Collateral artery bypass in the infrapopliteal segment

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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. 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. It is well known that the quality of life of these patients is poor. The medial sural artery and descending genicular artery were previously reported as targets of collateral bypass grafting. 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 infrapopliteal arteries, resulting in difficulty with endovascular therapy and the requirement of bypass grafting to the arterial segment. 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.)

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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. Intraarterial 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...
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 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).
lower extremity nerve blockade, not general anesthesia. Plain old balloon angioplasty was performed to maintain graft patency after thrombectomy using a Thrombust® 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
shown in Fig 3, D, and achieved complete wound healing.

Regarding previous reports of collateral artery bypass grafting, there are only literatures related to the perigenicular artery 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 al7 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.

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