Observational Study

Medicine

OPEN

Staged treatment with arterial reconstruction and flap transplantation for ischemic mangled extremity

An observational study

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Abstract

Patients with traumatic ischemic mangled extremities first undergo arterial reconstruction using autogenous vein grafts, followed by flap transplantation as a staged treatment for soft tissue reconstruction. This study aimed to report the outcomes of such a staged treatment. Thirteen patients underwent arterial reconstruction between February 2015 and April 2017 due to damage to the major blood vessels by the traumatic mangled extremities. Of them, 6 patients (5 males and 1 female with a mean age of 51 years, age range: 36–60 years) who underwent soft tissue reconstruction due to necrosis were retrospectively analyzed. The average Mangled Extremity Severity Score was 7.2 (range, 6–8). Injuries were found in the lower leg (4 cases), foot (1 case), and wrist and hand (1 case). Arterial reconstruction was performed using autologous venous grafts. The reconstructed arteries included the posterior tibial artery (3 cases), anterior tibial artery (1 case), dorsalis pedis artery (1 case), and radial artery (1 case). The blood circulation status of the reconstructed blood vessels was assessed using computed tomography angiography at an average of 5 weeks (range, 4–6 weeks) after arterial reconstruction. For some necrotic soft tissues, debridement and flap transplantation were performed an average of 7 weeks (range, 6–8 weeks) after arterial reconstruction. Soft tissue reconstruction was performed with an anterolateral thigh free flap in 4 cases, a local flap in 1 case, and a muscle flap in 1 case. In 5 out of 6 cases, blood circulation was maintained in the reconstructed blood vessels, resulting in the salvaging of the extremities. All the patients who underwent flap surgery survived. Notably, there were no special complications during a follow-up visit conducted at an average of 19 months post-reconstruction. To treat an ischemic mangled extremity, the limbs should first be salvaged with arterial reconstruction, followed by subsequent appropriate flap surgery when soft tissue necrosis occurs at the mangled site as a staged treatment.

Abbreviations: ALT = anterolateral thigh, CTA = computed tomography angiography, MESS = Mangled Extremity Severity Score.

Keywords: limb salvage, soft tissue injuries, surgical flaps, transplants, vascular system injuries

1. Introduction

In the treatment of ischemic mangled extremities, major blood vessels must be reconstructed for limb salvage because of bleeding and ischemia.[1] Soft tissue infections, osteomyelitis, and nonunion can occur. Thus, it is necessary to reconstruct the soft tissues as early as possible.[2] However, revascularization of damaged blood vessels is the most important factor in extremity rescue.[3] Methods of revascularization include direct repair, autologous vein grafting, and artificial blood vessel transplantation. If direct repair is not possible, an autologous vein graft is recommended because of long-term patency rate of autogenous vein graft.[4–6] If it is difficult to treat with direct sutures, the soft tissue should be reconstructed.[2] However, there is a disadvantage in that it is difficult to accurately predict the extent of further infection and necrosis of the contaminated tissue at an early stage. After the extent of necrosis has been sufficiently determined, it may be necessary to proceed with the reconstruction of the soft tissue in stages. Patients with traumatic ischemic mangled extremities first undergo arterial reconstruction using autogenous vein grafts, followed by flap transplantation as a

The authors have no funding to disclose.

The authors have no conflicts of interest to disclose.

The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

This study received approval from the Institutional Review Board at Jeonbuk National University Hospital (CUH 2022-05-033-006).

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How to cite this article: Lee Y-K, Jeon M, Ho J-W. Staged treatment with arterial reconstruction and flap transplantation for ischemic mangled extremity: An observational study. Medicine 2024;103:23(e38385).

Received: 20 January 2024 / Received in final form: 4 March 2024 / Accepted: 7 May 2024

http://dx.doi.org/10.1097/MD.0000000000038385

staged treatment for soft tissue reconstruction. This study aimed to report the outcomes of such a staged treatment.

2. Materials and methods

Thirteen patients underwent arterial reconstruction between February 2015 and April 2017 because of damage to the major blood vessels caused by a traumatic mangled extremity. Of these, 6 patients (5 males, 1 female; mean age: 51 years; age range: 36–60 years) who underwent soft tissue reconstruction due to necrosis were retrospectively analyzed. The causes of injuries included a traffic accident in 5 cases and an industrial accident in 1 case. The average Mangled Extremity Severity Score (MESS) was 7.2 (range, 6–8). Injuries were found in the lower leg (4 cases), foot (1 case), and wrist and hand (1 case). Bone fixation for lower-extremity fractures, except for the foot, was performed by trauma surgeons. Arterial reconstruction was performed using autologous venous grafts. The reconstructed arteries included the posterior tibial artery (3 cases), anterior tibial artery (1 case), dorsalis pedis artery (1 case), and radial artery (1 case). In addition, the vein used for grafting was the greater saphenous vein in 5 cases. The vein for the reconstruction of the radial artery was obtained from a cephalic vein in the contralateral wrist. The mean length of the grafted vein was 5.2 cm (Table 1). The blood circulation status of the reconstructed blood vessels was assessed using angiography at an average of 5 weeks (range, 4–6 weeks) after arterial reconstruction. For some necrotic soft tissues, debridement and flap coverage were performed at an average of 7 weeks (range, 6–8 weeks). Based on our own soft tissue reconstruction treatment algorithm, anterolateral thigh (ALT) free flap in 4 cases, local rotational skin flap in 1 case, and soleus muscle flap in another case were performed (Fig. 1 and Table 2).

Postoperatively, the extremities were supported using a splint. The patients stayed in bed for 7 days as much as possible. They were intensively checked for capillary refilling, surface temperature, and color. The patients were concurrently treated with anticoagulant drugs (Prostagladin E1 60 mg/day, heparin 5000 u/day IV for 7 days, and aspirin 100 mg/day PO for 2 weeks). Wound dressing was performed in the 1st week. Wound irrigation using warm saline was then performed daily in the operating room to minimize infection until flap surgery.

3. Results

In 5 of 6 patients, the patency of the reconstructed artery was maintained, and limb salvage was achieved in all 6 patients. All the flaps survived well. The average flap size used was 100.8 cm^2 (range, 57–196 cm^2). The size of the local flap was 150 cm^2 and that of the muscle flap was 21 cm^2 (Table 2). There were no special complications, such as osteomyelitis, infection, or soft tissue necrosis, at the follow-up visit at an average of 19 months post-reconstruction. However, ankle arthrodesis was performed because of traumatic osteoarthritis in a patient with ankle dislocation. The patient who underwent reconstruction had discharges continuously. Thus, below the knee, amputation was performed at the patient's request 8 months after surgery.

3.1. Case 1

A 36-year-old male patient visited our hospital with a crush injury to the right lower extremity caused by a motorcycle accident. At the time of admission, the patient's MESS score was 6. Clinical photographs and computed angiography showed an open comminuted fracture of the right tibia and fibula, ankle dislocation, and impaired blood circulation of the 3 major arteries below the fracture site (Fig. 2A). External fixation was performed by the trauma surgeons. A posterior tibial artery defect was confirmed in the surgical field. Revascularization through posterior tibial artery reconstruction using the greater saphenous vein (9 cm) was performed (Fig. 2B). For soft tissue damage, the surrounding muscle tissue was applied, and a sterile dressing was maintained. Seven weeks after revascularization, blood circulation was confirmed by angiography (Fig. 2C). Eight weeks after revascularization, debridement was performed on the partially necrotic tissues in the distal lower leg (Fig. 2D). A 19 × 3 cm anterolateral thigh (ALT) free flap was harvested from the contralateral thigh. One artery was anastomosed to the anterior tibialis artery and 2 vena comitantes were anastomosed (Fig. 2E). Subsequently, the external fixation was changed to internal fixation in the 6th week. The flap survived without any complications. One year after the operation, the flap had survived in all extremities without side effects, showing satisfactory results (Fig. 2F).

3.2. Case 2

A 56-year-old female patient visited our hospital with a crush injury to the left lower extremity due to a motorcycle accident. At the time of admission, her MESS score was 8, and an open tibial fracture with severe contamination in the left lower leg was found according to clinical opinion (Fig. 3A). Computed tomography angiography (CTA) revealed an open fracture of the left tibia and fibula with impaired blood circulation in the popliteal artery (Fig. 3B). The fracture was fixed externally. The authors debrided the contaminated and necrotic muscle tissues. In addition, end-to-end repair of the popliteal artery was performed. However, reconstruction was performed using a 2 cm greater saphenous vein for the additionally damaged

Table 1

Demography of the patients.

Patient No.	Age (yr)	Sex	Cause	MESS[a]	Site of injury[b]	Reconstructed vessel[c] (repaired vessel)	Grafted vein[d] (length cm)
1	36	M	Autobike	6	Rt. lower leg	PTA	Lt. GSV (9 cm)
2	57	M	Autobike	8	Rt. lower leg	PTA	Rt. GSV (3 cm)
3	57	M	Industrial accident	7	Lt. wrist and hand	RA (ulnar artery)	Rt. CV (2 cm)
4	37	M	Car	6	Lt. foot	DPA	Lt. GSV (5 cm)
5	60	M	Car	8	Rt. lower leg	ATA	Lt. GSV (10 cm)
6	56	F	Car	8	Lt. lower leg	PTA (popliteal artery)	Rt. GSV (2 cm)

[a]MESS = Mangled Extremity Severity Score.

[b]Lt = left, Rt = right.

[c]ATA = anterior tibial artery, DPA = dorsalis pedis artery, PTA = posterior tibial artery, RA = radial artery.

[d]CV = cephalic vein, GSV = greater saphenous vein.

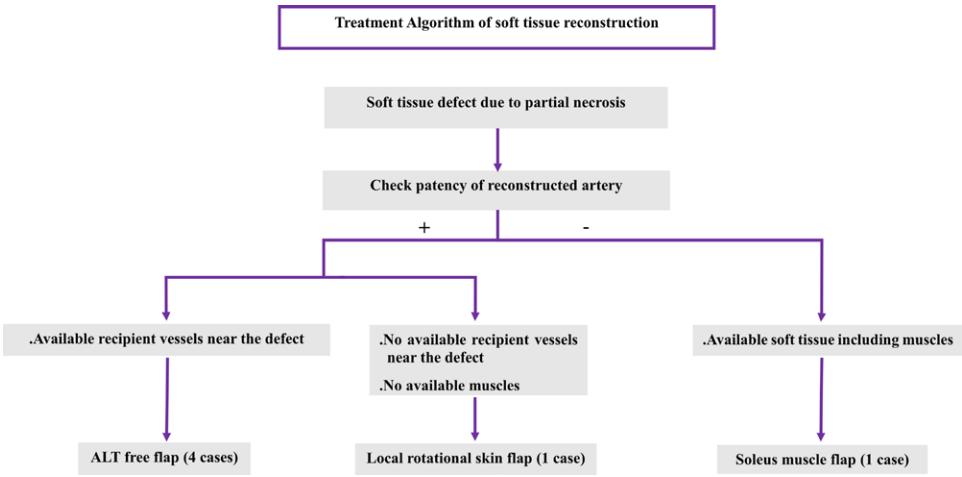

Figure 1. Treatment algorithm of soft tissue reconstruction based on clinical findings.

Table 2

Demography of the patients.

Patient No.	Interval between injury and flap surgery (wk)	Flap surgery[a] method	Flap size (cm)	Flap survival	Complication
1	8	ALT cutaneous	19 × 3	Yes	.
2	7	ALT fascio-cutaneous	13 × 5	Yes	.
3	6	ALT fascio-cutaneous	9.5 × 9	Yes	.
4	7	ALT cutaneous	28 × 7	Yes	Continuous discharge
5	8	Soleus muscle	Defect size 7 × 3	Yes	.
6	8	Local rotational	Defect size 15 × 10	Yes	.

[a]ALT = anterolateral thigh.

posterior tibial artery, which helped obtain lower limb circulation (Fig. 3C). Soft tissue necrosis was observed at 8 weeks after revascularization. After debridement, a 15 cm × 10 cm local rotation flap was performed (Fig. 3D). The patient survived without complications. Satisfactory results were obtained with extremity salvage without side effects until the final follow-up at 5 years after surgery (Fig. 3E).

4. Discussion

In general, if it seems difficult to treat a mangled extremity caused by blood vessel damage that cannot be directly repaired, vascular grafting using autologous veins can be regarded as the best method. It is known to be excellent considering the potential risk of infection and the long-term patency rate.[4–7] However, reconstruction using autologous veins might have disadvantages, such as a relatively long surgery time and difference in blood vessel thickness. For this reason, some recommend the use of artificial blood vessels for patients with unstable vital signs or patients with severe damage afterwards.[8] After considering the infection caused by damage to the soft tissue during emergency surgery, an autogenous vein graft was used, considering the patency rate. Regarding the patency rate of arteries reconstructed using vein graft, it has been reported that the patency rate decreases when vein graft is used, especially for coronary bypass surgery or distal ulnar artery reconstruction for hypothenar hammer syndrome treatment.[9,10] Therefore, Temming et al[11] and De Niet and Van Uchelen[12] have introduced arterial reconstruction using the autogenous descending branch of the lateral circumflex femoral artery and reported promising results. In the present study, occlusion of the reconstructed artery was confirmed in 1 of the 6 cases. Fortunately, limb salvage was achieved. Although the exact reason is not known, we suspect that our observation can be attributed to the fact that mangled limb injuries are different from amputation injuries, where once the fractured bone is reduced and arterial blood is supplied through the reconstructed vessel, arterial circulation is restored in relatively less damaged areas. However, we expect that using an autogenous arterial graft for artery reconstruction would result in a better patency rate of the reconstructed artery. Donor veins were collected from areas that were easy to collect. Thus, it was not difficult to collect because the thickness of the blood vessels increased as much as that of the damaged blood vessels.

The MESS is used as a numerical system to objectively judge the degree of soft tissue damage and decide amputation, especially when deciding on primary amputation for treating an ischemic mangled extremity.[13] In general, in the case of MESS with a score of 7 or higher, the prognosis is poor and amputation is predicted. However, in our case series, 4 of the 6 cases showed a MESS score of 7 or higher. Rather than simply making an early decision to amputate with MESS, after performing vascular reconstruction, confirming maintenance of blood circulation, and stabilizing soft tissues, reconstruction was performed in stages, and satisfactory results were obtained by salvaging the extremities without amputation in any patient. Therefore, treatment of the mangled extremity using MESS is not an absolute standard but rather a reference for treatment. We believe that efforts are necessary to achieve extremity salvage.

The decision to reconstruct soft tissue can typically be considered for cases with direct exposure to important structures, such as bones, ligaments, and nerves. For soft tissue damage that cannot be resolved by conservative treatment such as dressing, it might be difficult to protect structures.[14] It seems very difficult to decide whether or not to reconstruct limbs after a certain period of time has passed after damage to soft tissues. If it is impossible to perform primary repair of injured parts, it is possible to reduce the possibility of further complications by performing sufficient debridement and blocking contact with the outside through appropriate reconstruction as early

Figure 2. A 36-yr-old man was admitted following a motor vehicle accident with multiple injuries. (A) Preoperative photograph showing soft tissue injury and exposed bone fragment on the right lower leg (left). Preoperative computed tomography (CT) angiography showing comminuted fracture of the right tibia and fibula, ankle joint dislocation and the blockage of the right 3 main arteries at the fracture level (right). (B) Intraoperative photographs showing the reconstructed posterior tibial artery with greater saphenous vein graft (9 cm) (white arrows). (C) Angiography at 7 wk postoperatively showing good blood flow in the posterior tibial artery reconstruction site (black arrows). (D) Eight weeks later, postoperative photograph showing partial soft tissue necrosis at the fracture site. (E) Photograph showing soft tissue reconstruction using a 19 × 3 cm sized ALF free flap. (F) Photograph taken at 1 yr after ALT free flap showing well survived limb and well recovered soft tissues.

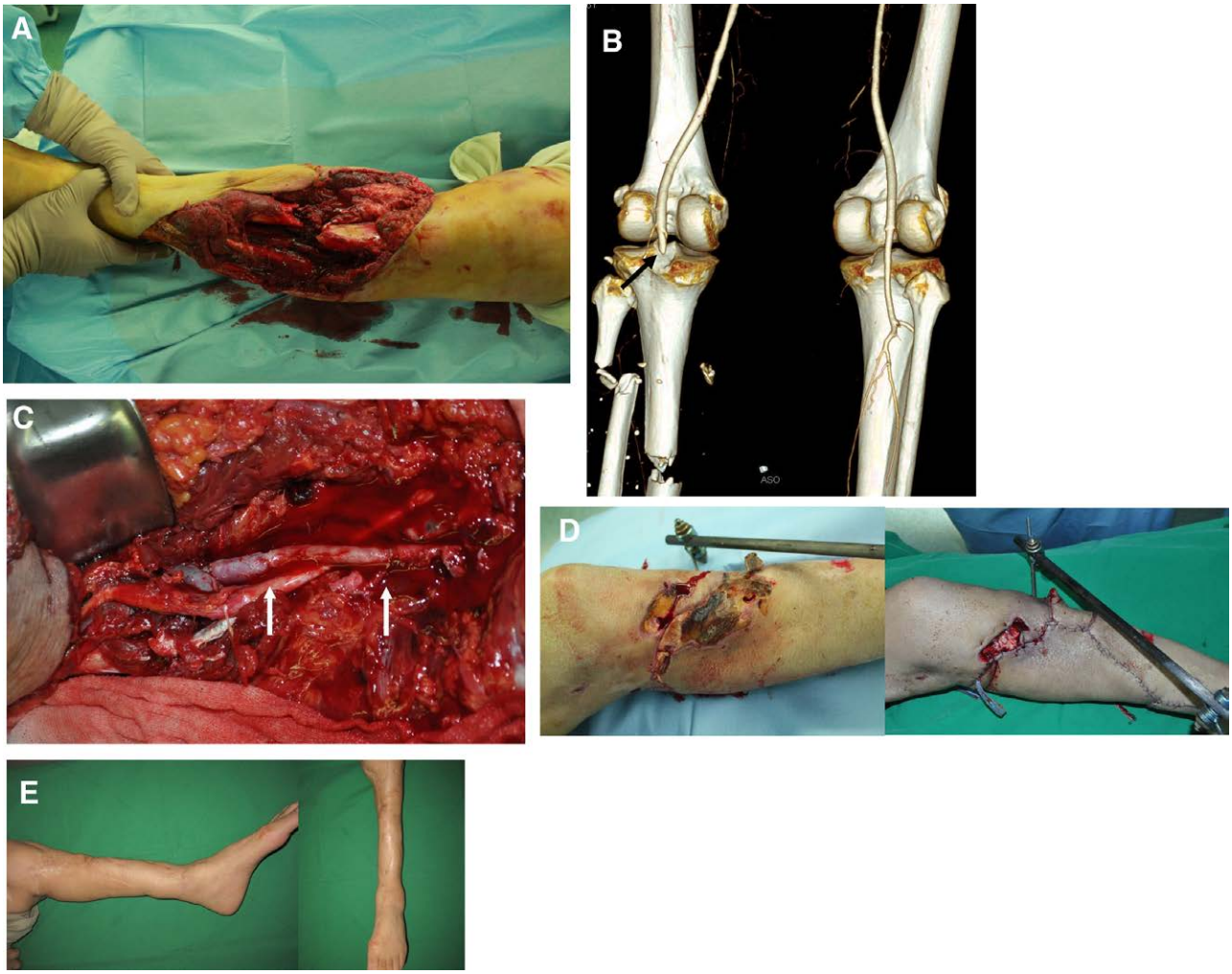

Figure 3. A 56-yr-old woman was admitted following a motor vehicle accident. (A) Preoperative photograph showing soft tissue damage and exposed bone fragments on the left lower leg with soft tissue contamination. (B) Preoperative computed tomography (CT) angiography showing tibia and fibula fractures and popliteal artery being blocked at knee joint level (black arrow). (C) Intraoperative photographs showing reconstructed posterior tibial artery with greater saphenous vein graft (2 cm) (white arrows). (D) At postoperative 8 wk, intraoperative photographs showing proximal soft tissue necrosis of the left lower leg (left) and soft tissue reconstruction using 15 × 10 cm sized local flap after debridement (right). (E) Photograph showing limb salvage with satisfactory recovery of soft tissue at 5 yr after surgery.

as possible.[2,15] If the fracture site is exposed due to fracture, exposure to the outside must be blocked by tissues rich in blood flow as early as possible to reduce the possibility of additional complications such as osteomyelitis and nonunion. This can be regarded as the standard treatment guideline for reducing the likelihood of complications based on Godina research.[16] Thus, a number of retrospective studies have reconstructed soft tissues within 72 hours to reduce the likelihood of soft tissue infection, osteomyelitis, and nonunion without showing significant differences until approximately 10 days.[17,18] However, it might be difficult to apply the same standard treatment guidelines to all patients. In many cases, it is difficult to immediately perform early treatment and reconstruction of soft tissue defects within 72 hours for several reasons. It might also be difficult to decide simultaneously on reconstruction as the primary treatment due to accumulated fatigue of medical personnel and the possibility of soft tissue necrosis. Therefore, we attempted to reconstruct blood vessels after trauma, prevent outside exposure by covering bones with nearby muscles, and offer an active cure to prevent complications. As a result, only 6 of the 13 patients had partial necrosis of their soft tissues after a crush injury. Thus, we believe that it is not necessary to reconstruct all the parts of the soft tissue. In addition, soft tissue reconstruction was performed 7 weeks after the vascular reconstruction. The results were successful after reconstruction. No special complications were found, except for chronic foot infection in a patient who showed continuous foot discharge. Although the timing of reconstruction is an important standard for treatment, we do not think it is necessary to apply it as an absolute standard for strictly observed treatment. The soft tissue reconstruction method should be determined by considering the patient's history, general condition, degree of accompanying injury, size of the injury, infection, and inflammation. There are several reconstruction methods such as simple sutures, skin grafts, local flaps, pedicled flaps, free flaps, and perforated flaps.

A simple method is often considered first, using the concept of a reconstructive ladder. A more difficult and complicated method can be considered if it is feasible. However, recently, new concepts such as a reconstructive elevator and reconstructive pie have been selected to obtain the best results in patient treatment, regardless of the difficulty of surgery.[19]

The ALT flap is versatile. It has the advantages of a large flap territory, durable skin quality, freedom from design, long vascular pedicle, and 3 to 4 mm thickness.[20] The authors reconstructed through an ALT free flap and found that it provided good soft tissue and blood supply to the defect site in 4 cases

where the extent of damage was wide and surrounding soft tissues were poor due to crush damage. We obtained good treatment results in patients who survived without complications, such as infection or nonunion after surgery. In 1 case, the defect site was relatively small, and the surrounding soft tissue was in good condition, making it possible to use thick muscle with abundant blood circulation. Thus, recovery was achieved by reconstruction using a soleus muscle flap. In another case, the ischemia time was 25 hours due to an accompanying injury. During the initial surgery, extensive debridement was performed up to the muscle, and blood circulation was checked. As a result, only the repaired popliteal artery and the reconstructed posterior tibial artery maintained blood circulation. Therefore, local flaps were selected that could be covered without creating a large empty space. All the patients survived without any side effects. The reconstruction method should be selected using the method with the best treatment outcome based on an accurate evaluation of each patient.

This study had some limitations. First, the number of cases was small, as data were obtained for 3 years in 1 hospital by 1 senior surgeon. Second, it was retrospectively analyzed without comparison with a group that underwent vascular reconstruction and flap surgery simultaneously at the time of injury. Third, another trauma surgeon treated the fractures. Thus, the long-term functional results of the injured limb could not be analyzed after surgery.

5. Conclusion

To treat an ischemic mangled extremity, the limbs should first be salvaged with arterial reconstruction through clear debridement and wound healing with subsequent appropriate flap surgery when soft tissue necrosis occurs at the mangled site.

Author contributions

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Visualization: Young-Keun Lee.
Writing – original draft: Young-Keun Lee, Mooheon Jeon, Ji Woong Ho.
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References

[1] Mavrogenis AF, Panagopoulos GN, Kokkalis ZT, et al. Vascular injury in orthopedic trauma. Orthopedics. 2016;39:249–59.
[2] Garner MR, Warner SJ, Heiner JA, Kim YT, Agel J. Soft tissue management in open tibial shaft fractures: a comparison of institutional preferences and resultant early clinical outcomes. Bone Jt Open. 2020;1:481–7.
[3] Jeon MH, Lee YK. Outcomes after arterial reconstruction with autogenous vein graft for limb salvage in traumatized extremity. Arch Hand Microsurg. 2021;26:184–92.
[4] Peck JJ, Eastman AB, Bergan JJ, Sedwitz MM, Hoyt DB, McReynolds DG. Popliteal vascular trauma. A community experience. Arch Surg. 1990;125:1339–43 [discussion 1343].
[5] Van Damme H, Zhang L, Baguet E, Creemers E, Albert A, Limet R. Crural artery bypass with the autogenous greater saphenous vein. Eur J Vasc Endovasc Surg. 2003;26:635–42.
[6] Chuong B, Katira K, Ramsay T, LoGiudice J, Martin A. Reliability of long vein grafts for reconstruction of massive wounds. J Clin Med. 2023;12:6209.
[7] Siddique MK, Bhatti AM. A two-year experience of treating vascular trauma in the extremities in a military hospital. J Pak Med Assoc. 2013;63:327–30.
[8] McCready RA, Logan NM, Daugherty ME, Mattingly SS, Crocker C, Hyde GL. Long-term results with autogenous tissue repair of traumatic extremity vascular injuries. Ann Surg. 1987;206:804–8.
[9] Cooper GJ, Underwood MJ, Deverall PB. Arterial and venous conduits for coronary artery bypass: a current review. Eur J Cardiothorac Surg. 1996;10:129–40.
[10] Dethmers RS, Houpt P. Surgical management of hypothenar and thenar hammer syndrome: a retrospective study of 31 instances in 28 patients. J Hand Surg Br. 2005;30:419–23.
[11] Temming JF, van Uchelen JH, Teller MA. Hypothenar hammer syndrome: distal ulnar artery reconstruction with autogenous descending branch of the lateral circumflex femoral artery. Tech Hand Up Extrem Surg. 2011;15:24–7.
[12] De Niet A, Van Uchelen JH. Hypothenar hammer syndrome: long-term follow-up after ulnar artery reconstruction with the lateral circumflex femoral artery. J Hand Surg Eur Vol. 2017;42:507–10.
[13] Lin CH, Wei FC, Levin LS, Su JI, Yeh WL. The functional outcome of lower-extremity fractures with vascular injury. J Trauma. 1997;43:480–5.
[14] Younger AS, Goetz T. Soft tissue coverage for posttraumatic reconstruction. Foot Ankle Clin. 2006;11:217–35, xi.
[15] Korompilias AV, Lykissas MG, Vekris MD, Beris AE, Soucacos PN. Microsurgery for lower extremity injuries. Injury. 2008;39:S103–8.
[16] Godina M. Early microsurgical reconstruction of complex trauma of the extremities. Plast Reconstr Surg. 1986;78:285–92.
[17] Lee ZH, Stranix JT, Rifkin WJ, et al. Timing of microsurgical reconstruction in lower extremity trauma: an update of the Godina paradigm. Plast Reconstr Surg. 2019;144:759–67.
[18] Lee ZH, Stranix JT, Levine JP. The optimal timing of traumatic lower extremity reconstruction: current consensus. Clin Plast Surg. 2021;48:259–66.
[19] Jeon BJ, Mun GH. Perspectives on reconstructive microsurgery in Korea. J Korean Med Assoc. 2011;54:604–16.
[20] Lee YK, Lee M. Treatment of infected achilles tendinitis and overlying soft tissue defect using an anterolateral thigh free flap in an elderly patient: a case report. Medicine (Baltim). 2018;97:e11995.