A neglected problem in the utilization of free anterolateral thigh flap towards reconstructing complicated wounds of extremities: the obliteration of deep dead space

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Abstract

Objective To investigate the clinical application of chimeric anterolateral thigh perforator flap in the treatment of complex wounds complicated with deep dead space of the extremities.

Methods From January 2014 to December 2018, 56 cases (38 males and 18 females) with wounds complicated with deep dead space received treatment of chimeric anterolateral thigh perforator flap. The average age was 33.4 years, ranged from 3 to 72 years. Causes of injury: 34 cases of vehicle or motorcycle bruise injuries, 12 cases of falling related injuries, and 10 cases of heavy objects crush injuries. All of these patients were experiencing severe limb injuries accompanied with varying levels of tissue necrosis, tissue infection and deep tissue exposure. Residual deep dead space was observed after debridement, including 41 cases of dead space caused by tendon and muscle exposure, 29 cases formed by bone and joint exposure, as well as 5 cases induced by exposure of internal fixators such as plates. The wound sized were from 8 cm×6 cm to 30 cm×15 cm. Forty-one cases were complicated with the ipsilateral fractures, and 21 cases were complicated with fractures in other bone parts or systematic injuries. Following thorough debridement and treatment with vacuum sealing drainage, the granulation tissues of the wound surface grew well with well-controlled infection, and then we used the chimeric anterolateral thigh perforator flap to obliterate the deep dead space and repair the wounds. The postoperative flap survival and infection condition were evaluated.

Results Among 56 patients, 2 cases developed vascular crisis, which was alleviated with timely vascular exploration. One case had excessive bleeding after flap grafting, which was resolved with surgical exploration. Three patients experienced partial necrosis of the flaps, leaving residual local wound, which were completely eliminated by secondary skin grafting in one case and by proactive dressing changes in the other 2 cases. Overall, the infection was effectively controlled, without persistent exudation or sinus tract formation after wound healing. While 5 cases lost to follow-up, the remaining 51 patients were followed up until 15 months, ranged from 9-24 months. Generally, the affected extremities recovered satisfactorily with normal appearances and texture of the flaps, along with normal functions. Importantly, no recurrence of infection was observed.

Conclusion During the grafting of chimeric perforator flap pedicled with descending branch of lateral circumflex femoral artery and lateral thigh muscle flap, the muscle flap is recommended to obliterate the deep dead space while the skin flap being used to cover the wound surface. The combination of these two methods performed well in the repair and reconstruction of the complex wounds of the extremities, possessing potential for broader clinical application.

Background

Microsurgery is an effective treatment towards various types of wounds in the extremities caused by high-energy trauma in clinical settings. High clinical efficacy has been reported in a large number of studies. Among these studies, free flaps were recommended to be used in the treatment of extensive soft-

tissue defects or complex wounds. Since its first description by Song *et al.*¹ in 1984, the anterolateral thigh flap has been considered to be a universal and preferential free flap^{2,3} for the reconstruction of limb wounds, owing to its constant anatomical position of nutrient vessels, long vascular pedicle, thick vascular diameter, as well as relatively concealed donor site. Our group previously utilized anterolateral thigh flap to reconstruct various types of wounds to achieve satisfactory outcomes^{4,5}. However, repeated exudation and persistent infection surrounding the postoperative flaps in partial complex wounds occurred during the treatment process. Particularly, local deep dead space was constantly observed during the second debridement and a large quantity of inflammatory tissues was noted. We believe that these wounds complicated with deep dead space may be an independent risk factor of the poor infection control after flap reconstruction, and the management of deep space plays important roles throughout the reconstruction of complex limb wounds.

Even after multiple times of debridement of deep tissue injuries, related to the post-traumatic ischemic necrosis and the limb infection, some patients experience wounds with residual deep space⁶. The three-dimensional feature of the residual deep space is associated with the poor blood supply, unsuccessful effusion drainage and deficient granulation growth. These factors may provoke or aggravate the infection that requires further debridement. In addition, the deep space may be enlarged after debridement, bringing challenges to the reconstruction in clinical settings in a vicious cycle pattern. To prevent this pattern, it is essential to obliterate the dead space with tissues that covers the wound surface and improves blood supply, for the promotion of the growth and healing of the tissue around the cavity. According to previous reports, conventional flap transplantation can only cover the superficial wounds^{5,7,8}. Despite the advantages such as excellent appearance and mild injury induction of the perforator, it fails to obliterate the dead space caused by trauma. Conventional musculocutaneous flap is formed by the musculocutaneous perforating branch from the vascular pedicle. The skin flap and muscle flap receive blood supply from same perforating branch, thus making it hard to separate them. The partial sliding does not fulfill the requirements of flexibilities to effectively obliterate the deep dead space. Regarding biomaterials, bone cement and negative pressure sponge for vacuum sealing drainage have been commonly applied as temporary filling materials to obliterate the dead space⁹⁻¹¹, due to the lack of biological activities. With the development of flap grafting technique, especially the broader adaption of chimeric perforator flap, other tissue flaps are incorporated when incising the skin flap. Specifically, the skin flap is responsible to cover the wounds, while the other tissue flaps, such as muscle flap, are employed to obliterate the deep space¹². To better meet the clinical requirements, we used the chimeric anterolateral thigh perforator flap (chimeric perforator flap pedicled with descending branch of lateral circumflex femoral artery and lateral thigh muscle flap) to treat wounds complicated with deep dead space of the extremities with slight modification from previous reconstruction methods. In this study, clinical data of 56 patients admitted to our hospital from January 2014 to December 2018 were collected and retrospectively analyzed to evaluate the clinical efficacy of this modified technique.

Materials And Methods

1. Baseline data

Fifty-six patients were enrolled, 38 males and 18 females, aged 3-72 years with an average of 33.4 years. Causes of injury: 34 cases of vehicle or motorcycle bruise injuries, 12 cases of falling related injuries, and 10 cases of heavy objects crush injuries. All of these patients experienced severe limb injuries accompanied with varying levels of tissue necrosis, tissue infection and deep tissue exposure. The residual deep dead space was observed after debridement, including 41 cases of dead space caused by tendon and muscle exposure, 29 cases formed by bone and joint exposure, and 5 cases induced by exposure of internal fixators such as plates. The wound sized were from 8 cm×6 cm to 30 cm×15 cm. Forty-one cases were complicated with the ipsilateral fractures, and 21 cases were complicated with fractures in other bone parts or systematic injuries.

2. Treatment methods

2.1 Preparation prior to wound reconstruction: According to the conditions of the wound contamination or infection prior to wound reconstruction, 56 patients were treated with debridement and vacuum sealing drainage as previously described ^{4,5,13}. Following the wound cleaning, the chimeric perforator flap pedicled with descending branch of lateral circumflex femoral artery and lateral thigh muscle flap was applied to obliterate the dead space and reconstruct the wounds.

2.2 General or combined spinal-epidural anesthesia was given. The patients were required to lay in a supine position. Preoperative Doppler ultrasound was performed to locate the descending branch of lateral circumflex femoral artery. According to the methods of Luo S *et al.* ¹⁴ and Lee YC *et al.* ¹⁵, a line from the anterior superior iliac spine to the external superior margin of patella was taken as the axis, and the midpoint of the line was regarded as the center. The line was delineated based on the sizes and shapes of the wounds, and the anterolateral thigh flap was designed. The inner margin of the flap was incised, and each perforator vessel of the flap was identified under the skin or fascia lata. The descending branch of lateral circumflex femoral artery was identified between the rectus femoris and the lateral femoral muscle, and the perforator vessels of each flap was separated in the combined forward and reverse patterns. According to the size of deep dead space and the requirements of tissue reconstruction, one or more leaves of muscle flaps in an appropriate size and length were harvested with the descending branch of lateral circumflex femoral artery as the pedicle. The chimeric flap was grafted to the recipient site after the incising of the pedicle. With the adjustment of the distance between the chimeric flap and the vascular pedicle at the recipient site, the lateral thigh muscle flap was utilized to obliterate the deep dead space and fixed by intermittent sutures. Then, the perforator flap was used to cover the wound surface and the distal end of the flap was sutured and fixed. The vascular pedicles of the skin flap and muscle flap were organized to prevent the vascular transposition and acute angle placement. The descending branch of lateral circumflex femoral artery and its accompanying vein were anastomosed with the vessels at the recipient site under microscope. Specific adjustments were adopted according to the patient's conditions (Fig 1). For instance, we enlarged the anastomosis sites of blood vessels by anastomosing the vessels of the skin flap with the distal vessels of the muscle flap for 5 patients with

vascular separation between the skin flap and muscle flap. In contrast, the vascular pedicles of the lengthened flaps were grafted with the great saphenous vein or the descending branch of lateral circumflex femoral artery and vein^{13, 16}, for 6 cases with insufficient length of vascular pedicles.

2.3 Intensive observation and essential braking were delivered after operation. Conventional microsurgical therapies, such as anti-inflammation, anti-spasm and anti-coagulation, were given as needed. According to preoperative bacterial culture results, appropriate antibiotics were selected for subsequent treatment. The blood supply of the flap and the blood ooze beneath the flap were intensively monitored, and postoperative complications including vascular crisis were timely and effectively managed. Based upon the status of wound and deep tissue reconstruction, active and passive rehabilitation exercises were actively carried out as soon as possible after the operation. Moreover, the survival and infection of flaps were evaluated postoperatively.

Results

Among 56 patients, 2 cases developed vascular crisis, which was alleviated with timely vascular exploration. One case had excessive bleeding after flap grafting, which was resolved with surgical exploration. Three patients experienced partial necrosis of the flaps and, leaving residual local wound surfaces, which were completely eliminated by secondary skin grafting in one case and by proactive dressing changes in the other 2 cases. Overall, the infection was well controlled. No persistent exudation or sinus tract formation occurred after wound healing. Except 5 cases lost to follow-up, the remaining 51 patients were followed up until 15 months on average (ranged 9-24 months). Generally, the affected extremities recovered satisfactorily with normal appearances and texture of the flaps, along with normal functions. Importantly, no recurrence of infection was observed.

Typical cases were shown in Fig. 2-4.

Discussion

Soft-tissue defects of limbs complicated with deep dead space caused by high energy injury bring challenges to the wound reconstruction in the clinical setting. Tissue defects, with poor local blood circulation, along with unsuccessful drainage often induce infections. The conventional skin flap and musculocutaneous flap are difficult to obliterate the dead space in irregular shape effectively. In addition, some vital tissues and organs, such as bones, large blood vessels, nerves, muscles, tendons at a special site may exist in the deep space. Therefore, we are facing a dilemma, since thorough debridement could lead to serious functional loss of these tissues or organs, whereas incomplete debridement could cause infections. Furthermore, some special dead space, which are associated with the articular cavity, internal fixation, pressure ulcer or diabetes mellitus, further increase the difficulty of wound reconstruction. In other words, if flap were utilized to reconstruct the wound surface independently without appropriate treatment on the deep dead space, the implantation of the flap will be affected by potential infections, ultimately leading to sinus tract formation and wound healing delay. To overcome the challenges in these

types of reconstructions associated with the three-dimensional requirement of the flap, the elimination of the dead space, as well as the coverage of the very large surface soft-tissue defect in a single procedure with primary closure of the donor site are needed ¹⁷.

The chimeric perforator flap is a special form of perforator flap, which refers to two or more different types of independent tissue flaps (such as skin, fascia, muscle, bone, etc.) harvested in the same vascular supply area. At least one perforator flap is included in these independent tissue flaps, and the nutrient vessels originate from the same primary blood vessels. Anastomosing a group of vascular pedicle (primary blood vessels) can reconstruct the blood circulation of multiple independent tissue flaps at the same time. Chimeric perforator flaps refer to perforator flaps which contains two or more different kinds of independent tissue flaps (such as skin, fascia, muscle and bone, etc.) incised from the same vascular supply area (donor site). At least one perforator flap is included in these independent tissue flaps, and the nutrient vessels originate from the same primary blood vessels. Anastomosing a group of vascular pedicle (primary blood vessels) can reconstruct the blood circulation of multiple independent tissue flaps at the same time ^{17, 18}. In this study, we used the chimeric perforator flap pedicled with descending branch of lateral circumflex femoral artery, which is a special type of perforator flap ¹⁹. In addition to the merits of traditional anterolateral thigh flap, it holds advantages as described in the following. The blood supply of the multiple independent tissue flaps can be simultaneously reconstructed by anastomosing one group of blood vessels. This technique retains the advantages of musculocutaneous flap, such as excellent blood supply and potent anti-infection capability. Both perforator flap and muscle flap have vascular pedicles with a sufficient length. The lateral thigh muscle flap has excellent shaping ability, to effectively obliterate irregular dead space. In addition, perforator flap can cover various types of wound surfaces flexibly to achieve three-dimensional reconstruction of tissue defect. Moreover, the delivery of skin grafting on the exposed muscle flap minimizes the incisional area of skin flap, which is consistent with the concept of “appropriate incision amount” without incising other ineffective tissues while incising the multi-leaf skin flaps and muscle flaps.

Thigh anterolateral muscle is rich, even if the amount of the harvested tissue is larger, also will not cause limb dysfunction. In a study that involves 65 patients underwent free anterolateral thigh chimeric free flap reconstruction of defects in the head and neck regions, Kun Wu et al.² reported a new classification concept to divide the anterolateral thigh chimeric into 3 types: trunk type (I type 16.9%), branch type (II type 69.3%) and bifurcation type (III type 13.8%). It had a certain significance for all kinds of tissue defect repair. In our present study, 5 cases showed vascular variations, in which the skin flap and muscle flap vessels were separated and did not originate from the common junction. To solve this problem, a novel chimeric flap by anastomosing the nutrient vessels of the perforator flaps with the distal vessels of the muscle flaps was developed, and the flaps survived well after operation.

The chimeric perforator flap pedicled with descending branch of lateral circumflex femoral artery is a novel and practical procedure, which achieves three-dimensional reconstruction of the wounds with expanded application range of flaps for the reconstruction of complex soft-tissue defects of the extremities. There are some previous studies utilized similar concept but different details. For example,

N.A.S. Posch et al. ²⁰ used combined free partial vastus lateralis with anterolateral thigh perforator flap to reconstruct extensive composite defects. Liming Qing et al. ²¹ designed individual vastus lateralis muscle-chimeric multi-lobed anterolateral thigh perforator flap to reconstruct complex three-dimensional defects in the extremities. Xiaoju Zheng et al. ²² performed single stage reconstruction and revascularization using a free flow-through chimeric anterolateral thigh perforator flap under emergency. In our study, we reconstruct the limb defects complicated with residual deep space in 56 cases and achieved high clinical efficacy in 51 cases with complete post-operational follow-up, while no persistent wound exudation or sinus tract formation observed. Consistently, in the study of adult chronic tibial osteomyelitis cases, Buono Pet al. ²³ demonstrated that fasciocutaneous and perforator free flaps offer a comparable efficacy to the muscle flaps for infection treatment, with a significantly higher patient satisfaction and aesthetic result. To be noted, the cases of extremity defects complicated with the closure of deep space were included in our current study, and alternative surgical methods should be combined for those with structural tissue defects. If structural tendon, nerve and bone tissue defects were observed at the recipient site, the reconstruction of these tissues should be performed using techniques such as free revascularized fibula and iliac crest bone flaps ²⁴ or Ilizarov technique ²⁵, Mesquelet technique ²⁶ etc.. Postoperative clinical efficacy and limb function of these methods were not be described here.

In this study, vascular crisis occurred in 2 patients after operation and extensive bleeding occurred in one case after flap grafting, which require accurate judgment and precise operation to be dealt with. The main cause of vascular crisis is thrombosis ²⁷, associated with the quality of blood vessels at the recipient site, such as the intimal separation, especially in the patients with serious contusion, long-term wound infections, diabetes mellitus, smoking, old age, etc. Consequently, it is essential to dissect and separate the healthy vessels to anastomose with the vessels at the donor site. In a severely traumatized extremities with multiple levels of injury, recipient vessels are often limited by the pedicle length and flap dimensions. The success of free tissue transferred to cover these complex tissue defect depends on the proper selection of recipient vessels ²⁸. Under this condition, a vein graft is usually used to gain additional length. However, the harvesting of great saphenous vein could cause damage to the new donor cite, since some patients may have insufficient veins. Alternatively, the descending branch of the lateral femoral circumflex artery and venae comitantes as an arteriovenous interposition graft can be used in the reconstruction of a trauma-related extremity defect ¹⁶. Because the perforating branch vessels are relatively thin, a certain amount of surrounding tissues should be preserved to avoid distortion, traction or compression of the perforating branch vessels. Particularly, vascular traction could be caused by extensibility of muscle during the filling of muscle flap. Moreover, attention should be paid to hemostasis at the recipient wounds, the incised skin flap and muscle flap, especially for the inflammatory granulation tissues with sufficient blood supply. If intraoperative hemostasis were not performed effectively by bandages or anticoagulation and antispasmodic drugs, massive hemorrhage or hematocoele at the wound sites will occur.

Conclusions

Deep dead space is a problem in the process of limb wound reconstruction that can be easily neglected. The chimeric perforator flap pedicled with descending branch of lateral circumflex femoral artery can be applied to treat limb wounds complicated with residual deep dead space, which uses muscle flap to effectively obliterate the dead space and employs perforator flap to reconstruct wounds. This technique in our study yields satisfactory clinical efficacy, providing foundations for the further clinical application.

Declarations

Ethics approval and consent to participate

The protocol was approved by the ethics committee of Southern Medical University Affiliated Nanfang Hospital. All patients agreed to participate in this paper and were consented accordingly.

Consent for publication

We agree to have this work publicized if accepted.

Availability of data and materials

None

Competing interests

The authors do not have any competing interests.

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Follow-up and data collection to patient: Xiaohu Wu and Yunbiao Chen.

Study design: Gao-hong Ren and Runguang Li.

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Figures

Figure 1

Diagram illustrated the design process of chimeric anterolateral thigh perforator flap for the repair of complex wounds complicated with deep dead space of the extremities (a-c).

Figure 2

Case 1. A male patient, 49 years old, was admitted to our hospital due to postoperative deformity and infection of the right foot for over 6 months. Upon admission, a large quantity of purulent secretion was noted in the medial wounds of the right foot, accompanied with sinus tract formation in the right calcaneus, stiffness and deformity of the ankle (a). After admission, thorough debridement combined with VSD was performed (b). At 1 week after the VSD removal, granulation tissues surrounding the wounds grew well (c). The chimeric anterolateral thigh perforator flap was designed and harvested, and the perforator flap was thinned (d-f). The muscle flap was utilized to obliterate the dead space of calcaneal defects (g, h). The skin flap was used for wound surface coverage and the blood supply was excellent after vascular anastomosis (i). During postoperative 1-year follow-up, the foot infection was effectively controlled, with aesthetic appearance of the skin flap (j, k), and the weight-bearing and walking functions of the foot was restored (l).

Figure 3

Case 2. A 24-year-old patient suffered from bilateral Pilon fractures caused by high falling, open fracture (Gustilo type II) on the right side. After admission, thorough debridement was given, followed by internal fixation of the tibial and fibular fractures (a, b), wound healing was poor, secondary infection occurred, and the internal fixation plate was exposed. The internal fixation plate was removed and filled with bone meal (c), but the wound infection remained uncontrolled (d). The chimeric anterolateral thigh perforator flap was designed and excised (e, f). The muscle flap was employed to obliterate the dead space (g, h), the skin flap was used for wound surface coverage (i). Postoperative infection was well controlled and the flaps were normal in appearance and texture (j).

Figure 4

Case 3. A male patient, 22 years old, was transferred from a local hospital due to postoperative infection for two weeks caused by traffic accident injury of the right leg. Upon admission, extensive necrosis of the lateral soft tissues of the middle and lower right leg observed, accompanied with fracture of the middle fibula, free and exposed bones and purulent secretions in the wounds (a, b). Upon admission, thorough debridement combined with vacuum sealing drainage (twice) was performed, and granulation tissues surrounding the wounds grew well (c-e). The chimeric anterolateral thigh perforator flap was designed and harvested (f, g). The muscle flap was utilized to obliterate the dead space of the lateral leg, and the skin flap was used to cover the wound surface. The blood supply was excellent after vascular anastomosis (h, i). The flap was normal in appearance (j, k). During postoperative follow-up for 1 year, no obvious sinus tract formation was observed and the infection was properly controlled.