Evidence of nutritional vascular formation from the "nutrient flap" in a patient with no-option chronic limb-threatening ischemia: An indocyanine green fluorescence imaging study

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ABSTRACT

The concept of a "nutrient flap," in which ischemic tissue is nourished by a transferred well-perfused flap, has been advocated for use since the early days of free flap procedures. Several studies have reported cases of no-option chronic limb-threatening ischemia salvaged by nutrient free flap transfer. However, it has been difficult to prove the actual dynamic flow and nutritional vascular formation. Thus, the existence of a nutrient flap has remained unproved. In the present report, we have described the case of free flap transfer for a patient with no-option chronic limb-threatening ischemia in whom we detected evidence of a nutrient flap using indocyanine green fluorescence imaging. (J Vasc Surg Cases Innov Tech 2022;8:408-11.)

Keywords: Chronic limb-threatening ischemia; Distal bypass; Distal venous arterialization; Indocyanine green fluorescence imaging; Nutrient flap

The concept of a "nutrient flap," in which ischemic tissue is nourished by a transferred well-perfused flap, has been advocated for use since the early days of free flap procedures.[1-5] Nutrient flap transfer has been applied, especially for the treatment of no-option chronic limb-threatening ischemia (CLTI). However, even among the reported cases in which a nutrient flap was successfully applied, no study has reported the detection of the dynamic flow of nutritional vascular formation over the flap edge. Therefore, the nutrient flap concept has remained unproved.

In the present report, we have described the case of free flap transfer for a patient with no-option CLTI. We succeeded in detecting a dynamic and widespread blood supply from the flap to the surrounding ischemic tissue, which we consider evidence of a nutrient flap, using indocyanine green (ICG) fluorescence imaging. The

Fig 1. Preoperative appearance of the affected foot, with almost no granulation observed after amputation of the third toe with incisional drainage. The second toe had been amputated before.

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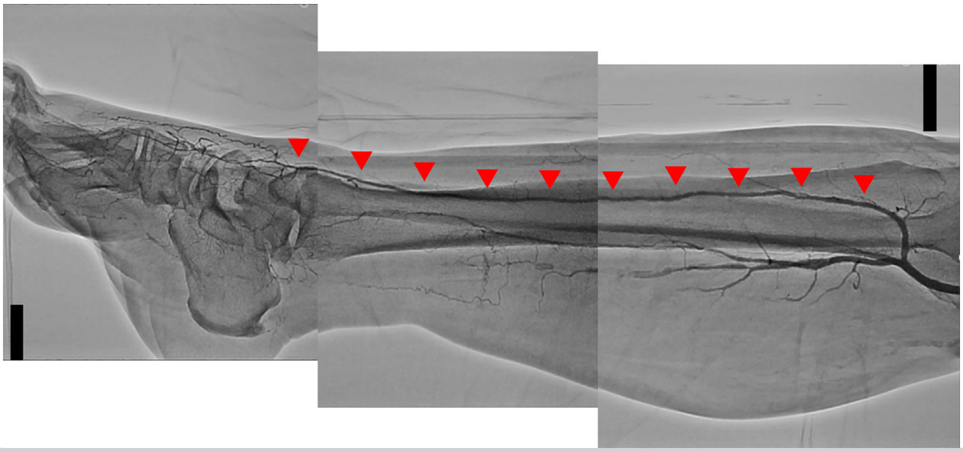

Fig 2. Findings from preoperative angiogram of the affected limb. Only the anterior tibial artery appeared patent up to the ankle area (*red triangles*). Almost no valid arteries were found in the inframalleolar area.

patient provided written informed consent for the report of his case details and imaging studies.

CASE REPORT

The patient was a 54-year-old man with diabetes mellitus, chronic kidney disease requiring hemodialysis, and CLTI. In the Society for Vascular Surgery WIfI (wound, ischemia, foot infection) classification,[6] the wound grade was 3 (extensive ulcer and gangrene), the ischemia grade was 3 (ankle brachial index <0.39, toe pressure <30 mm Hg), and the foot infection grade was 2 (moderate). The overall clinical stage was 4 (high risk). The grade of the inframalleolar/pedal disease descriptor using the Global Limb Anatomic Staging System was P2 (no target artery crossing the ankle into the foot).[6] The patient had rest pain in the right foot, and his third toe had developed necrosis and infection (Supplementary Fig). Consequently, endovascular therapy and metatarsophalangeal joint amputation of the third toe with incisional drainage were performed (Fig 1). Only the anterior tibial artery was recanalized up to the ankle area (Fig 2), and wound healing and pain relief could not be achieved (Fig 2).

In addition, no valid target arteries were available for bypass surgery at the inframalleolar area. Therefore, arteriovenous shunt anastomosis (distal venous arterialization [DVA]; femoral artery–saphenous vein graft–foot dorsal vein) was performed (Fig 3). Wound healing could not be achieved after 2 months of observation. Therefore, a free flap transfer (anterolateral thigh flap) was performed. The anastomotic site of the arteriovenous shunt was disconnected, and the proximal stump (saphenous vein graft) was anastomosed to the pedicle artery of the flap, and the distal stump (foot dorsal vein) was anastomosed to the pedicle vein of the flap.

On postoperative day 1, thrombotic occlusion of the arterial bypass graft occurred, and the thrombosis was successfully removed by open surgery. The flap was completely salvaged, and the postoperative course was subsequently uneventful with antiplatelet and anticoagulation therapy (aspirin, 100 mg/d, and additional warfarin with an adjusted to prothrombin time international normalized ratio of >2.0). However, at 9 months postoperatively, thrombotic occlusion of the bypass graft had occurred again. Suction thrombectomy via endovascular therapy was performed successfully. The adjusted to prothrombin time international normalized ratio was decreased to 1.62 at the time of bypass occlusion.

At 13 months postoperatively, the flap and foot had both survived in a completely wound-free state (Fig 4), and ambulation with an ankle foot orthosis was possible. ICG fluorescence imaging with direct injection into the bypass graft was performed with 0.2 mL of 0.25% ICG solution directly injected percutaneously into the bypass graft using a 30-gauge needle. The foot area was then observed using an infrared imaging camera device (SPY-PHI; Stryker Inc, Kalamazoo, MI). An immediate and widespread blood supply from the flap into the surrounding ischemic tissue was confirmed, especially on the plantar side, an area in which no valid native artery was present (Supplementary Video; Fig 4).

However, thrombotic occlusion of the bypass graft had occurred a third and fourth time at 14 and 16 months postoperatively, respectively. After the fourth occlusion, the flap became necrotic, and the patient had required a Lisfranc joint amputation.

DISCUSSION

Previous reports regarding the nutrient flap had presented only still images of blood flow, without showing dynamic perfusion from the flap into the surrounding tissue.[1-5] In the present case, we were able to demonstrate dynamic blood migration from the flap to the adjacent ischemic tissue (Supplementary Video), which we considered evidence of a nutrient flap. However, we found that the method has a substantial risk of causing thrombotic occlusion of the bypass graft owing to the limited runoff route for the blood flow. To the best of our knowledge, the long-term results for this method have not yet been reported. The present case showed both the promising results of nutrient flap formation and the disappointing outcome of flap necrosis. The flap functioned as a nutrient flap for 16 months, during which time it kept the ischemic foot viable.

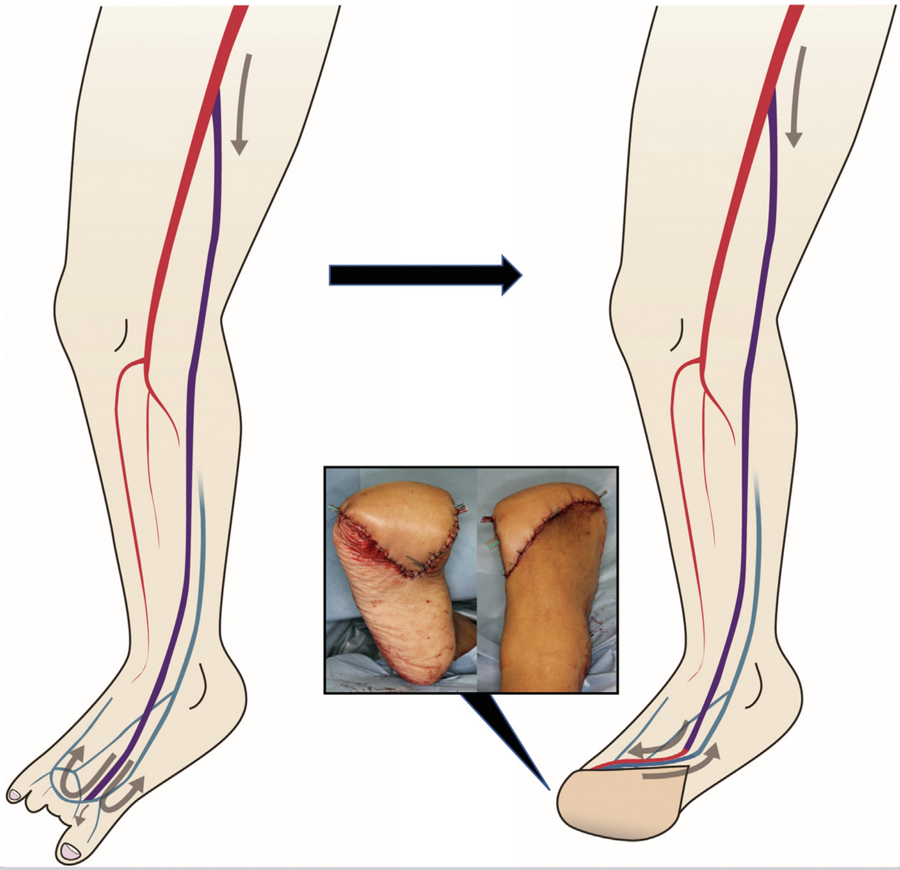

Fig 3. Schematic illustrations of the two-stage surgery. **Left,** The first stage with arteriovenous shunt anastomosis (distal venous arterialization [DVA]; femoral artery—saphenous vein graft—foot dorsal vein) was performed with the expectation of a blood supply to the necrotic area through a venous route. **Right,** The second stage included metatarsophalangeal joint amputation of all toes and an anterolateral thigh flap transfer. The arteriovenous shunt was disconnected to use the stumps as the recipient artery and vein (arterial bypass graft and foot dorsal vein). The patient had had a tattoo on the thigh area that was included in the edge of the flap. **Inset,** Immediate postoperative photographs after the second stage operation.

One of the superior points of ICG fluorescence imaging is the high sensitivity in the detection of microvascular skin perfusion and tissue viability.[7-9] ICG is usually administered via an intravenous route. However, the method of direct ICG injection into the bypass graft can restrict the inflow route of ICG to solely from the flap to the surrounding ischemic tissue. In our patient, the dorsal side of the foot area had been nourished to some extent by the native anterior tibial artery. However, the plantar side had no arteries as a source of blood supply (Fig 2). It is, therefore, reasonable to suppose that blood flow migration had occurred more on the plantar side and that flap perfusion was indispensable to keeping the plantar area viable.

A nutrient flap does not receive any perfusion other than that from the flap pedicle and requires direct blood flow from the flap pedicle (bypass graft in the present case) to maintain survival and function. The anterolateral thigh flap is a fasciocutaneous flap. In our patient, the thigh flap had had intravascular calcification because of the location on the thigh. Thus, the intravascular resistance of the flap was considered to have been high originally. A larger musculocutaneous flap (generally the latissimus dorsi musculocutaneous flap) might have relieved the intraflap vascular resistance.[10,11] The latissimus dorsi musculocutaneous flap was not chosen because our patient had had excessive dorsal fat tissue and a tattoo across the whole dorsal surface. Moreover, preoperative ultrasound detected a reliable cutaneous perforator in the thigh area, although that might not have been the best site for selection. From another perspective, the previously created arteriovenous shunt was disconnected at the free flap transfer, which restricted the runoff route of the bypass graft and possibly caused high intra-bypass vascular resistance. The performance of a free flap transfer without disconnecting the arteriovenous shunt might have been a more appropriate option. The 1-year primary patency for open DVA was reported to vary from 44% to 88%.[12] However, the use of the double runoff route for the flap and DVA for the bypass graft could bring some advantages in flow velocity and vascular resistance and could

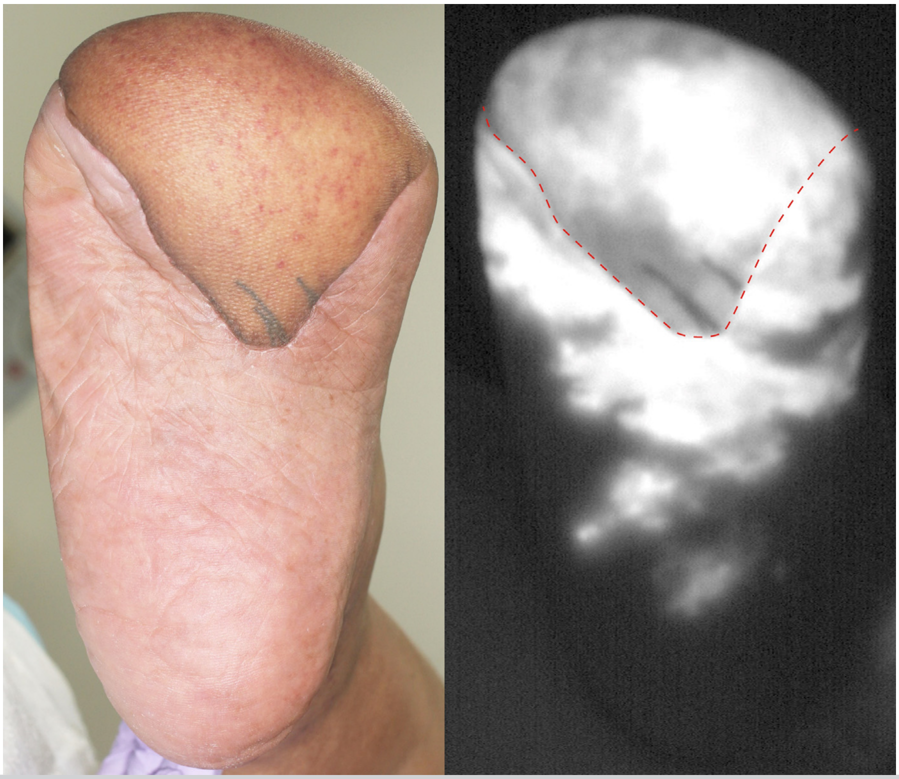

Fig 4. Left, Postoperative appearance of the affected foot at 13 months postoperatively. The flap and foot survived with a completely wound-free state. **Right,** Indocyanine green (ICG) fluorescence imaging after direct injection into the bypass graft. ICG imaging detected the dynamic flow of nutritional vascular formation over the flap edge. The *red dotted line* indicates the border between the flap and the foot.

have positive effects on long-term patency.[10] Improvement of the method is necessary to ensure long-term patency of the bypass graft and make nutrient flap transfer a viable option for salvaging limbs with no-option CLTI.

CONCLUSIONS

ICG fluorescence imaging could detect evidence of nutrient flap formation in a patient who had received a free flap transfer through a long arterial bypass for no-option CLTI. The flap served as a nutrient flap for the surrounding ischemic tissue; however, it had become necrotic at 16 months postoperatively. Further accumulation of cases and improvements in the techniques are needed to determine the optimal application of nutrient flap transfer for no-option CLTI.

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Supplementary Fig. Photographs of the affected foot before debridement.