Modified Recipient Blood Flow-preserved Cross-leg Anterolateral Thigh Flap Procedure for Complex Lower Extremity Reconstruction

Hong-Xiang Zhou (✉ zhouhx8888@163.com)

Anhui Medical University <https://orcid.org/0000-0002-2845-8967>

Liang He

Anhui Medical University

Dong Yin

Anhui Medical University

Yang Niu

Anhui Medical University

Zhe Jin

Anhui Medical University

Jun-Jie Li

Anhui Medical University

Qian-Kun Wang

Anhui Medical University

Tao Zhou

Anhui Medical University

Research Article

Keywords: Cross-leg anterolateral thigh flap, Flow-through, Free skin wrapping of the vascular pedicle, Microanastomosis

Posted Date: April 19th, 2021

DOI: <https://doi.org/10.21203/rs.3.rs-411666/v1>

License: © ⓘ This work is licensed under a Creative Commons Attribution 4.0 International License. [Read Full License](#)

Abstract

Background: Complex lower limb reconstruction following severe trauma remains a challenge for reconstructive surgeons. We here introduce a modified recipient blood flow-preserved cross-leg anterolateral thigh flap procedure and evaluate its clinical efficacy.

Methods: Between January 2013 and December 2019, 22 patients (range 10 to 64 years old) with unilateral lower limb injuries underwent the modified recipient blood flow-preserved cross-leg anterolateral thigh flap procedures. Among them, 16 cases were traffic accidents, 5 cases were stubborn ulcers, and 1 case was degloving injury. The arterial pedicle of flap was prepared as Y-shaped fashion and microanastomosed to contralateral posterior tibial artery in a flow-through style. A split-thickness skin graft was applied to wrap the vascular pedicle after anastomosis. The flap was designed as single or bilobed fashions according to the shape of defects. The tissue defects ranged from 12×6 to 21×18 cm². The vascular pedicle was divided 4 weeks after vascular anastomosis. Doppler ultrasound was performed to evaluate the blood flow of the recipient posterior tibial artery during postoperative follow-up.

Results: All of 22 flaps survived. The flap sizes ranged from 14×7.5 to 24×21 cm². Eighteen flaps were designed as single fashion, and four flaps were bilobed fashion. Twenty patients underwent fasciocutaneous flap transplantation, and two underwent musculocutaneous flap transplantation. Two cases developed local lysis of the flap, and the wound healed after further debridement. Direct suture of the donor-site incision were performed in 16 cases, while additional full-thickness skin grafting were performed in remaining 6 cases. Further bone transport procedure was performed in 15 patients with severe tibia bone defects. Blood flow of recipient posterior tibial arteries were all confirmed during follow-up. The postoperative follow-up ranged 18 to 84 months, and no long-term complications were observed.

Conclusions: The modified recipient blood flow-preserved cross-leg anterolateral thigh flap procedure is an ideal method to repair large tissue defects without sacrificing major artery of uninjured lower limb.

Background

Complex lower extremity injury due to high-energy trauma remains a severe clinical challenge to date. This kind of lower limb trauma is frequently characterized by compromised main vessels and extensive soft tissue defects, which are always accompanied with other conditions such as bone exposure, bone defects and infection. In such situation, local pedicled flap strategies are unachievable due to poor surrounding soft tissue. Besides, free flap transfers within injured lower limb are also impossible for the reason of unavailable recipient vessels in ipsilateral leg. Cross-leg pedicled flaps are reliable choices to salvage traumatized lower limb with complex soft tissue and vessels damage. Since it was first introduced by Hamilton in 1854, the cross-leg pedicled flap methods have been widely used in complex lower extremity reconstruction, and various cross-leg pedicled flap procedures have been reported for different degrees and different locations of lower limb injury [1, 2]. The common feature of these procedures is that the pedicled flaps are designed based on the major arteries of healthy-sided lower limb, mainly including the posterior tibial artery and the peroneal artery [3–9]. Although cross-leg pedicled flaps have a favorable survival rate of nearly 100%, its disadvantages are also apparent, for example, limited coverage of the tissue defects, sacrifice of the healthy-sided tissues or vessels, and aesthetic impairment of the healthy leg [2].

Since the advent of microsurgery technology, microsurgical free flap transfer has gradually become the preferred strategy for complex lower extremity reconstruction. When there are no available recipient vessels in injured-sided lower limb, cross-leg free flap procedures are optional methods [10]. In this procedure, the free flap is temporarily nourished by suitable recipient arteries of the contralateral lower limb. When the flap is adequately revascularized, the vascular pedicle is divided from the flap. To ensure the survival rate of the free flaps, major arteries of the contralateral leg are always chosen as the recipient arteries, and end-to-end microanastomosis is preferred. The main disadvantage of this procedure is that the blood supply to distal lower limb is obviously reduced. Currently, a cross-leg flow-through pedicled free flap procedure is established, which preserves the integrality of recipient vessels and blood circulation in healthy lower limb [11–13]. In this promising procedure, the donor artery is prepared as a reverse Y-shaped fashion and further inserted to the recipient artery by anastomosing the Y-shaped arterial branches to the two transected ends of the recipient artery. However, Y-shaped arterial bifurcation is not always available. In addition, postoperative management of the pedicle is also difficult.

In this study, we introduce a modified recipient blood flow-preserved cross-leg anterolateral thigh flap procedure to reconstruct the severely damaged lower limb. By presenting our clinical outcomes of the modified procedure, we hope to further popularize the clinical application of the cross-leg free flaps.

Methods

Patients

A retrospective study was conducted on patients who suffered from severe unilateral lower limb trauma and underwent the modified recipient blood flow-preserved cross-leg anterolateral thigh flap procedure in our hospital between January 2013 and December 2019. A total of 22

consecutive patients were included. There were 17 male and 5 female. The average age was 37 years old (range, 10–64 years old). Among them, 16 cases were admitted or transferred to our emergency department due to traffic accident, 5 cases were admitted to our outpatient department due to stubborn ulcer, and 1 case was admitted to our emergency department due to degloving injury. Among the 16 traffic accident patients, except for one with injury at dorsum pedis, the rest had severe open tibia fractures, in which 7 cases were Gustilo IIIB injuries and 8 cases were Gustilo IIIC injuries [14]. Among the 5 stubborn ulcer patients, all were caused by trauma a few years ago (range, 3–10 years). Twelve patients sustained left-sided lower limb injuries, and ten patients sustained the right-sided. Among all the patients, 19 cases were involved in the crus, 2 cases were involved in the medial malleolus, and 2 cases were involved in the dorsum pedis. For emergency patients, the wounds were thoroughly debrided and covered with vacuum sealing drainage devices (VSD devices). Temporary internal or external fixations of the fractures were performed, if necessary. When patients' vital signs were stable and the wounds' infections were controlled, free flap transplantation was performed. For non-emergency patients, flap procedure was performed after effective control of the wounds' infections. Before flap transplantation, computed tomography angiography (CTA) was routinely performed to evaluate the circulation of the injured lower limb. In this study, all patients had major arteries damaged in the injured lower limb, and 86% of them had two or more arteries compromised. These arteries included the peroneal artery (PA), the anterior tibial artery (aTA), the posterior tibial artery (pTA), and the dorsalis pedis artery (DPA). Among all the patients, 4 cases had hypertension, and 1 case had diabetes. Detailed demographic information on each patient is shown in Table 1.

Table 1
The demographic and surgical details of the patients

Case	Sex	Age	Injury type	Injury location	Soft tissue defect (cm ²), fracture status	Artery injury	Comorbidities	Flap type	Flap area (cm ²)	Complication	Second procedure
1	F	55	traffic accident	crus (R)	18×15, Gustilo IIIC	PA, aTA and pTA	hypertension	single	22×17	/	Ilizarov
2	M	55	stubborn ulcer	crus (R)	24×14	aTA and pTA	/	single	27×16	/	/
3	M	33	traffic accident	knee and crus (L)	27×13, Gustilo IIIC	PA, aTA and pTA	/	single	30×16	/	Ilizarov
4	M	29	traffic accident	crus (R)	22×11, Gustilo IIIC	PA, aTA and pTA	/	bilobed	25×12	/	Ilizarov
5	M	24	degloving injury	crus and foot (L)	22×16 (entire planta)	aTA and pTA	/	single	24×19	/	/
6	M	10	traffic accident	crus (R)	22×15, Gustilo IIIC	PA, aTA and pTA	/	single	24×18	/	Ilizarov
7	M	26	stubborn ulcer	medial malleolus (L)	14×8	pTA	/	bilobed	17×8	/	/
8	M	20	traffic accident	crus (L)	17×10, Gustilo IIIB	PA and aTA	/	single	19×12	/	Ilizarov
9	F	18	traffic accident	crus (R)	20×14, Gustilo IIIC	PA, aTA and pTA	/	single	23×17.5	local lysis	debridement and Ilizarov
10	M	60	traffic accident	crus (R)	20×12, Gustilo IIIB	aTA and pTA	/	single	24×15	/	Ilizarov
11	M	48	traffic accident	dorsum pedis (L)	21×18	aTA and DPA	hypertension	single	24×21	/	/
12	M	64	traffic accident	crus (L)	12×8, Gustilo IIIB	aTA and pTA	diabetes	single	14×10	/	Ilizarov
13	M	23	traffic accident	crus (L)	15×10, Gustilo IIIB	aTA and pTA	/	bilobed	22×9	/	Ilizarov
14	M	38	traffic accident	crus (L)	26×13, Gustilo IIIC	PA, aTA and pTA	/	single	30×15	/	Ilizarov
15	F	42	traffic accident	crus (L)	17×11, Gustilo IIIB	aTA and pTA	/	single	19×14	local lysis	debridement and Ilizarov

M male, F female, PA peroneal artery, aTA anterior tibial artery, pTA posterior tibial artery, DPA dorsalis pedis artery, Ilizarov Ilizarov technique, Patients were listed by admission time

Case	Sex	Age	Injury type	Injury location	Soft tissue defect (cm ²), fracture status	Artery injury	Comorbidities	Flap type	Flap area (cm ²)	Complication	Second procedure
16	M	37	traffic accident	crus (R)	18×10, Gustilo IIIC	PA, aTA and pTA	/	single	21×12	/	Ilizarov
17	M	21	traffic accident	crus and dorsum pedis (L)	15×9, Gustilo IIIB	aTA, pTA and DPA	/	single	17×11	/	Ilizarov
18	M	44	stubborn ulcer	crus (L)	15×8	aTA	/	single	17×10	/	/
19	F	46	stubborn ulcer	medial malleolus (R)	12×6	pTA	/	single	14×7.5	/	/
20	M	60	stubborn ulcer	crus (L)	17×12	PA and pTA	hypertension	single	20×14	/	/
21	M	22	traffic accident	crus (R)	22×12, Gustilo IIIC	PA, aTA and pTA	/	bilobed	26×13	/	Ilizarov
22	F	46	traffic accident	crus (R)	12×10, Gustilo IIIB	aTA and pTA	hypertension	single	15×13	/	Ilizarov
M (77%)		10–64	traffic accident (73%)	crus (86%), L (55%)	12–27 × 6–18	two or more (86%)		single (82%)	14–30 × 7.5–21	local lysis (9%)	Ilizarov (68%)
M male, F female, PA peroneal artery, aTA anterior tibial artery, pTA posterior tibial artery, DPA dorsalis pedis artery, Ilizarov Ilizarov technique, Patients were listed by admission time											

This study was approved by the Ethics Committee of the First Affiliated Hospital of Anhui Medical University. All patients signed the informed consent for clinical data publication. All procedures were in compliance with the tenets of the Helsinki Declaration.

Surgical Procedure

In this study, all patients' surgeries were performed by the same surgeon (the first author, Dr. Zhou). All patients underwent the modified recipient blood flow-preserved cross-leg free flap transplantation using the anterolateral thigh fasciocutaneous or musculocutaneous flap (Fig. 1). Briefly, under general anesthesia, VSD devices or fracture fixation devices were removed. Thorough debridement of necrotic tissue was performed. The edge of the tissue defect was trimmed, and the defect size was measured. According to the size and shape of the tissue defects, we designed a suitable anterolateral thigh flap, which was about 2–3 cm longer in length and width compared to the defects. The flap was chosen on the same side of the injured leg, if patient had no special requirement. According to the methods introduced in previous literature, a standard anterolateral thigh flap based on the lateral circumflex femoral arterial system was harvested [15, 16]. The descending branch of the lateral circumflex femoral artery was dissected proximally between the rectus femoris muscle and the vastus lateralis muscle. At the proximal arterial bifurcation, the lateral circumflex femoral artery and its transverse branch were also exposed to a length of about 2 cm. This arterial bifurcation was prepared as a Y-shaped fashion. The descending arterial branch and its accompanying veins were prepared as the vascular pedicle and divided from the lateral circumflex femoral vascular system with a sufficient length about 8–10 cm. In addition, the flap was prepared as single or bilobed fashion according to the defect shape. Then, the posterior tibial vessels and great saphenous vein of the uninjured lower limb were dissected and prepared as recipient vessels. After insert of the flap to the tissue defect, the two arterial ends of the Y-shaped pedicle (lateral circumflex femoral artery inlet and transverse branch outlet) were microanastomosed to the proximal and distal transected ends of the posterior tibial artery, respectively. Two comitant veins were also reconstructed microsurgically. After confirming the blood reperfusion of both the flap and the distal posterior tibial artery, a split-thickness skin graft was applied to protectively wrap the vascular pedicle. Finally, the two legs were fixed in a parallel position by cross external fixation devices. The fixed distance between two legs was adjusted according to the length of the vascular pedicle, which should make the pedicle completely free of tension. Three weeks later, we assessed the revascularization of the flap by means of intermittent pedicle clamping for about one week. After confirmation of flap revascularization, the vascular pedicle was transected and ligated,

and the flap was divided from the recipient leg. The cross external fixation devices were also removed, and physiotherapy programme was conducted after surgery. In addition, for patients with large segmental tibia bone defect, bone transport procedure (Ilizarov technique) was performed 4 weeks after pedicle division according to the methods reported in previous literature [17–19].

Three to six months after pedicle division, color Doppler ultrasound was performed to evaluate the blood flow of the recipient posterior tibial artery.

Results

In this study, the contralateral posterior tibial artery was chosen as recipient artery in all patients. The defect sizes of the injured lower limbs ranged from 12 to 27 cm in length and 6 to 18 cm in width (mean length $\times$ width, $18.5 \times 11.6 \text{ cm}^2$). The sizes of the anterolateral thigh flaps ranged from 14 to 30 cm in length and 7.5 to 21 cm in width (mean length $\times$ width, $21.5 \times 13.6 \text{ cm}^2$). The flap was designed as single fashion in 18 cases and bilobed fashion in 4 cases. Twenty patients underwent fasciocutaneous flap transplantation, and the remaining two (case 9 and case 14) who had deep dead space in defect site underwent musculocutaneous flap transplantation. In each dressing change, the vascular pedicle was protected by embedding with petrolatum gauze pieces. All of 22 flaps survived uneventfully. Among all the patients, two cases experienced postoperative local lysis of the flap (case 9 and case 15), and the wound healed after further debridement and positive dressings. There were 16 cases who underwent direct suture of the donor-site incision, and the remaining 6 underwent full-thickness skin grafting after partial suture and VSD coverage. No complications occurred at the donor site among all patients. Fifteen patients with severe tibia bone defects underwent further bone transport procedures after flap transplantation. Anterograde blood flow of the recipient posterior tibial artery was confirmed using Doppler ultrasound test in all patients during follow-up. Overall, all patients were satisfied with the clinical results, and no complications were observed during the long-term follow-up (range 18 to 84 months).

Typical cases were presented in Figs. 2, 3, 4, 5, and 6. Detailed information is shown in Table 1.

Discussion

Severe lower limb trauma with large-sized soft tissue defects and tibia bone exposure is frequently encountered at emergency department, and further reconstruction remains a big challenge for surgeons [20]. In this situation, flap procedures were necessary for defect coverage and limb salvage. However, local flap technique or ipsilateral free flap transplantation are often impossible due to extensive tissue defect and potential vascular damage. In this study, we introduced a modified recipient blood flow-preserved cross-leg anterolateral thigh flap procedure for reconstruction of complex lower limb injuries. This method is an effective and safe alternative for patients with different sizes of tissue defect in unilateral lower limb.

The cross-leg flap technique has been applied to patients with lower limb injuries a long time ago. Since it was first introduced by Stark in 1952, various cross-leg flap procedures were reported, including pedicled flap procedures and free flap procedures [1, 21]. For small-sized tissue defect, cross-leg pedicled flap procedure was preferred for the reason that it is relatively easy and safe to perform [22]. However, for large-sized defect, cross-leg free flap procedure was the optimal strategy [23, 24]. The cross-leg free flap surgery has been applied to lower limb reconstruction since 1979 [25]. In this procedure, the free flap was temporarily nourished by vessels of uninjured lower limb, and was divided from the intact leg after flap revascularization. Skilled microsurgical technique is requisite for this procedure. With the popularity of microsurgical techniques, free flap transplantation has gradually become the standard method for salvaging severely traumatized lower limb [23, 26, 27]. A favorable lower extremity salvage rate of 93% was reported in free flap transplantation [27]. In free flap procedure, compared with end-to-side fashion, an end-to-end anastomosis between recipient vessels and donor vessels is preferred, which obviates the potential thrombosis caused by changes of blood flow at the anastomosis site. However, the major drawback of end-to-end anastomosis is sacrificing the recipient artery, which results in a considerable reduction of blood supply to distal leg. In early-stage clinical studies of cross-leg free flap technique, recipient arterial sacrifice was considered inevitable [28]. Nevertheless, in recent years, several innovative techniques were reported to preserve the integrity of the recipient artery. In 2000, Topalan et al. introduced a latissimus dorsi free flap with Y-shaped arterial pedicle in lower limb construction. This strategy not only provided blood supply to the flap, but also preserved the blood flow of the recipient artery, which was called the flow-through technique [13, 29]. For the case without arterial bifurcation, Akyurek et al. introduced a two-stage method to restore the continuity of the recipient artery in 2002 [30]. In the first stage, an end-to-end anastomosis was performed between the thoracodorsal artery of latissimus dorsi free flap and the uninjured recipient posterior tibial artery. After flap revascularization, the thoracodorsal artery was transected and rerouted to the distal end of the posterior tibial artery in the second stage. In 2016, Gencel et al. performed the cross-leg flow-through pedicled latissimus dorsi free flap procedure on 6 patients with high voltage electrical injuries [11]. In this small sample clinical study, the thoracodorsal artery and circumflex scapular artery (or serratus branch) were prepared as T-shaped pedicle, and further anastomosed to the contralateral posterior tibial artery. Adequate diameter and blood flow of the posterior tibial vascular system contribute to the survival of the flap. In 2020, Bali et al. conducted a study of 12 patients who underwent recipient blood flow-preserved cross-leg free flap procedures [12]. In Bali's study, an anterolateral thigh fasciocutaneous flap was used in 8 patients for reconstruction of small or medium defects, while a latissimus dorsi flap was used in 4 patients with large defects. Besides, the arterial pedicle was designed as T-shaped fashion in anterolateral thigh flap but not in latissimus dorsi flap. Thus, the blood flow of recipient

posterior tibial artery was reestablished in the first stage of anterolateral thigh flap procedure (flow-through technique), while in the second stage of latissimus dorsi flap procedure (rerouting technique). To our knowledge, there are only a few studies of flow-through pedicled cross-leg free flap procedures for lower limb reconstruction in previous literature, all of which involve fewer cases [11, 12, 29, 31–34]. Among these studies, the flaps are chosen based on the size and shape of the tissue defect. Generally, the anterolateral thigh flap is preferred in relative small-sized defect, while the latissimus dorsi flap is suitable in relative large-sized defect. Compared with the anterolateral thigh flap, the latissimus dorsi flap is relatively traumatic to harvest and difficult to prepare a Y-shaped arterial pedicle. Besides, the surgical position needs to be changed during the cross-leg latissimus dorsi flap transplantation. Therefore, the anterolateral thigh flap is more ideal for complex lower limb reconstruction, but it is hindered in popularity due to limited defect coverage. Traditionally, the proximal part of the free flap is used to cover the vascular pedicle, which will lower the effective flap area for defect coverage. In present study, we performed a modified flow-through pedicled cross-leg free flap procedure on patients with different size of unilateral lower limb tissue defect. Compared to previous techniques, our method has several advantages.

First, a meshed split-thickness skin was used to wrap the vascular pedicle. For anterolateral thigh flap, a sufficient length of vascular pedicle can be harvested. Instead of flap coverage, we performed free skin wrapping technique to protect the vascular pedicle. On the one hand, the obtained flap can be fully used for defect coverage, which means that the anterolateral thigh flap procedure is also suitable for patients with large-sized tissue defects. Our study suggests that various defects ranging from 72 to 378 cm² could be effectively covered by relevant-sized anterolateral thigh flaps. On the other hand, compared with flap coverage, skin wrapping is more convenient for postoperative blood flow observation and dressing change, and is much easier for pedicle division in the second-stage procedure [12]. The free skin wrapping technique has been reported previously [35]. Serel et al. reported a case who had unhealed wound on the right foot and underwent cross-leg anterolateral thigh perforator flap procedure, in which a split-thickness skin was used to wrap the vascular pedicle [35]. Together with our results, a meshed split-thickness skin grafting is an effective and convenient method for vascular pedicle coverage.

Second, the lateral circumflex femoral arterial system is employed for design of the Y-shaped arterial pedicle. The lateral circumflex femoral artery consistently gives off transverse branch and descending branch. This arterial bifurcation is not difficult to dissect and prepare as a Y-shaped fashion. The anterolateral thigh free flap is widely used in post-traumatic reconstruction, including upper limb, lower limb and body trunk [15, 36, 37]. For reconstruction of different injury types, the anterolateral thigh flap can be harvested as fasciocutaneous or musculocutaneous flap. Generally, satisfactory survival rate and aesthetic outcome can be achieved by the anterolateral thigh flap procedure [36]. In addition, the anterolateral thigh flap is rich in its arterial perforator system, which is beneficial to flap survival on the one hand, and can be designed as single or bilobed style on the other hand. A bilobed flap is an optimal and practical choice to cover irregular tissue defects. In particular, when the defect width is large, a large-length single anterolateral thigh flap can be redesigned as a large-width bilobed flap. In our case series, both single and bilobed flap procedures produces good clinical results.

Third, the anterolateral thigh flap harvest and cross-leg flap transplantation are performed in the same surgical position, which can shorten the first-stage operation time. Furthermore, the vascular pedicle is easily divided after the flap revascularization, which greatly shortens the second-stage operation time. After flap transplantation, the parallel external fixation between two legs is relatively comfortable.

There are some limitations of our study. Postoperative parallel fixation of two lower limbs are necessary, and the fixation time is relatively long (4 weeks). Pressure ulcer prevention and physical therapy intervention should be carried out during the fixation period. In our procedure, the incision of flap donor site is relatively large, which requires further skin grafting in partial cases (27% in our study). This study is a retrospective design and its sample size is relatively small, which calls for a large-sample prospective study in the future.

Conclusion

In conclusion, the modified recipient blood flow-preserved cross-leg anterolateral thigh flap procedure is an effective and promising technique for complex lower extremity reconstruction. This technique is an ideal method to repair large tissue defects without sacrificing major artery of uninjured lower limb.

Abbreviations

Not applicable

Declarations

Ethics approval and consent to participate

This study was approved by the Ethics Committee of the First Affiliated Hospital of Anhui Medical University. All patients signed the informed consent for clinical data publication.

Consent for publication

Written informed consent was obtained from all patients.

Availability of data and materials

Not applicable.

Competing interests

The authors declare no competing interests.

Funding

Not applicable.

Authors' contributions

All authors have made substantial contributions. Hong-Xiang Zhou and Liang He contributed to the study design, the data collection and analysis. Hong-Xiang Zhou prepared the manuscript. Dong Yin, Yang Niu, Zhe Jin and Jun-Jie Li contributed to the data collection and the manuscript modification. Qian-Kun Wang and Tao Zhou contributed to the data analysis and the literature review. Hong-Xiang Zhou contributed to the study design and was the chief investigator of this study. All authors contributed to data interpretation.

Acknowledgements

Not applicable.

Authors' information

¹ Department of Orthopedics, the First Affiliated Hospital of Anhui Medical University, Anhui, China

² Department of Orthopedics, the Fuyang People's Hospital of Anhui Medical University, Anhui, China

Conflicts of Interests:

The authors declared no potential conflicts of interest with respect to the study, authorship, and/or publication of this article.

Funding:

This study received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

Ethical approval details: This study was approved by the Institutional Review Board of the First Affiliated Hospital of Anhui Medical University.

References

1. Mahajan RK, Srinivasan K, Ghildiyal H, et al. Review of cross-leg flaps in reconstruction of posttraumatic lower extremity wounds in a microsurgical unit. *Indian J Plast Surg.* 2019 2019-01-01;52(1):117-124.
2. Van Boerum MS, Wright T, McFarland M, et al. Cross-Leg flaps for lower extremity salvage: a scoping review. *J Reconstr Microsurg.* 2019 2019-09-01;35(7):505-515.
3. Eser C, Gencel E, Kesiktaş E, et al. A convenient flap for repairing the donor area of a distally based sural flap: gastrocnemius perforator island flap. *J Plast Reconstr Aesthet Surg.* 2016 2016-08-01;69(8):1109-1115.
4. Wang ZQ, Cao YL, Huang YF, et al. Cross-leg repair of large soft-tissue defects in distal sites of the feet by distally based neuro-fasciocutaneous flaps with perforating vessels. *Genet Mol Res.* 2014 2014-07-25;13(3):5484-5491.
5. Keklik B, Basaran K, Yazar S, et al. Posterior tibial artery cross-leg perforator flap: a case report. *Int J Low Extrem Wounds.* 2012 2012-06-01;11(2):77-79.
6. Demiralp CO, Akkaya H, Duman Y, et al. Reconstruction of traumatic lower extremity soft tissue defects with the combination of ipsilateral and contralateral perforator flaps. *Int J Low Extrem Wounds.* 2012 2012-12-01;11(4):304-306.
7. Georgescu AV, Irina C, Ileana M. Cross-leg tibial posterior perforator flap. *Microsurgery.* 2007 2007-01-20;27(5):379-383.
8. Li F, Zeng B, Fan C, et al. Distally based extended peroneal artery septocutaneous perforator cross-bridge flap without microvascular anastomoses for reconstruction of contralateral leg and foot soft tissue defects. *J Reconstr Microsurg.* 2010 2010-05-01;26(4):243-249.

9. Eser C, Kesiktaş E, Gencil E, et al. An alternative method to free flap for distal leg and foot defects due to electrical burn injury: distally based cross-leg sural flap. *Ulus Travma Acil Cerrahi Derg.* 2016 2016-01-01;22(1):46-51.
10. Manrique OJ, Bishop SN, Ciudad P, et al. Lower extremity limb salvage with cross leg pedicle flap, cross leg free flap, and cross leg vascular cable bridge flap. *J Reconstr Microsurg.* 2018 2018-09-01;34(7):522-529.
11. Gencil E, Eser C, Kesiktaş E, et al. A cross flow-through pedicle free latissimus dorsi flap for high voltage electrical burns. *Burns.* 2016 2016-06-01;42(4):e55-e60.
12. Bali ZU, Karatan B, Tuluy Y, et al. Preserving the blood flow of the recipient artery in cross-leg free flap procedure for lower extremity reconstruction. *Int J Low Extrem Wounds.* 2020 2020-09-01;19(3):255-261.
13. Bullocks J, Naik B, Lee E, et al. Flow-through flaps: a review of current knowledge and a novel classification system. *Microsurgery.* 2006 2006-01-20;26(6):439-449.
14. Yim GH, Hardwicke JT. The evolution and interpretation of the Gustilo and Anderson classification. *J Bone Joint Surg Am.* 2018 2018-12-19;100(24):e152.
15. Wong CH, Wei FC. Anterolateral thigh flap. *Head Neck.* 2010 2010-04-01;32(4):529-540.
16. Ren GH, Xiang DY, Wu XH, et al. A neglected problem in the utilization of free anterolateral thigh flap toward reconstructing complicated wounds of extremities: the obliteration of deep dead space. *J Orthop Surg Res.* 2020 2020-10-21;15(1):483.
17. Wani N, Baba A, Kangoo K, et al. Role of early Ilizarov ring fixator in the definitive management of type II, IIIA and IIIB open tibial shaft fractures. *Int Orthop.* 2011 2011-06-01;35(6):915-923.
18. Aktuglu K, Erol K, Vahabi A. Ilizarov bone transport and treatment of critical-sized tibial bone defects: a narrative review. *J Orthop Traumatol.* 2019 2019-04-16;20(1):22.
19. Li R, Zhu G, Chen C, et al. Bone transport for treatment of traumatic composite tibial bone and soft tissue defects: any specific needs besides the Ilizarov technique? *Biomed Res Int.* 2020 2020-01-20;2020:2716547.
20. Parrett BM, Matros E, Pribaz JJ, et al. Lower extremity trauma: trends in the management of soft-tissue reconstruction of open tibia-fibula fractures. *Plast Reconstr Surg.* 2006 2006-04-01;117(4):1315-1322, 1323-1324.
21. Stark RB. The cross-leg flap procedure. *Plast Reconstr Surg* (1946). 1952 1952-03-01;9(3):173-204.
22. Lu L, Liu A, Zhu L, et al. Cross-leg flaps: our preferred alternative to free flaps in the treatment of complex traumatic lower extremity wounds. *J Am Coll Surg.* 2013 2013-09-01;217(3):461-471.
23. Ducic I, Rao SS, Attinger CE. Outcomes of microvascular reconstruction of single-vessel lower extremities: limb salvage versus amputation. *J Reconstr Microsurg.* 2009 2009-11-01;25(8):475-478.
24. Morris AM, Buchan AC. The place of the cross-leg flap in reconstructive surgery of the lower leg and foot: a review of 165 cases. *Br J Plast Surg.* 1978 1978-04-01;31(2):138-142.
25. Taylor GI, Townsend P, Corlett R. Superiority of the deep circumflex iliac vessels as the supply for free groin flaps. *Plast Reconstr Surg.* 1979 1979-12-01;64(6):745-759.
26. Heller L, Levin LS. Lower extremity microsurgical reconstruction. *Plast Reconstr Surg.* 2001 2001-09-15;108(4):1029-1041, 1042.
27. Fischer JP, Wink JD, Nelson JA, et al. A retrospective review of outcomes and flap selection in free tissue transfers for complex lower extremity reconstruction. *J Reconstr Microsurg.* 2013 2013-07-01;29(6):407-416.
28. Yu ZJ, Zeng BF, Huang YC, et al. Application of the cross-bridge microvascular anastomosis when no recipient vessels are available for anastomosis: 85 cases. *Plast Reconstr Surg.* 2004 2004-10-01;114(5):1099-1107.
29. Topalan M. A new and safer anastomosis technique in cross-leg free flap procedure using the dorsalis pedis arterial system. *Plast Reconstr Surg.* 2000 2000-02-01;105(2):710-713.
30. Akyurek M, Safak T, Ozkan O, et al. Technique to re-establish continuity of the recipient artery after end-to-end anastomoses in cross-leg free flap procedure. *Ann Plast Surg.* 2002 2002-10-01;49(4):430-433.
31. Miyamoto S, Kayano S, Fujiki M, et al. Early mobilization after free-flap transfer to the lower extremities: preferential use of flow-through anastomosis. *Plast Reconstr Surg Glob Open.* 2014 2014-03-01;2(3):e127.
32. Devansh S. Lateral thigh free flap with flow-through vascular pedicle. *Ann Plast Surg.* 2011 2011-07-01;67(1):44-48.
33. Nasir S, Aydin MA, Sonmez E, et al. Flow-through free latissimus dorsi flap for reconstruction of injured limbs: evaluation of hemodynamic effects on extremity circulation. *Ann Plast Surg.* 2010 2010-08-01;65(2):164-169.
34. Ozkan O, Ozgentas HE, Dikici MB. Flow-through, functioning, free musculocutaneous flap transfer for restoration of a mangled extremity. *J Reconstr Microsurg.* 2005 2005-04-01;21(3):167-172.
35. Serel S, Kaya B, Demiralp O, et al. Cross-leg free anterolateral thigh perforator flap: a case report. *Microsurgery.* 2006 2006-01-20;26(3):190-192.

36. Wei FC, Jain V, Celik N, et al. Have we found an ideal soft-tissue flap? an experience with 672 anterolateral thigh flaps. *Plast Reconstr Surg.* 2002 2002-06-01;109(7):2219-2226, 2227-2230.
37. Zhang ZY, Feng SM, Zhou MM, et al. Clinical application of anterolateral thigh perforator flap for the reconstruction of severe tibia exposure. *Eur Rev Med Pharmacol Sci.* 2015 2015-12-01;19(24):4707-4714.

Figures

Figure 1

a, b Illustration of the modified recipient blood flow-preserved cross-leg anterolateral thigh flap procedure

Figure 2

Case 20, a 60-year-old man. a A stubborn ulcer in the left crus for 5 years. b Preoperative CTA showed that only the anterior tibial artery was unobstructed in the left crus. c An anterolateral thigh flap was harvested. d The defect size was 17×12 cm² after thorough debridement. e The

modified cross-leg flow-through flap transplantation was performed. f, g A meshed split-thickness skin was prepared and used to wrap the vascular pedicle. h Four days after flap procedure

Figure 3

Case 7, a 26-year-old man. a A stubborn ulcer in the left medial malleolus for 4 years. b A bilobed flap was prepared. c The arterial pedicle was prepared as Y-shaped fashion and microanastomosed to contralateral posterior tibial artery in a flow-through style. Two comitant veins were also microanastomosed. d The modified cross-leg free flap procedure was performed. e The vascular pedicle was divided 4 weeks after flap transplantation. f One month after pedicle division

Figure 4

Case 2, a 55-year-old man. a A stubborn ulcer in the right crus for 8 years. b The modified cross-leg free flap procedure was performed. c, d One week and three months after pedicle division

Figure 5

Case 1, a 55-year-old woman. a Gustilo IIIC trauma in the right crus. b The defect size was 18 × 15 cm² after thorough debridement. c The modified cross-leg free flap procedure was performed. d Fifteen months after pedicle division

Figure 6

Case 16, a 37-year-old man. a Gustilo IIIC trauma in right crus. b, c The modified cross-leg free flap procedure was performed. d Five days after pedicle division. The upper-right photo showed the cross section of the vascular pedicle