Am J Transl Res 2023;15(5):3631-3638
www.ajtr.org /ISSN:1943-8141/AJTR0148788

Original Article

Effects of anterolateral femoral free flap transplantation on the repair of soft tissue defect of hands and feet and risk factors for flap necrosis

Yefeng Lu, Dan Shen, Jinlin Cao, Xuehui Huang, Junhui Zhou

Department of Hand and Foot Microsurgery, Yuyao People's Hospital of Zhejiang Province, Ningbo, Zhejiang, China

Received December 27, 2022; Accepted February 6, 2023; Epub May 15, 2023; Published May 30, 2023

Abstract: Objective: To retrospectively analyze the effect of anterolateral femoral free flap transplantation in repairing hand and foot soft tissue defects and the risk factors for skin flap necrosis. Methods: The clinical data of 62 patients with hand and foot soft tissue defects admitted to Department of Hand and Foot Microsurgery in Yuyao People's Hospital of Zhejiang Province from January 2018 to December 2021 were retrospectively analyzed. According to the different methods of skin flap transplantation, these patients were divided into a control group (n=30, conventional skin flap transplantation) and an observation group (n=32, anterolateral femoral free skin flap transplantation). The clinical outcomes and postoperative flap survival rate were compared between the two groups. The risk factors of flap necrosis were analyzed by univariate and multivariate Logistic regression. Results: The surgical time, intraoperative blood loss and hospital stay in the observation group were significantly less than those in the control group (all $P<0.05$). The survival rate of skin flap in the observation group was significantly higher than in the control group ($P<0.05$). Logistic regression analysis showed that intraoperatively incomplete hemostasis, inappropriate selection of anastomotic vessels, irrational use of antibiotics, infection and unstable fixation were independent risk factors for skin flap necrosis following hand and foot soft tissue defects surgery. Conclusion: Anterolateral femoral free flap transplantation is beneficial to improve the clinical outcomes in patients with hand or foot soft tissue defects, increase the survival rate of skin flap and promote recovery. Incomplete hemostasis during operation, inappropriate choice of anastomotic vessels, irrational application of antibiotics, concurrent infection and unstable fixation are independent risk factors for postoperative flap necrosis.

Keywords: Hand and foot soft tissue defect, anterolateral femoral flap transplantation, flap necrosis

Introduction

With the rapid development of the economy, hand and foot injuries caused by industry and traffic accidents are on the rise year by year. When hands and feet are injured, this is often accompanied by avulsion or defect of soft tissue [1], neurovascular injury, bone and joint exposure, which has a serious impact on the daily life and activities of patients. Therefore, timely repair and treatment are required. For soft tissue defects in hand and foot, skin flap transplantation is usually performed [2].

Free skin flap transplantation is defined as the anastomosis of isolated skin flap to the blood vessels in the damaged area through the vascular anastomosis technology, thus establishing a better blood supply and venous return. Abdominal flap is one of the most commonly applied flaps in traditional repair of skin defect. However, there are some limitations: blood supply to the flap is easily affected by a change in body position; the recovery of sensory nerve function is poor; and vascular crisis is frequently observed. Recently, the anterolateral femoral free flap has been applied by more surgeons. It was shown that the anterolateral femoral free flap could meet the requirements for repairing wounds of hands and feet in different degrees [3, 4]. The vascular pedicle of the anterolateral thigh flap is the descending branch of the lateral femoral circumflex artery, which has obvious advantages. For example, the vascular

pedicle is relatively constant and long, the vascular diameter is large, and a large area can be obtained. Moreover, this kind of flap can carry the anterolateral thigh cutaneous nerve, which is conducive to the reconstruction of sensory function. After the flap is removed, the donor area is less affected, and it is not easy to damage the important blood vessels of the limbs. The lateral thigh flap can not only repair the soft tissue defects of hands and feet, but also repair the wound defects of various parts of the body, with a wide range of applications [5, 6].

Necrosis of the anterolateral femoral flap was previously thought to be associated with diabetes, severe hypertension, long operative time, the number of venous anastomoses, and vascular crisis. In diabetes patients, due to the metabolic disorder, the ability of platelet adhesion increases, which increases the blood viscosity, leading to slow local blood flow, and long-term effects can lead to atherosclerosis [7]. In addition, such patients often have poor wound healing effect or delayed healing, and the skin flap is prone to infection and necrosis [8]. In patients with severe hypertension, the elasticity of blood vessels is often poor, the intima of blood vessels is prone to atherosclerosis, and the thickening of the endothelium in blood vessels is prone to thrombosis, which is not conducive to the healing of skin flaps. Long operative time is associated with necrosis of this kind of flap. Long operative time can increase the probability of thrombosis and prolong the time of tissue ischemia. Ischemia reperfusion of the flap would lead to the swelling and damage of endothelial cells, and affect the ability of anti-platelet aggregation [9]. Anastomosis of two veins is better than that of one vein. If one vein is blocked, the other vein can maintain venous return. Anastomosis of two veins can effectively improve blood flow rate and reduce the risk of skin flap congestion [10]. After bacterial infection, the secreted bacterial toxin may cause necrosis of the skin flap. Anti-infection treatment should be performed in time after surgical operations, in order to reduce the probability of skin flap infection. Vascular crisis refers to the obstruction of blood circulation after vascular anastomosis, which leads to flap necrosis [11]. Vascular crisis can be divided into arterial crisis and venous crisis. The venous crisis is caused by the relatively short pedicle of the perforator when the flap is cut. The mechanical lumen obstruction of the venous vessel occurs during the operation of traction and compression, which increases the probability of thrombosis at the anastomotic orifice. Vasospasm is the main cause of arterial crisis at 2 days after operation, while vascular obstruction is the main cause of arterial crisis within 1 day after operation. However, risk factors for flap necrosis are uncertain. In this study, 62 patients with hand and foot soft tissue defects admitted to our hospital from January 2018 to December 2021 were selected as the study objects. The clinical efficacy of anterolateral thigh flap and conventional flap transplantation in the treatment of hand and foot soft tissue defects was analyzed retrospectively, and other risk factors in addition to the above causes resulting in flap necrosis were also investigated. The results of this study would provide the clinical evidence for free skin flap transplantation.

Materials and methods

General information

This retrospective study had been approved by the ethical committee of Yuyao People's Hospital of Zhejiang Province (No. 201711-108). 62 patients with soft tissue defect of hand and foot admitted to the Department of Hand and Foot Microsurgery, Yuyao People's Hospital of Zhejiang Province between January 2018 to December 2021 were enrolled in this study. Inclusion criteria: ① All patients who were diagnosed with hand and foot soft tissue defects after admission with the requirement of surgical flap transplantation; ② Patients without trauma history of hand and foot; ③ Patients without coagulation dysfunction; ④ Patients with an age over 20; ⑤ Patients who had signed the operative consent before surgery. Exclusion criteria: ① Patients with trauma or abnormal function of heart, liver, lung and other organs; ② Patients with malignant tumors; ③ Patients with limb fracture or spinal fracture; ④ Patients with Immune immune system diseases; ⑤ Patients with infectious diseases including tuberculosis; ⑥ Patients with mental disorders that couldn't cooperate with surgical treatment.

According to the methods of skin flap transplantation, these patients were divided into control group and observation group. There

were 32 patients in the observation group and they received the anterolateral femoral free flap transplantation treatment. There were 30 patients in the control group and they underwent routine skin flap transplantation treatment.

Surgical procedure

The anterolateral femoral free flap transplantation was performed in patients from observation group. The details were as follows: The perforating point of the descending branch of the lateral circumflex femoral artery was explored and marked by ultrasonic examination. The area and shape of the skin flap were calculated according to the area and shape of the hand or foot soft tissues defects. The skin flap area was required to be 20% larger than the soft tissue defects. The skin flap was cut according to the design shape. The medial edge of the flap was cut to the deep fascia. The skin and deep fascia were temporarily fixed. The skin flap was lifted from the inside out, and it was carefully explored to find the perforating vessels with appropriate diameter. The space between the lateral thigh muscle and the rectus femoris muscle was open to determine the source of the perforating branch. If it was necessary to cut the lobulated skin flap, two or more perforating branches should be exposed, and the appropriate perforating branch should be selected according to the distance and length of each perforating branch. During the operation, the musculocutaneous perforator to the main trunk of the descending branch of the lateral circumflex femoral artery should be carefully separated. The lateral edge, the distal and proximal ends of the skin flap was cut. The blood supply of the skin flap was evaluated after separating the skin flap. If the blood supply was good, the pedicle could be cut and the skin flap was immediately kept in the receiving area. The wound in the receiving area was cleaned and stopped bleeding. The peripheral areas and wound edge were temporarily fixed, and the blood supply of the skin flap was reconstructed by anastomosing vessels under the microscope.

The conventional skin flap transplantation was conducted in patients in control group. After the expansion of the wound, the wound was sutured to make the vascular anastomosis in an everted state. The pedicled skin flap, the abdominal pedicled skin flap, and the crossing legs pedicled skin flap were selected according to the specific situation. During the anatomy, the distal end of the thicker pedicled blood vessel branch was ligated. The recipient area and the blood vessels of skin flap were carefully anastomosed to construct the vascular access.

Outcome measures

Indicators such as postoperative flap survival conditions and risk factors of flap necrosis were considered as primary ones. Indicators such as surgical time, intraoperative blood loss and length of stay in hospital were considered as secondary.

Comparisons were performed between control group and observation group in the term of surgical time, intraoperative blood loss, and length of stay in hospital.

The flap survival conditions at one month after operation were compared between two groups. It included ten items such as sweating, skin color, and appearance. The scores for each item ranged from 0-10 points. The full score was 100 points. If the score was less than 40 points, it indicated that the skin flap was necrotic. The higher scores suggested the better survival of the skin flap.

The risk factors for flap necrosis after the repairing treatment of hand or foot soft tissues defects were analyzed by univariate and multivariate Logistic regression.

Statistical analysis

All data included in this study were analyzed with SPSS 25.0 software. Measured data were expressed as mean ± standard deviation, and independent-sample T test was used for comparison between the two groups. Enumerated data were expressed as number/percentage, and Chi-square test was used for comparison between two groups. The risk factors for flap necrosis following the repairing treatment of hand or foot soft tissues defects were evaluated by univariate and multivariate analysis. P <0.05 was considered significant.

Results

General information

No obvious differences were observed in comparisons of general information including gender, age, causes of injury, hand injuries and foot

Table 1. Comparison of general information between observation group and control group

Value		Observation group (N=32)	Control group (N=30)	t/x^2	*p*
Gender	Male	18	17	0.753	0.453
	Female	14	13		
Age (years)		36.04±5.21	37.15±4.93	0.554	0.496
Cause of injury	Traffic accident injuries	14	12	0.698	0.487
	Twist trauma	10	9		
	High-explosive injury	5	6		
	Other injuries	3	3		
Hand injuries		17	16	0.491	0.536
Foot injuries		15	14	0.503	0.524

Table 2. Comparison of intraoperative and postoperative indexes between control group and observation group

Group	Time of operation (min)	Intraoperative blood loss (mL)	Hospital stays (d)
Observation group	169.85±21.42	100.97±18.12	15.42±1.75
Control group	225.73±22.04	152.45±20.57	24.03±2.64
T value	15.382	13.770	7.594
P value	<0.001	<0.001	<0.001

Table 3. Comparison of the survival rate of flaps after surgery between two groups

Group	Cases	Survival	Partial necrosis	Complete necrosis	Overall survival rate
Observation group	32	30	2	0	93.75%
Control group	30	24	4	2	80.0%
χ^2 value					5.903
P value					0.003

injuries, as seen in **Table 1** (P>0.05), indicating the two groups were comparable.

Comparison of clinical index

As shown in **Table 2**, compared to those in control group, patients in observation group had significantly less intraoperative blood loss, shorter surgical time and length of stay in hospital (all P<0.001).

Comparison of the postoperative survival rate of skin flaps

After operation, in the observation group, there were 2 patients with partial necrosis, while there were 4 cases with partial necrosis, 2 cases with complete necrosis in the control group. The total survival rate in the observation group was significantly higher than that in the control group (P=0.003), as shown in **Table 3**.

Results of univariate analysis

As described in **Table 4**, univariate analysis results showed that incomplete hemostasis during operation (χ^2=9.493, P<0.001), inappropriate selection of anastomotic vessels (χ^2=11.521, P<0.001), irrational use of antibiotics (χ^2=10.578, P<0.001), infection (χ^2=13.751, P<0.001) and unstable fixation (χ^2=17.305, P<0.001) were considered as the risk factors for skin flaps necrosis following hand and foot soft tissue defect surgery.

Results of multivariate analysis

As presented in **Table 5**, the multivariate analysis results indicated that incomplete hemostasis during operation (OR=2.886, 95% CI: 1.147-7.249, P=0.021), inappropriate selection of anastomotic vessels (OR=3.005, 95% CI: 1.242-7.308, P=0.013), irrational use of antibiotics (OR=2.789, 95% CI: 1.329-5.882, P=0.005), infection (OR=2.816, 95% CI: 1.251-6.353, P=0.021) and unstable fixation (OR=2.757, 95% CI: 1.247-6.105, P=0.014) were independent risk factors for skin flaps necrosis following hand and foot soft tissue defects surgery.

Table 4. Univariate analysis results of skin flap necrosis following operation

Item		Survival (N=54)	Necrosis (N=8)	t/χ^2	p
Gender	Male	30 (55.56%)	5 (62.5%)	0.723	0.512
	Female	24 (44.44%)	3 (37.5%)		
Age		34.97±3.04	34.82±4.11	0.535	0.503
Intraoperatve hemostasis	Complete	43 (79.63%)	2 (25.0%)	9.493	<0.001
	Incomplete	11 (20.37%)	6 (75.0%)		
Inappropriate selection of anastomotic vessel		10 (18.52%)	5 (62.5%)	11.521	<0.001
Rational application of antibiotics	Yes	46 (85.19%)	2 (25.0%)	10.578	<0.001
	No	8 (14.81%)	6 (75.0%)		
Evidences of infection		6 (11.11%)	5 (62.5%)	13.751	<0.001
Unstable fixation		3 (5.56%)	5 (62.5%)	17.305	<0.001

Table 5. Multivariate analysis results of skin flap necrosis following operation

Item	*B*	*SE*	*Wald*	*P Value*	*OR*	*95% CI*
Incompletely Intraoperatve hemostasis	1.053	0.457	5.118	0.021	2.886	1.147-7.249
Inappropriate selection of anastomotic vessel	1.098	0.449	5.869	0.013	3.005	1.242-7.308
Irrational application of antibiotics	1.024	0.382	7.392	0.005	2.789	1.329-5.882
Evidence of infection	1.039	0.407	6.323	0.011	2.816	1.251-6.353
Unstable fixation	1.026	0.401	6.291	0.014	2.757	1.247-6.105

Note: OR: Odds Ratio; SE: Standard Error.

Discussion

The four limbs are indispensable key organs for people to complete the activities of daily living. There are widely distributed blood vessels and nerves in limbs. Injury impairs life quality. Skin flap transplantation is an important method for the treatment of hand and foot soft tissue defects [12]. Although conventional skin flap transplantation can repair part of the damaged skin, the scope of application is small and it requires multiple surgical treatments. Moreover, postoperative treatment is relatively troublesome, and the donor site is more traumatic. In recent years, free skin flap transplantation is more and more widely used. It has become one of the main methods for repairing the traumatic hand and foot soft tissue defects [13]. Compared to conventional flap transplantation, free flap transplantation has significant advantages. For example, the requirement of position is not high, and it can maintain the aesthetic appearance. In additional, the hospital stay is short, and it can greatly reduce the pain in patients.

For the anterolateral femoral flap used in this study, its anatomical characteristics are obvious. The blood supply of the anterolateral femoral flap is mainly from the descending branch of the lateral circumflex femoral artery, and the remaining blood supply is from the ascending branch and oblique branch of the artery. Some studies showed that in the distribution of perforating branches of the anterolateral femoral flap, double perforating branches accounted for about 55%, three perforating branches accounted for about 30%, and single perforating branch accounted for about 15% [14, 15]. Other studies showed that the septocutaneous perforators in the anterolateral femoral flap are easily to be separated, and the survival rate of the skin flap following transplantation is relatively high [16, 17]. Another feature of anterolateral femoral flap is that it can be made into a sensory flap with nerves. When repairing hand and foot soft tissue defects, the anterolateral femoral flap with the lateral femoral cutaneous nerve can better improve the sensory function of the flap. It is believed that the lateral femoral cutaneous nerve can be used as the sensory nerve of the anterolateral femoral flap [18]. The anterolateral femoral flap can be used to repair large soft tissue defects in limbs. In this study, the results showed that the operation time and hospitalization time of the patients in the observation group were significantly shorter

than those in the control group, and the amount of intraoperative bleeding was obviously lower than that in the control group, indicating that the application of free skin flap transplantation from the anterolateral femoral region to repair traumatic soft tissue defects of limbs showed little impact on their clinical indicators, and it was conducive to promoting the recovery of patients. These results were similar with the previous studies reported by Xie et al. [19] In addition, the survival rate of the skin flap in the observation group was 93.75%, which was significantly higher than that in the control group (80.0%). This shows that the anterolateral femoral free skin flap transplantation improved the survival rate of the flap in patients with traumatic soft tissue defects in limbs. The study of Yang et al. also obtained similar results [20]. The transplantation of free anterolateral femoral skin flap could keep the blood supply of the skin flap and the local area at all times by selecting a suitable skin flap area and adopting scientific operation techniques, and lead to the less possibility of infection, further avoiding necrosis of the skin flap.

We believe that the following cautions should be focused on during the anterolateral femoral flap operation [21, 22]: (1) Before the operation, the vascular conditions of the donor and recipient areas should be understood well, and then a suitable surgical plan was formulated. (2) If it is difficult to obtain the flap or the flap is bloated in relatively obese patients, the flap is needed to be thinned and reshaped. (3) Attention should be paid to the control of wound infection. Thoroughly clean the wound before operation to prevent venous crisis. (4) The thickness and shape of the flap should be designed in advance. The length and width of the flap have an impact on the blood supply range and the venous return pressure. The reflux veins should be anastomosed as much as possible during the operation. (5) Avoid excessive muscle separation during operation, prevent vascular pedicle torsion and reduce the incidence of venous crisis. (6) Because the skin flap is relatively thin and the blood supply is difficult to master, it is necessary to use ultrasound to check the blood flow of the skin flap after operation and carefully observe whether there is a vascular crisis.

The advantages of the anterolateral femoral flap are as follows [21, 23]: (1) The operation is relatively easy, the patient's position does not need to be changed during the operation, and two groups of actions can be performed simultaneously during the operation, which is conducive to reducing the operation time and amount of bleeding during the operation, and increasing the survival rate of the flap. (2) The anterolateral femoral flap can repair most of the tissue defects, with a wide range of applications. The blood vessels are relatively constant during the operation and are easy to be anastomosed. Intraoperative drainage can effectively reduce the obstruction of venous return caused by hematoma in the flap area and the occurrence rate of vascular crisis is low. (3) During the operation, the trauma to the patient is small. After the blood supply of the flap is determined, the pedicle can be cut again, and then the blood vessels can be drawn out to prevent the injuries of nerve and muscle.

Survival of the skin flap in patients receiving free flap repairment directly affects the subsequent recovery and quality of life. If the skin flap is necrotic, it needs to be operated on again, which would cause great physiological and psychological trauma in patients. Some studies reported that there are many factors leading to flap necrosis, such as diabetes, severe hypertension, long operation time, large wound depth and area, unreasonable intraoperative manipulation, number of vein anastomoses, and vascular crisis [24, 25]. In addition to the above factors, it is of great clinical significance to explore and analyze whether there are other factors that affect flap necrosis. Understanding the risk factors is beneficial to formulating relevant preventive and control plans in advance and improving the success rate of flap transplantation.

Logistic multifactor analysis results of this study showed that incomplete hemostasis during operation, inappropriate choice of anastomotic vessels, unreasonable application of antibiotics, concurrent infection and unstable fixation were important risk factors for flap necrosis after operation. Incomplete hemostasis during operation would lead to excessive blood accumulation in the lower layer of the flap, thus the increasing tension of the flap could cause vascular embolism or spasm [26]. Inappropriate choice of anastomotic vessels would directly affect the blood supply in the body and the flap, and the bad blood supply

would directly lead to the flap necrosis. Unreasonable use of antibiotics would gradually make the skin flap become a place where bacteria gathered, and can also directly cause the necrosis of the skin flap. A concurrent infection would directly affect the microcirculation in the skin flap area, and the skin flap would gradually become inflamed, leading to obstruction of the anastomotic orifice [27]. Poor blood supply would cause necrosis of the skin flap. The flap should be effectively fixed after transplantation. If the fixation is not stable, the activities would make the flap necrotic and fall off, which is not conducive to postoperative recovery [28].

However, this study has several shortcomings that should be recognized. First, this is a retrospective study and there were no long-term follow-up results. Second, the sample size was small, which may affect its findings. Third, the data were collected from single center, which may affect its generalization to other hospitals.

In conclusions, the anterolateral femoral free flap transplantation has the advantages of shorter surgical time and hospital stay, less degree of trauma to patients, and higher survival rate of the flap in repairing the soft tissue defects of limbs. In addition, incomplete hemostasis during operation, inappropriate choice of anastomotic vessels, irrational application of antibiotics, concurrent infection, and unstable fixation are independent risk factors for postoperative flap necrosis.

Disclosure of conflict of interest

None.

Address correspondence to: Junhui Zhou, Department of Hand and Foot Microsurgery, Yuyao People's Hospital of Zhejiang Province, No. 800, Chengdong Road, Yuyao, Ningbo 315400, Zhejiang, China. Tel: +86-0574-63623569; Fax: +86-0574-63623569; E-mail: zhoujh_@outlook.com

References

[1] Dhar LK, Talukder A, Kaiser A, Razia S, Jahan I and Islam MS. Posterior tibial artery perforator based propeller flap for lower leg and ankle defect coverage: a prospective observational study. Mymensingh Med J 2019; 28: 311-316.

[2] Arslan H and Demiroz A. Comparison of subacute and delayed free flap reconstruction in the treatment of open lower extremity fractures. Ulus Travma Acil Cerrahi Derg 2019; 25: 188-192.

[3] Tanaka K, Igari K, Kishino M, Usami S, Homma T, Toyofuku T, Inoue Y and Okazaki M. The possibility of free tissue transfer as a nutrient flap for critical ischemic foot: a case report. Microsurgery 2017; 37: 694-698.

[4] Cho EH, Garcia RM, Pien I, Kuchibhatla M, Levinson H, Erdmann D, Levin LS and Hollenbeck ST. Vascular considerations in foot and ankle free tissue transfer: analysis of 231 free flaps. Microsurgery 2016; 36: 276-283.

[5] Manrique OJ, Bishop SN, Ciudad P, Adabi K, Martinez-Jorge J, Moran SL, Huang T, Vijayasekaran A, Chen SH and Chen HC. Lower extremity limb salvage with cross leg pedicle flap, cross leg free flap, and cross leg vascular cable bridge flap. J Reconstr Microsurg 2018; 34: 522-529.

[6] Ehrl D, Heidekrueger PI, Schmitt A, Liska F, Ninkovic M, Giunta R and Broer PN. The anterolateral thigh flap for achilles tendon reconstruction: functional outcomes. Plast Reconstr Surg 2019; 143: 1772-1783.

[7] Fridoni M, Kouhkheil R, Abdollhifar MA, Amini A, Ghatrehsamani M, Ghoreishi SK, Chien S, Bayat S and Bayat M. Improvement in infected wound healing in type 1 diabetic rat by the synergistic effect of photobiomodulation therapy and conditioned medium. J Cell Biochem 2019; 120: 9906-9916.

[8] Lu J, DeFazio MV, Lakhiani C, Abboud M, Penzler M, Elmarsafi T, Kim PJ, Attinger CE and Evans KK. Limb salvage and functional outcomes following free tissue transfer for the treatment of recalcitrant diabetic foot ulcers. J Reconstr Microsurg 2019; 35: 117-123.

[9] Kang CS and Kim TG. Distally-based free anterolateral thigh flap with a modified vena comitans. Arch Plast Surg 2019; 46: 84-87.

[10] Meloni M, Morosetti D, Giurato L, Stefanini M, Loreni G, Doddi M, Panunzi A, Bellia A, Gandini R, Brocco E, Lazaro-Martinez JL, Lauro D and Uccioli L. Foot revascularization avoids major amputation in persons with diabetes and ischaemic foot ulcers. J Clin Med 2021; 10: 3977.

[11] Zhan Y, Fu G, Zhou X, He B, Yan LW, Zhu QT, Gu LQ, Liu XL and Qi J. Emergency repair of upper extremity large soft tissue and vascular injuries with flow-through anterolateral thigh free flaps. Int J Surg 2017; 48: 53-58.

[12] Deng C, Wu B, Wei Z, Li H, Zhang T and Wang D. Interperforator flow pattern and clinical application of distal extended peroneal artery perforator flaps. Ann Plast Surg 2018; 80: 546-552.

[13] Olsson M, Jarbrink K, Divakar U, Bajpai R, Upton Z, Schmidtchen A and Car J. The human-

istic and economic burden of chronic wounds: a systematic review. Wound Repair Regen 2019; 27: 114-125.
[14] Lin CH, Hsieh YH and Lin CH. The medial sural artery perforator flap in lower extremity reconstruction. Clin Plast Surg 2021; 48: 249-257.
[15] Abdelrahman M, Jumabhoy I, Qiu SS, Fufa D, Hsu CC, Lin CH, Lin YT and Lin CH. Perfusion dynamics of the medial sural artery perforator (MSAP) flap in lower extremity reconstruction using laser Doppler perfusion imaging (LDPI): a clinical study. J Plast Surg Hand Surg 2020; 54: 112-119.
[16] Lofstrand JG and Lin CH. Reconstruction of defects in the weight-bearing plantar area using the innervated free medial plantar (instep) flap. Ann Plast Surg 2018; 80: 245-251.
[17] Niu Z, Chen Y, Li Y, Tao R, Lei Y, Guo L, Zhang F, Zhang H, Zhang Q, August M and Han Y. Comparison of donor site morbidity between anterolateral thigh and radial forearm free flaps for head and neck reconstruction: a systematic review and meta-analysis. J Craniofac Surg 2021; 32: 1706-1711.
[18] Li B, Chang SM, Du SC, Zhuang L and Hu SJ. Distally based sural adipofascial turnover flap for coverage of complicated wound in the foot and ankle region. Ann Plast Surg 2020; 84: 580-587.
[19] Xie S, Deng X, Chen Y, Song D, Li K, Zhou X and Li Z. Reconstruction of foot and ankle defects with a superthin innervated anterolateral thigh perforator flap. J Plast Surg Hand Surg 2016; 50: 367-374.
[20] Yang WG, Chiang YC, Wei FC, Feng GM and Chen KT. Thin anterolateral thigh perforator flap using a modified perforator microdissection technique and its clinical application for foot resurfacing. Plast Reconstr Surg 2006; 117: 1004-1008.
[21] Jaiswal D, Ghalme A, Yadav P, Shankhdhar V and Deshpande A. Free anteromedial thigh perforator flap: complementing and completing the anterolateral thigh flap. Indian J Plast Surg 2017; 50: 16-20.
[22] Hu Y, Wang Y, Cao S, Zhang N, Xu W and Li X. Customizing anterolateral thigh flap with MRA DISCO imaging for individualized reconstruction of extremity defects. J Surg Res 2022; 283: 733-742.
[23] Manjunath KN, Waiker PV, Shanthakumar S and Kumaraswamy M. Efficacy of pedicled anterolateral thigh flap for reconstruction of regional defects-a record analysis. Acta Chir Plast 2022; 64: 6-11.
[24] Qiu D, Wang X, Wang X, Jiao Y, Li Y and Jiang D. Risk factors for necrosis of skin flap-like wounds after ED debridement and suture. Am J Emerg Med 2019; 37: 828-831.
[25] Wei JW, Dong ZG, Ni JD, Liu LH, Luo SH, Luo ZB, Zheng L and He AY. Influence of flap factors on partial necrosis of reverse sural artery flap: a study of 179 consecutive flaps. J Trauma Acute Care Surg 2012; 72: 744-750.
[26] Agostini T, Lazzeri D and Spinelli G. Anterolateral thigh flap: systematic literature review of specific donor-site complications and their management. J Craniomaxillofac Surg 2013; 41: 15-21.
[27] Ghali S, Bhatt KA, Dempsey MP, Jones DM, Singh S, Arabi S, Butler PE, Gallo RL and Gurtner GC. Treating chronic wound infections with genetically modified free flaps. Plast Reconstr Surg 2009; 123: 1157-1168.
[28] Zhang P, Feng J, Liao Y, Cai J, Zhou T, Sun M, Gao J and Gao K. Ischemic flap survival improvement by composition-selective fat grafting with novel adipose tissue derived product-stromal vascular fraction gel. Biochem Biophys Res Commun 2018; 495: 2249-2256.