Special Considerations for Diabetic Foot Reconstruction

Hyunsuk Peter Suh, MD, PhD[1] Changsik John Park, MD, PhD[1] Joon Pio Hong, MD, PhD, MMM[1]

[1] Department of Plastic Surgery, ASAN Medical Center, University of Ulsan College of Medicine, Seoul, Korea

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Address for correspondence Hyunsuk Peter Suh, MD, PhD, Department of Plastic Surgery, Asan Medical Center, 88, Olympic-Ro 43-Gil, Songpa-Gu, Seoul 05505, South Korea (e-mail: hpetersuh@gmail.com).

Abstract

Successful reconstruction of diabetic ulcers using free flap surgery can prevent further amputation and promote limb salvage to maintain normal gait of the patient and increase the quality of life after surgery. To minimize the postoperative complication and days of stay in hospital, surgeons should thoroughly investigate the risk factors and underlying conditions, including the general condition and local factors.

Keywords

- diabetic ulcer
- reconstruction
- debridement

The spectrums of diabetic ulcer vary from superficial ulceration to critically ischemic limb or severely infected wound with osteomyelitis. The principal pathogenesis involving the diabetic ulcer also differs and may further increase the risk of flap surgery and morbidity during the limb salvage procedures.[1–4] Vasculopathy, wound infection, renal failure, use of an immunosuppressive agent, the presence of heart disease, foot deformity, neuropathy, and many other risk factors can contribute to the difficulties of flap surgery.[5–8] Among the risk factors, vasculopathy and wound infection are the two most important factors that should be evaluated and corrected before flap operation.

Vasculopathy

Nearly 50% of the patients who had diabetic ulcers showed some degree of peripheral vasculopathy.[6,9,10]In patients with vasculopathy, vessel evaluation should be done thoroughly. If there is severe atherosclerosis in the target recipient vessel, the surgeon should go for a distant vessel from the defect as a recipient vessel and harvest long pedicled flap for anastomosis.

Preoperative Evaluation of Flow and Tissue Perfusion

Computed tomography (CT) angiography, conventional angiography, and color Doppler are the standard methods to evaluate the vascular status. With CT angiography, surgeon can assess not only the peripheral vessel but also the calcification of major vessels, including superficial femoral artery and even the condition of donor vessel. But in some cases with circumferential calcification, the lumen of the peripheral vessel cannot be seen in CT angiography image, and the vasculopathy could be exacerbated. With conventional angiography, not only the obstruction can be checked but also the flow volume of through the vessel can be indirectly measured.[11–13] And intraluminal angioplasty can be done with minimal radioactive dye by skillful interventionist in renal function impairment patients.

Management of Inflammation

Infection in diabetic wound aggravates the tissue necrosis. Diabetic patients have an abnormal immune response and an increased susceptibility to infection.[6,14] The inflammation itself also increases the pressure of the tissue and promotes progressive tissue necrosis. Once it becomes infected, it can be aggravated rapidly along the fascia and soft tissue and cause severe infection and tissue necrosis in a few days. Even after proper use of the antibiotics nonviable tissue can remain in the wound. Serial surgical debridement is essential for ulcer with inflammation.[15–17] At the initial phase, the purpose of debridement is to cease inflammation progression by exposing all the pocket for pus collection and remove most of the necrotic tissue (►**Fig. 1**). In the acute and severe inflammatory phase of the diabetic ulcer, daily debridement is essential to

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Fig. 1 (**A**) Initial appearance after emergency room. Necrosis of skin is noticed with local heat and pus coming out from the margin of necrotic skin. Surgical debridement was arranged within 2 hours after visit. (**B**) Three days after initial debridement, still there is minimal amount of necrotic tissue on the surface of the wound. (**C**) Ten days after initial debridement, small amount of granulation tissue is seen on some surface of the wound.

slow down the progression of inflammation as the necrosis advances to surrounding tissue rapidly to proximal.

Serial Surgical Debridement with Proper Antibiotic Use

Once the patients arrive at the hospital, timely aggressive management can delay the progression of infection and preserve the maximal length of the limb and reach the goal of limb salvage. If there is active inflammation left under the flap, surgical debridement is the single method to manage it and to prevent aggravation. Conservative methods such as negative pressure dressing or frequent dressing change cannot replace the role of surgical debridement. Initial debridement should be performed within 12 hours of arrival. Initial debridement is focused on the removal of infected necrotic tissue and identifying the pocket and dead space under the skin. Proper deep tissue culture is achieved during the debridement before starting the empirical antibiotics. If the obvious wound and infection do not improve or subside even after the proper surgical debridement and antibiotics, surgeons should consider that the treatment offered for the patients is not correct. In this situation, additional debridement should be done to find the pocket or magnetic resonance imaging should be checked. Surgeons should also consider the resistance to the antibiotics. Antibiotics should be changed based on systemic symptoms, wound condition, and blood tests.[18,19]

The Timing of Flap Coverage after Vascular Intervention

As there is the accumulative rate of occlusion after days of angioplasty, the flap is considered on the same day or within 1 week after the angioplasty or bypass surgery.[20] In a severe ischemic patient who had successful revascularization, reperfusion insult is higher compared with a less ischemic limb or nonsuccessful revascularization especially during the 2to 3 days postoperatively. If the reperfusion insult and inflammatory reaction are suspected before revascularization, surgery can be delayed at least 2 to 3 days after the revascularization and another debridement in between intervention and flap surgery can be performed.

The Timing of Flap Coverage after Infection Control

Wound preparation should be done correctly before the flap coverage. There should be, at least, no skin redness caused by soft tissue inflammation and no purulent discharge from the dead space. Number of the debridement before the flap coverage can vary according to the severity of the inflammation and amount of necrotic tissue. There should be a target date for coverage that should be at maximum of 7 to 10 days after the initial visit.

Soft Tissue Reconstruction

Once the wound preparation is done, and reasonable tissue perfusion is achieved, soft tissue flap coverage is considered in patients with the extensive and recalcitrant wound. Bone exposure or full-thickness defect on the plantar surface is a common reason for reconstruction (►**Figs. 2** and **3**).

Recipient Vessel Selection

The most challenging step of the surgery and the most important factor of successful flap reconstruction are finding the good recipient vessel for proper perfusion of the flap. Biphasic pulsatile signal or acoustic wave from handheld Doppler does not guarantee the good recipient vessel for anastomosis. The sensitivity of handheld Doppler is very high and can trace a vessel less than 0.2 to 0.3mm diameter that cannot match the physiologic demand for flap survival. The surgeon should look for the vessel based on anatomical knowledge, preoperative radiologic study, and intraoperative Doppler tracing. If the vessel has adequate flow for the anastomosis, you can see the pulsation of the vessel under the loupe magnification. If there is severe calcification in the long segment, there might be no visible pulsation. In this situation, handheld Doppler helps to evaluate the flow within the calcified vessel. Small branches (0.5–1mm) from the dorsalis pedis or digital artery can be used for end-to-end anastomosis for forefoot reconstruction that can be named as supermicrosurgery. A small branch from the pedal artery is usually preserved from atherosclerosis and calcification in most of the cases if the flow is still maintained on severely calcified pedal arteries. If there is a peripheral artery, medial plantar, lateral plantar artery, or dorsalis pedis artery within or

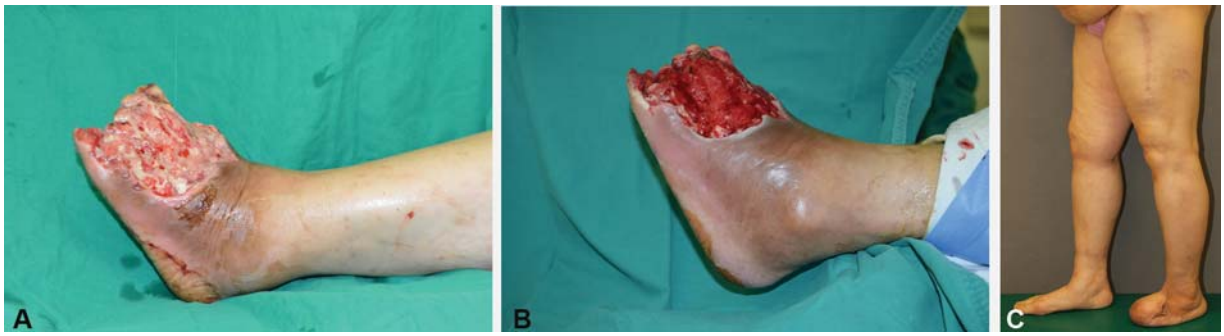

Fig. 2 A 49-year-old diabetic woman referred to the clinic for limb salvage. (**A**) Toe amputation was done, and necrotic tissue was covering the wound bed. (**B**) After the wound debridement and angioplasty wound bed is free of necrotic tissue and covered with granulation tissue. (**C**) After removal of necrotic bone, perforator flap was used to cover the transmetatarsal amputation stump and flap was free of reulceration for 3 years.

Fig. 3 A 67-year-old female had a small wound on the first toe on her left foot after clipping of toenail, and it got infected after a week. She had a systemic infection, and laboratory finding showed an elevated inflammatory reaction. (**A**) She was referred to the clinic because of the aggravation of the wound even after first toe ray amputation. (**B**) Serial debridement was done, and negative pressure wound dressing was performed. Bone and joint space were exposed. (**C**) The defect was covered with anterolateral thigh perforator flap. (**D**) The flap was free from the recurrence for 3 years and 6 months.

near the defect, it can be used as an end-to-side method or flow-through method.

Flap Selection

The flap should be well-vascularized after surgery and should fight against the remaining inflammations under the flap and wound bed. The flap should also bear the sheer stress of wearing the shoe and stand against the pressure during weight-bearing. Authors use perforator flap for most of the soft-tissue defects in diabetic limb salvage including the cases for plantar surface reconstruction, based on the knowledge that preoperative wound condition is more important than the component of the flap. As far as the proper wound bed preparation is well made before the flap coverage, it was possible to salvage the limb and also minimize the donor site complication and morbidity by using perforator flap. Authors prefer to use anterolateral thigh perforator flap or superficial circumflex iliac artery perforator (SCIP) for most of the cases. For the small-to-moderate size defect, SCIP flap is the flap of choice (►**Fig. 4**).

Microanastomosis and Vessel Insetting

In the author's experience, one of the reasons for flap failure in diabetic reconstruction is the arterial occlusion that is higher than other flap surgeries. Because of the calcification and phosphate deposition of the medial and intimal wall, the intimal wall is already injured before the anastomosis and makes it impossible to make a proper intima-to-intima contact after the microanastomosis that may lead to higher postoperative thrombus formation after the microanastomosis and vascular procedures.

If the named artery, used for end-to-side anastomosis, is severely calcified, authors try to find the 5 mm length of the spared lesion for anastomosis. If the spared segment cannot be seen or if still there is calcification on the vessel media, Dafilon8–0 or 9–0 monofilament suture (B Braun Medical Inc., PA) that has strong 5mm needle can be used. After the successful anastomosis, the vessel should be placed with extra care. If the recipient vessel and end-to-side-anastomosed donor pedicle are calcified, there is a higher chance of compression and fracture compared with the noncalcified vessel that might lead to vessel occlusion.

Postoperative Management

In ischemic limb reconstruction, postoperative blood pressure control and hydration are critical for successful free flap reconstruction. In elder patients with hypertension, blood pressure varies much during and after the surgery because of the vessel calcification according to the hydration status and the depth of physical tone. Surgeons should know the proper blood pressure for each patient and flap for optimal perfusion during the recipient vessel preparation and after microanastomosis and try to maintain the pressure especially 2 to 3 days after surgery. Sometime inotropic agent should be used to maintain if the hydration itself is not possible or not enough. Compared with the

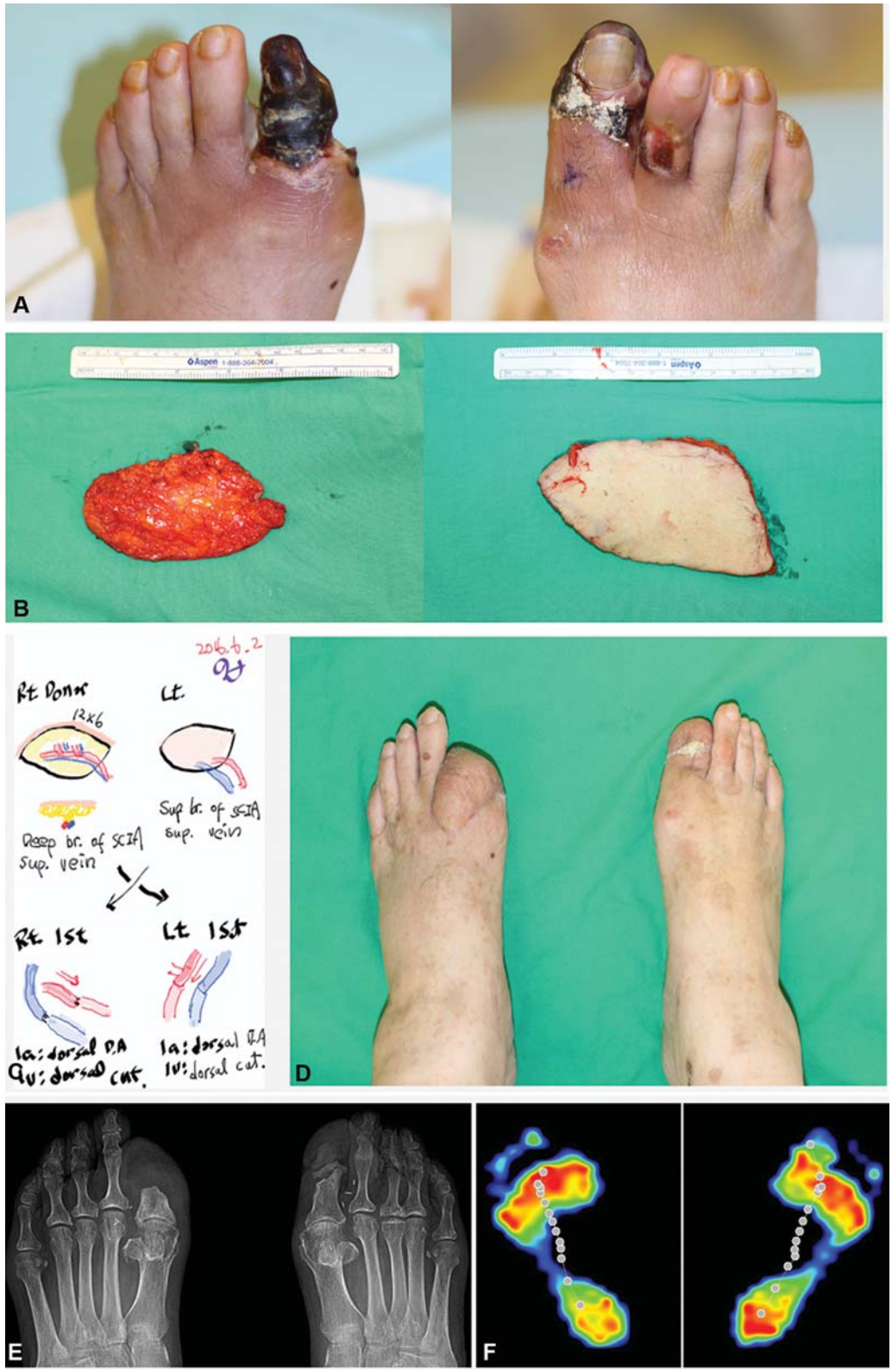

Fig. 4 (**A**) A 67-year-old female had a small wound on the first toe on her left foot after clipping of toenail, and it got infected after a week. She had a systemic infection, and laboratory finding showed an elevated inflammatory reaction. (**B**) Bilateral superficial circumflex iliac artery perforator was elevated. (**C**) Dorsal digital arteries were used as a recipient vessel. (**D**) The defect was covered with SCIP flap and was free from the recurrence for 3 years and 6 months, and (**E**) bone was free from the osteomyelitis. (**F**) The patient had normal plantar pressure during her ambulation to the forefoot and minimal additional pressure to the tip.

dobutamine, α1 adrenergic agents are more efficient to increase the flow to the flap by elevating the blood pressure with minimal effect on the vasospasm of peripheral vessels and pedicle of the flap.[21] If the patient is on fasting status after surgery, normal saline is the best fluid to hydrate the patient for maintaining the intravascular fluid and blood pressure.

Do-No-Harm Approach

The purpose of diabetic limb reconstruction is to preserve the length of the limb to maintain the gait and way of living. But the surgeon should keep in mind that if the flap reconstruction fails because of partial necrosis or postoperative infection, amputation level can go even more proximal than just doing amputation of the bone and covering with filet flap from the beginning. The surgeon should try not to harm depending on the skills they have for reconstructive surgery.

Conclusion

The serial debridement, infection control, vascular intervention, and postoperative management are as important as the flap elevation and microsurgical procedures for the successful reconstruction of a diabetic limb with free flap surgery.

Conflict of Interest
None declared.

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