The skin perfusion pressure (SPP) was 17, 24, and 41 mmHg on the dorsal, medial, and lateral plantar surfaces, respectively. His right foot appeared red, with a high C-reactive protein value (14.5 mg/dL). The Wound, Ischemia, and foot Infection (WIfI) classification indicated clinical stage 4 (W3, I3, fI2). Computed tomography showed severe calcifications extending from the common iliac artery to the foot arteries (Fig 1, *B*). Intra-arterial digital subtraction angiography (IADSA) demonstrated two stenotic lesions in the popliteal arterial segment. Only the peroneal artery (PA) was patent, and the other two infrapopliteal arteries exhibited chronic total occlusion. There was no suitable recipient artery for anastomosis in the foot segment (Fig 1, *C*). Interestingly, a collateral artery developed along the area of the posterior tibial artery. Revascularization was chosen to improve foot ischemia. First, endarterectomy with patch plasty was performed because of the significant stenotic lesions in the popliteal segment with the objective of increasing arterial inflow into the infrapopliteal arterial segment (Fig 2, *A*). The forefoot was subsequently amputated to control deep tissue infection by drainage and debridement despite no improvement in the SPP after revascularization based on inflow reconstruction and a patent PA; however, wound healing was delayed for 2 months (Fig 2, *B* and *C*). Unfortunately, a new ulcer developed on the right heel (Fig 2, *D*). Primary amputation was considered at this point; however, the patient was ambulatory before the onset of CLTI, and his general condition gradually improved due to release from pain after the first revascularization and control of foot infection. He did not agree to major amputation even if a new heel ulcer developed. Additional surgical revascularization was required to improve the wound status. On the basis of the IADSA findings, we decided to reconstruct the collateral artery perfusing into the foot segment for the following reasons: (1) the PA was already perfused as one straight line to the ankle level and not indicated as a revascularization, and foot ischemia had not yet been resolved; and (2) reconstruction of the collateral artery perfusing into the foot segment seemed to be effective for

From the Department of Vascular Surgery, Asahikawa Medical University.

Author conflict of interest: none.

Correspondence: Nobuyoshi Azuma, MD, PhD, Department of Vascular Surgery, Asahikawa Medical University, 2-1-1-1 Midorigaoka-Higashi, Asahikawa 078-8510, Japan (e-mail: nazuma@asahikawa-med.ac.jp).

2468-4287

https://doi.org/10.1016/j.jvscit.2020.12.003

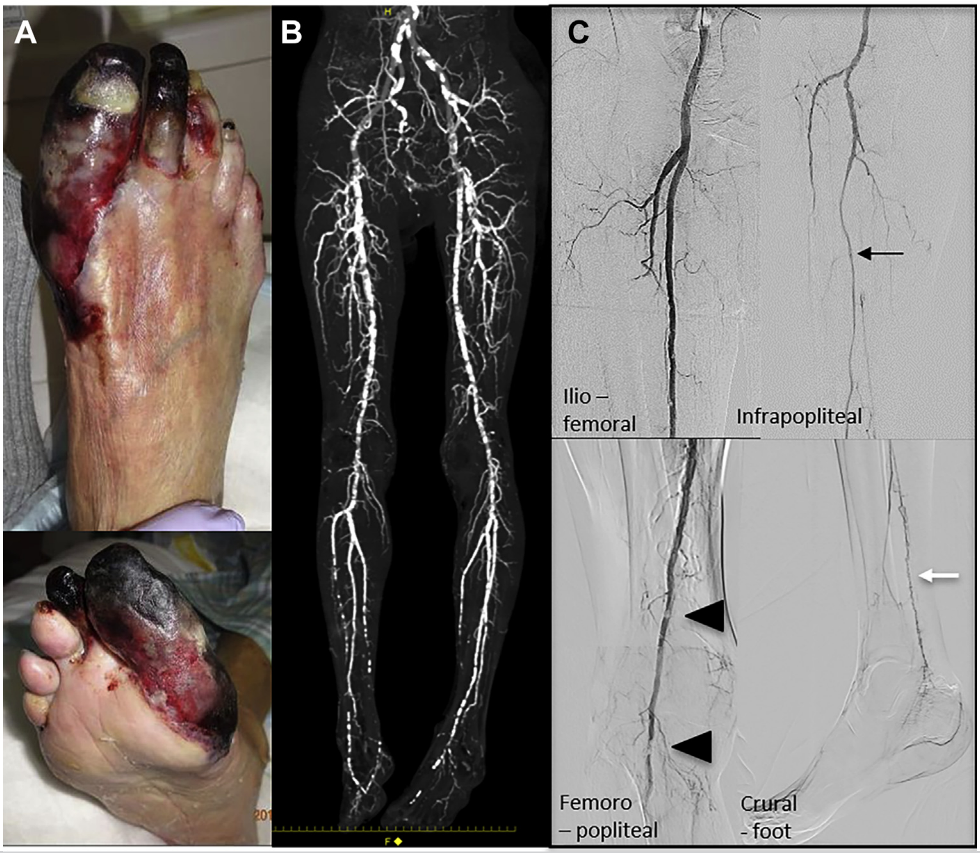

Fig 1. Preoperative clinical and radiographic findings. Gangrene on multiple toes of the right foot at admission **(A)**. Computed tomography angiography demonstrates severe calcifications in lower extremity arteries **(B)**. Intra-arterial digital subtraction angiography shows two significant stenoses of the popliteal artery (*arrowheads*), an intact peroneal artery (PA) (*black arrow*), and a developed collateral artery perfusing into the foot segment (*white arrow*). The anterior and posterior tibial arteries show chronic total occlusion **(C)**.

wound healing based on direct revascularization with the angiosome concept (Fig 2, *E*). Even though bypass grafting was not successful, arterial damage at the anastomosis site would not influence the subsequent patency of the collateral artery because the PA, the blood source to the collateral artery, was patent. He finally agreed to this plan to pursue his limb salvage. In the prone position, bypass surgery was performed from the below-the-knee popliteal artery to the collateral artery using the right upper extremity vein in a reversed fashion (Fig 2, *F*). A skin incision was placed between the Achilles tendon and the fibula. The collateral artery was searched by intraoperative use of a Doppler probe and angiography and was ultimately traced into the tibial nerve bundle after peeling the nerve (Fig 2, *G*). The artery was clamped with a microclip. The anastomosis was created by 8-0 polypropylene continuous sutures with three corner stitches placed on each heel and toe of the anastomosis (Fig 2, *H*). Although the graft flow immediately after the anastomosis was 5 mL/min (VeriQ System; Medistim, Oslo, Norway), we continuously inserted several medications into the vein graft through a microcatheter (Argyle PI Catheter; Cardinal Health, Dublin, Ohio). The catheter was transcutaneously inserted into a branch of the vein graft that was left in advance during harvesting of the vein graft and fixed at the branch and on the skin using 6-0 polypropylene sutures. Heparin and prostaglandin E1 were continuously administered through the catheter placed as follows: heparin (200 units) and prostaglandin E1 (2 μg/h) were continuously administered for 7 days (typically, 2000 units of heparin was mixed with 20 μg of prostaglandin in 20 mL of saline and continuously administered at a rate of 2 mL/h). The administration of heparin and vasodilators was continued to prevent thrombus formation and to decrease arterial resistance until re-endothelization on the luminal surface of the vein graft.[9] The forefoot was subsequently amputated to control deep tissue infection by drainage and debridement despite no improvement in the SPP after the revascularization based on inflow reconstruction and patent PA placement. Although the graft flow increased to 67 mL/min 1 month after the surgery, the flow decreased at 3 months after surgery due to negative remodeling of the graft over time. To achieve wound healing and long-term outcomes, multiple procedures, including two revascularizations, three graft revisions, three debridements, and skin grafting, were required (Fig 3, *A* and *B*). All procedures were undertaken under regional anesthesia or

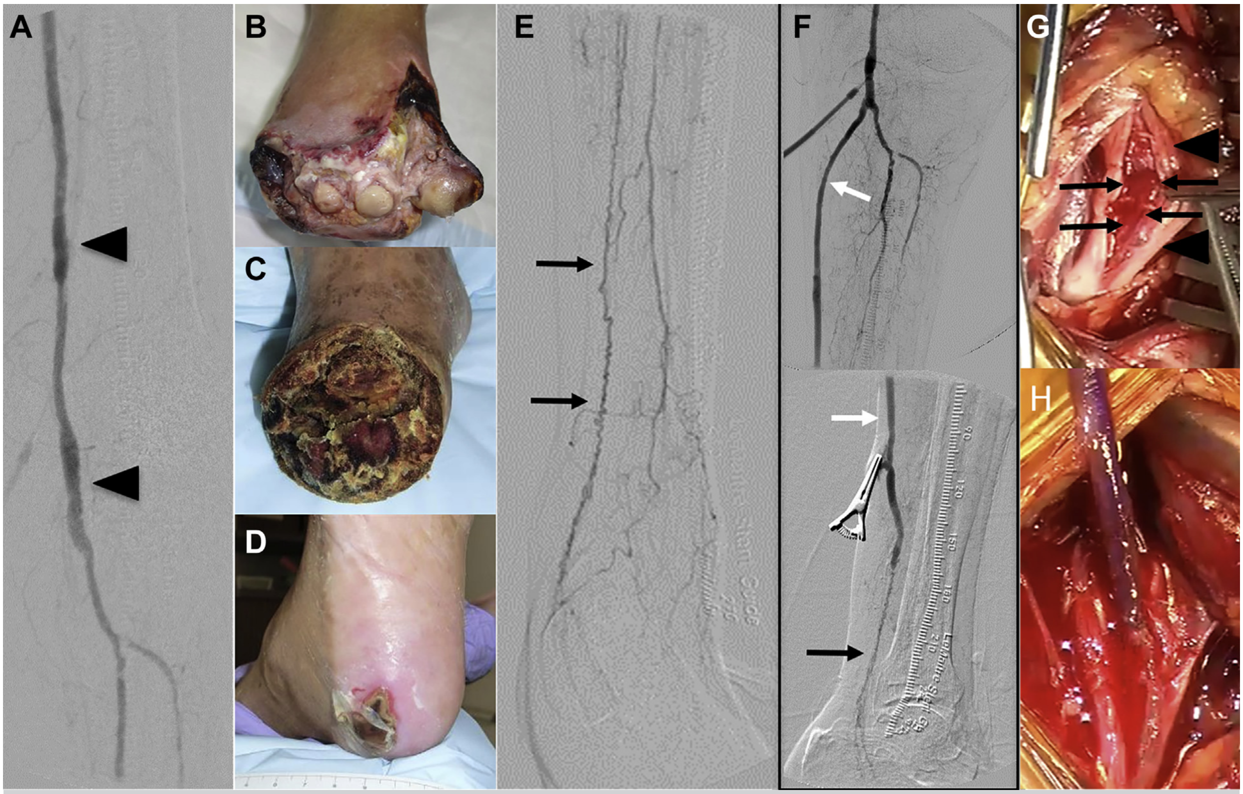

Fig 2. Postoperative angiography in a prone position of the popliteal artery repaired by endarterectomy with vein patch plasty (*arrowheads*, **A**). Photographs of the right forefoot on which minor amputation was performed after endarterectomy **(B)** and of delayed wound healing of the right forefoot 6 weeks after the first amputation **(C)**. A newly developed heel ulcer during forefoot treatment **(D)**. Intraoperative angiography of the collateral artery (*black arrows*) used for bypass surgery **(E)** and collateral bypass grafting (*white arrow*, **F**). Operative findings of the preincisional collateral artery (*black arrow*) and tibial nerve bundle (*arrowheads*) exposure **(G)** and the distal anastomosis site **(H)**. Figures **A, E, F,** and **G** were taken in the prone position.

lower extremity nerve blockade, not general anesthesia.[10] Plain old balloon angioplasty was performed to maintain graft patency after thrombectomy using a Thrombuster aspiration catheter (KANEKA, Tokyo, Japan) (Fig 3, *C*). The graft patency was maintained until the time of complete wound healing. Regarding his activity, wheelchair use was continued until the time of wound healing. However, his walking ability did not fully recover (standing with an assistance), and he ultimately died due to malnutrition and cholangitis several months after the time of wound healing with a patent graft (Fig 3, *D*). However, the revascularizations completely released the patient from severe resting pain, leading to a shorter bed-leaving time and improvements in appetite and amount of dietary intake. He was satisfied with improvements in his quality of life.

DISCUSSION

We report a case of collateral artery bypass surgery that achieved wound healing. Although the treatment strategy was difficult and with technical limitations, especially limited autogenous vein availability, severely calcified arteries, and no usual target arteries, wound healing was achieved through staged revascularization.

The described collateral artery is unnamed, and it descended to the periphery along the tibial nerve in this case. IADSA also showed a corkscrew appearance; thus, it was identified as a collateral artery. Operative findings also demonstrated that the artery was anatomically different from the posterior tibial artery. It may have developed exceptionally because of alternate blood flow to preserve tissue after chronic total occlusion of the infrapopliteal and foot arterial systems. A new heel ulcer developed, which meant that further revascularization was needed to resolve foot ischemia. Thus, we decided to perform revascularization targeting the collateral artery. Regarding the possibility of endovascular therapy, we considered that clinical outcomes including technical success or durability of patency could not be expected because both the anterior and posterior tibial arteries were totally occluded with severe calcification and had no runoff artery in the foot segment. Computed tomography imaging was a good guide for approaching the target artery (Fig 3, *E*). The artery displayed no calcification and was small in diameter. Although collateral bypass grafting was not purposefully performed to anticipate the plantar arch perfusion, it was successful, as

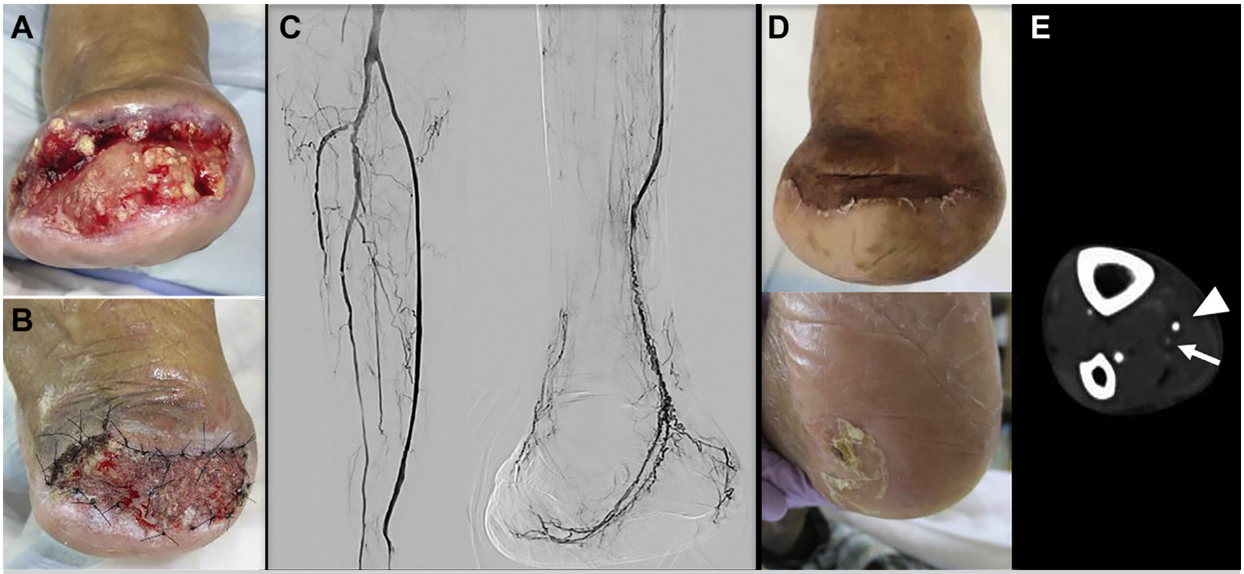

Fig 3. Process of wound healing after collateral bypass surgery. Increasing granulation on the right forefoot 2 months after the bypass surgery **(A)** and skin grafting **(B)**. Angiography of the vein graft after endovascular treatment for vein graft thrombosis **(C)**. Foot photographs after achieving wound healing **(D)**. Computed tomography angiography demonstrated a developed collateral artery (*white arrow*, **E**) behind the posterior tibial artery (*arrowhead*).

shown in Fig 3, *D*, and achieved complete wound healing.

Regarding previsou report of collateral artery bypass grafting, there are only literatures related to the perigenicular aretery segment. Various criteria must be fulfilled to achieve the physiological principles of collateral artery bypass: the collateral arteries must be disease free along their entire lengths, they must have a diameter comparable to that of the distal leg arteries, and they must be connected to other collateral arteries and original arteries.[8] In the current case, the collateral artery ran from the middle of the lower thigh to the plantar area with a constant arterial diameter, which seemed feasible as a bypass target. Because arteries observed in the planter segment exhibited a corkscrew appearance, they were not indicated as a distal target for bypass grafting. In addition, they were the only runoff arteries, and a surgical procedure in this segment was avoided due to possible damage. In addition, revascularization of the collateral artery was applied as direct revascularization with the angiosome concept for the current patient on dialysis. Regarding its advantages, Barral et al[7] concluded that this technique is particularly useful when saphenous veins are not long enough, when no other outflow vessels are available, or when other outflow vessels are very calcified and not safely clamped. Regarding its disadvantages, the graft patency rate is probably poor, as shown in this report. Regular graft surveillance by ultrasound sonography demonstrated that graft narrowing was progressive with a decrease in graft flow, and the graft diameter was reduced by half with negative postoperative remodeling to adapt to the diameter of the collateral artery and distal runoff arteries. Thus, the possibility of graft failure is probably much higher than that of perigenicular collateral artery bypass; we must keep this possibility in mind, and frequent vein graft surveillance is essential.[11] This type of bypass grafting is quite exceptional and should only be used as the last resort when other conventional bypass techniques are impossible.[12] After understanding the preferred criteria and disadvantages, the collateral artery may be an option for bypass targets even if it develops in the distal infrapopliteal segment. Thus, candidates for this procedure should be limited to patients who have collateral arteries that meet certain anatomical conditions and whose collateral artery is patent as a runoff artery in the foot segment. Patients who maintain walking ability and have good autogenous veins are better candidates for this procedure than for durable graft patency.

CONCLUSION

We performed collateral artery bypass surgery in the distal infrapopliteal segment as a distal target in a patient with CLTI and achieved wound healing. The collateral artery can be used as a bypass target in patients whose arteries in the infrapopliteal and foot segments are severely diseased.

REFERENCES

1. Azuma N, Uchida H, Kokubo T, Koya A, Akasaka N, Sasajima T. Factors influencing wound healing of critical ischaemic foot after bypass surgery: is the angiosome

important in selecting bypass target artery? Eur J Vasc Endovasc Surg 2012;43:322-8.
2. Kikuchi S, Sasajima T, Inaba M, Uchida D, Kokubo T, Saito Y, et al. Evaluation of paramalleolar and inframalleolar bypasses in dialysis- and nondialysis-dependent patients with critical limb ischemia. J Vasc Surg 2018;67:826-37.
3. Soor GS, Vukin I, Leong SW, Oreopoulos G, Butany J. Peripheral vascular disease: who gets it and why? A histomorphological analysis of 261 arterial segments from 58 cases. Pathology 2008;40:385-91.
4. Conte MS, Bradbury AW, Kolh P, White JV, Dick F, Fitridge R, et al. Global vascular guidelines on the management of chronic limb-threatening ischemia. J Vasc Endovasc Surg 2019;69:3-125.
5. Das SK, Yuan YF, Li MQ. Predictors of delayed wound healing after successful isolated below-the-knee endovascular intervention in patients with ischemic foot ulcers. J Vasc Surg 2018;67:1181-90.
6. Sprengers RW, Teraa M, Moll FL, Wit GA, Graaf Y, Verhaar MC, et al. Quality of life in patients with no-option critical limb ischemia underlines the need for new effective treatment. J Vasc Surg 2010;52:843-9.
7. Barral X, Salari GR, Toursarkissian B, Favre JP, Gournier JP, Reny P. Bypass to the perigeniculate collateral vessels. A useful technique for limb salvage: preliminary report on 22 patients. J Vasc Surg 1998;27:928-35.
8. Luccia ND, Sassaki P, Durazzo A, Sandri G, Kikuchi M, Hirata C, et al. Limb salvage using bypass to the perigeniculate arteries. Eur J Vasc Endovasc Surg 2011;42:374-8.
9. Ishikawa M, Sasajima T, Kubo Y. Re-endothelialisation in autogenous vein grafts. Eur J Vasc Endovasc Surg 1996;11:105-11.
10. Kikuchi S, Yamaguchi T, Miyake K, Uchida D, Koya A, Iida T, et al. Effectiveness and safety of ultrasound guided lower extremity nerve blockade in infragenicular bypass grafting for high risk patients with chronic limb threatening ischaemia. Eur J Vasc Endovasc Surg 2019;58:206-13.
11. Latour B, Nourissat G, Duprey A, Berger L, Favre JP, Barral X. Bypass to the perigeniculate collateral arteries: mid-term results. Eur J Vasc Endovasc Surg 2008;35:473-9.
12. Miyake K, Kikuchi S, Okuda H, Koya A, Abe S, Sawa Y, et al. Successful limb salvage through staged bypass combined with free gracilis muscle transfer for critical limb ischemia with osteomyelitis after failed endovascular therapy. Surg Case Rep 2018;4:40.

Submitted Sep 17, 2020; accepted Dec 9, 2020.