Flap transfer for traumatic defects of the upper extremity: experience of 35 cases

Yongqiang Kang

Wuxi Hand Surgery Hospital

Xiaoyun Pan

Wuxi Hand Surgery Hospital

Yongwei Wu

Wuxi Hand Surgery Hospital

Yunhong Ma

Wuxi Hand Surgery Hospital

Jun Liu

Wuxi Hand Surgery Hospital

Yongjun Rui (✉ wswkryj@163.com)

Wuxi Hand Surgery Hospital

Research article

Keywords: upper extremity, flap transfer, reconstruction, open fracture

Posted Date: February 21st, 2020

DOI: <https://doi.org/10.21203/rs.2.24194/v1>

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

Version of Record: A version of this preprint was published at Journal of Orthopaedic Surgery and Research on April 7th, 2020. See the published version at <https://doi.org/10.1186/s13018-020-01647-0>.

Abstract

Background

Despite advances in microsurgical techniques of flap transfer, complex upper extremity trauma reconstruction remains a challenge for surgeons.

Methods

We retrospectively analyzed data from patients undergoing subacute upper extremity flap reconstruction, including flap choices, complications and success of flap reconstructions.

Results

Thirty-five patients underwent free flap procedures, including 24 anterolateral thigh flaps (68.57%), five latissimus dorsi flaps (14.29%) and six lateral arm flaps (17.14%). Flap sizes ranged from 3 × 4 to 33 × 11 cm². The mean time of flap reconstruction was 14 days (range 5–29). Two flaps developed partial necrosis, both of which were later treated with skin-grafting. Traumatic wound infections occurred in three patients. All upper limb trauma was completely covered.

Conclusions

All three types of skin flaps used to reconstruct severe upper limb soft tissue defects achieved satisfactory function and appearance with negligible complications and low amputation rates during the subacute period.

Introduction

With the development of microsurgical technologies, plastic surgery has undergone tremendous advances. Operations previously requiring several procedures now can be completed in one operation, and some wounds that were difficult or even impossible to repair can be repaired successfully. Nevertheless, because of the complexity of severe upper limb trauma, wound coverage after severe limb injury remains challenging for surgeons. Furthermore, compared to the lower limbs, the requirements of flap transfer for upper limb reconstruction require more than just wound coverage. The goals of upper extremity reconstruction are optimization of functional and aesthetic outcomes while minimizing donor damage and prevention of infections while providing adequate soft-tissue protection of vital structures.

The concept of the perforator flap was first proposed by Koshima(1) in 1989. The technique entails only minimal damage to the donor area of the flap while obtaining the best appearance and function. For this reason, the technique is widely used in plastic surgery for soft tissue reconstruction. There are many perforator vessels throughout the body, and the best perforator flap donor area can be selected according to the particular situation of the recipient area. Chimeric skin flaps can be designed to repair wounds with muscle and bone defects or severe infections. In recent years, the survival rate of flaps covering upper limb trauma have been above 90%. Vitse(2) et al. reported that the survival rate of perforator-based propeller flaps flap transfer reached about 97%; Howard(3) et al. reviewed survival rates of anterolateral thigh flaps for upper extremity trauma reconstruction and found encouraging rates ranging from 90–100%. Nevertheless, in addition to the selection of flap donor sites, there are other factors that play indispensable roles in wound repair.

Although the timing of tissue transfer has been hotly debated for years, the effects of timing remain uncertain with respect to patient outcomes. It was originally suggested by Godina(4) that microsurgical reconstructions of the wounds within 3 days would decrease the rate of infection and shorten hospital stay and bone-healing time. Since then, 72 hours has been considered the “golden window” for flap reconstruction(5). However, in recent years, with improvements in preoperative management, especially with the application of Vacuum Sealing Drainage (VSD) negative pressure aspiration, researchers have found that the time of flap transplantation beyond the golden window achieved satisfactory outcomes(6). Derderian(7) et al. reported a 25-year experience for microvascular free-tissue transfer for traumatic defects of the upper extremity. The authors suggested that the preferred timing for microvascular free-tissue transfers to the upper extremity was 6 to 21 days post injury because of decreasing the rate of flap failures, re-explorations, infections, osteomyelitis, and nonunions.

Despite the high success rate of skin flaps, some issues remain unresolved. To begin resolving these issues, we reported our experience using flap transfer for traumatic defects for the upper extremity during the past several years. We analyzed the flap choices, the timing, incidence of complications, and success of flap reconstructions used for devastating upper extremity injuries.

Patients And Methods

We performed a retrospective study of patients who came to our hospital for treatment of complex upper limb trauma with flap transfers between July 2013 and December 2016. Only cases reconstructed during the subacute phase were included. Thirty-five flaps were transferred in 35 upper extremities for delayed reconstruction in the subacute period, including 24 anterolateral thigh (ALT) flaps, five latissimus dorsi flaps and six lateral arm flaps. There were 25 male and 10 female patients, whose ages ranged from 23 to 69 years. The causes of injury were 12 machine crush injuries, 18 machine strangulation injuries, two chainsaw accidents, two traffic accidents and one incident of heavy bruising. Data collected included the type of tissue transfer, postoperative flap complications, infection data, and outcomes (Tables 1–3).

Results

The three upper extremity reconstructive tissue transfers used were anterolateral thigh flaps (69.57%), latissimus dorsi flaps (14.29%), and lateral arm flaps (17.14%). Five defects of the major arteries were reconstructed with the ALT flaps using a flow-through pattern. Four defects were reconstructed with the ALT flaps using split skin paddles flaps. Three defects were reconstructed with ALT flaps without the fascia lata. The dimensions of the ALT flaps ranged from 8 to 33 cm in length and 6 to 11 cm in width. Latissimus dorsi flaps ranged from 28 to 36 cm in length and 7 to 9 cm in width. The lateral arm flaps ranged from 4 to 10 cm in length and 3 to 6 cm. Flap procedures were performed during the subacute period, with an average time to reconstruction of 14 days (range, 5–29 days). Some defects were not completely covered and were grafted with split-thickness skin grafts secondarily.

All but two of 35 flaps survived completely with three flaps requiring microvascular re-exploration. The hospital stays ranged from 12 to 103 days (average, 39 days). The two lost partial flaps were an anterolateral thigh flap and a latissimus dorsi flap, both because of deficient blood supply. Traumatized wound infections occurred in three patients, and further debridement was performed in two patients except one healed after five change dressings at his bedside. Two resulted from progressive muscle and soft-tissue necrosis of the wounds. Rehabilitation training was performed by physical therapists within 7 days of admission. The follow-up periods ranged from 19 to 62 months. No patients had postoperative complications at donor sites. One patient had chronic infection with a discharging sinus after 13 months. Washout was performed after rehospitalization, and the sinus healed. No bacterial growth was observed in secretions. Three patients, all with latissimus dorsi flaps, had S₁ sensation; Eight patients had S₂ sensation, including two latissimus dorsi flaps, four ALT flaps and two lateral arm flaps; Fifteen patients, two with lateral arm flaps and 13 with ALT flaps, had S₃ sensation; Nine patients had S₄ sensation, including two lateral arm flaps and seven ALT flaps.

Representative cases

Case 1

A 48-year-old woman suffered a rolling-machine crush injury of her right forearm, with extensor side and palm skin avulsion, radius fracture, and devascularization of the hand and forearm. Emergency exploration revealed segmental ulnar artery defects; however the nerve was spared. The extensor group muscles were crushed and partially disrupted. Bone reduction and internal fixation using plates were performed. A free right anterolateral thigh flap using the flow-through technique with a segment of the descending branch of the lateral circumflex femoral artery about 12 cm long was harvested 3 weeks later. The anterolateral thigh flap was about 7 × 28 cm² in size. An iliac bone graft was performed for the radius defect 7 months postoperatively. Range of motion of the right wrist was 30 degrees in flexion, with wrist extension of about 40 degrees at 15 months postoperatively (Fig. 1).

Case 2

A 43-year-old woman suffered a crush injury of her left forearm, with extensor- and flexor-side skin avulsion, severe distal radioulnar fractures, and radial artery rupture. Emergency debridement and exploration were arranged. The flexor and extensor muscles at the distal forearm were totally debrided, only preserving the tendon; all devascularized tissues were debrided as completely as possible. Because there was a comminuted distal ulnar fracture and reduction was difficult, the distal radius was connected to the proximal ulna via internal fixation using dynamic compression plates. A free left anterolateral thigh flap about 30 cm long was harvested 2 weeks later. The anterolateral thigh flap was about 7 × 30 cm² in size. Range of motion of the right wrist was 30 degrees in flexion, with 50 degrees of extension at 27 months postoperatively. The pronation of forearm was 0 degrees and supination was 80 degrees. (Fig. 2).

Discussion

High-energy injuries are associated with loss of muscle, nerve, blood vessels, and bone, making it difficult to treat the wounds left after primary debridement. With the development of surgical techniques, especially microsurgery, many limbs have been preserved instead of being amputated. Therefore, the focus has shifted to how to improve the appearance and function of the preserved limbs.

For severely complex upper limb wounds, selecting the tissue with adequate blood supply to cover the wound is most important(8, 9). In our study, three kinds of flap were used to reconstruct upper limbs. The lateral arm flap could only be transplanted to repair smaller defects in the forearm or hand because of tissue limitations. The latissimus dorsi musculocutaneous flap provides sufficient tissue to repair the extensive soft tissue defects; however, patients later complained not only of postoperative bloated appearance, but they also complained of the heavier limb with limited flexibility of the affected limbs. The anterolateral thigh flap has been called a “universal flap”, designed to include several tissue components, has been widely used to repair soft tissue defects(10). We used the anterolateral thigh flap without fascia lata to repair the wounds without obvious bone exposure and infection, reducing damage to the donor site, while simultaneously improving the appearance of both donor and recipient site. For the patients with wide defect areas, lobulated flaps can be designed to change the width to length, ensuring one-stage closure of the donor area. This avoids several complications, including scarring, adhesions, and contour defects caused by skin grafting. If the damage involved the trunk vessels in the recipient area, flow-through flaps are the best choice because they provide simultaneous arterial reconstruction and soft-tissue coverage(11). The latissimus dorsi flap is most suitable for patients who needed restoration of elbow function, because this flap provides good dynamic muscles for the flexor and extensor muscle group (12).

Because of inter-individual variations in perforator anatomy, preoperative vascular mapping was introduced to help identify the dominant perforator. In our study, we performed computed tomography angiography (CTA) or color doppler sonography (CDS) to map perforators before applying an ALT perforator flap to repair soft tissue defects. According to our previous study(13), CTA had a higher sensitivity than CDS for detecting vessels. Therefore, we typically used CTA first to create clear 3D images of the vessels and surrounding structures, as well as to mark the skin. If the patient was allergic to iodine had renal insufficiency, they would undergo CDS to determine the position, path, caliber, and quality of the perforator vessels, and to mark the skin. We depended on the results of CTA and CDS to identify the best perforators to design the ALT perforator flaps. If the perforators are located precisely, the surgeon can identify the

path of the perforator in the surrounding area and minimize incisions of the muscle and deep fascia during the operation, thereby reducing complications at the donor site. Furthermore, this makes the surgeon's task easier.

There has been no consensus regarding the most appropriate time to cover upper limb wounds using skin flap transplantation. As early as 1986, early covering of the wound was suggested by Godina(4); it was suggested that if flap transplantation should be carried out within 72 hours to close the wound, the necrosis rate of the flap would be 0.75%, greatly reducing the postoperative infection rate and hospital stays. However, since 1990, several studies have shown that secondary tissue transplantation can achieve better effects. In particular, there has been application of the negative-pressure wound therapy technique(14). The benefits of negative-pressure wound therapy include increased perfusion, fresh granulation tissue, promotion of angiogenesis, wound area reduction, cellular proliferation, decreased bacterial contamination, and reduction of the inhibitory effects of wound exudates(12, 15). According to Derderian(7), covering the wound using tissue transplantation on the 6th and 21st day after injury has obvious advantages over other times; flap necrosis rates, postoperative infection rates, incidences of osteomyelitis and nonunion were lower and the one-stage operation time was shortened, making patients more tolerant of the secondary operations. Delayed closure of the wound prevents proliferation of anaerobic bacteria while allowing sufficient time to identify the tissue that survives during primary debridement, avoiding more radical scavenging of surviving tissue, or leaving possible necrotic tissue resulting in late wound deferred. However, the later the wound is closed, the worse the function of the affected limb, resulting in heavier psychological and economic burdens. The reasons for this can be summarized as follows: (1) Wound infections correlate with longer exposure times. Despite the fact that the VSD negative pressure sealing technique keeps the wound closed, it can only guarantee effective sealing for 3 days; (2) Long-term inflammatory stimulation causes edema and adhesion of surrounding tissues, leading to stiffness and tissue organization; (3) Long-term exposure of bony tissue can easily lead to nonunion, necrosis and bone infections, increasing the difficulty of bone tissue repair at the later stages; (4) Long-term bed-rest leads to disuse atrophy of muscle and late limb dysfunction; (5) Inflammation stimulates peripheral blood vessels and nerves, causing edema and adhesions with surrounding tissue, resulting in increased graft necrosis rates of the late flap.

Of the 35 patients we treated, individualized treatments were developed according to the patient's condition and injury, as well as their condition on admission. In the subacute stage, the wound was closed by tissue transplantation. Therefore, we believe that subacute wound closure, if possible within 5–30 days after emergency surgery, remains a better choice. Emergency flap transplantation is not recommended unless there are important vessels and nerves that must be repaired. Mundi(16) suggested that primary wound closure is best for fractures with less severe soft-tissue injuries, to allow for tension-free closure. For those injuries requiring delayed closure, definitive coverage should not be delayed beyond seven days, even in the setting of negative-pressure wound therapy. We believe that, for patients with severe open fracture of upper limb, phased treatment not only effectively reduces the infection rate, but also allows more choices of skin flap in the subacute stage. In our series, no patient underwent amputation. The two lost partial flaps were an anterolateral thigh flap and a latissimus dorsi flap, both because of deficient blood supply. (5.71%). Traumatized wound infection occurred in three patients (8.57%). Two of them resulted from progressive muscle and soft-tissue necrosis of the wound; however, the patient with superficial infection healed after five change dressings at the bedside. Zoran et al.(17), reported that the main reason for infection was most often nosocomial infection, in agreement with our series.

Patients with severe open fractures of the upper extremity often suffer severe trauma, requiring frequent operations and long periods of treatment. If there is difficulty in performing free flap transplantation, flap necrosis may lead to amputation. Therefore, it is very important to evaluate and select blood vessels in the recipient area before surgery. First, we should evaluate the patient's condition comprehensively according to the location of the wound and the degree of injury. Prior to surgery, CTA or B-ultrasound should be performed to verify vascular patency and diameter. During surgery, the quality of blood vessels should be accurately evaluated to avoid scarring vessels. Furthermore, heparin should be used to flush the vessels repeatedly during the operation to judge its quality and patency.

Conclusions

For extensive soft tissue defects of upper limb without obvious bone exposure, using an anterolateral thigh flap satisfies both appearance and function with negligible complications. For restoration of elbow function, the latissimus dorsi flap is preferable because it provides good dynamic muscle for the flexor and extensor muscle group. Preoperative perforator localization technology allows surgeons to accurately understand the vascular situation, thereby reducing the surgical failure rate. Devastating upper wounds can be successfully reconstructed in the subacute period with low flap failure, infection, and amputation rates.

Abbreviations

ALT: Anterolateral thigh; CDS: Color doppler sonography; CTA: Computed tomography angiography; VSD: Vacuum sealing drainage

Declarations

Acknowledgment

No.

Author contributions

Yongqiang Kang and Xiaoyun Pan designed the study, performed the operations, collected the clinical data, and completed the manuscript. Yongwei Wu, Yunhong Ma, Jun Liu and Li Fengfeng participated in the operations. Yongjun Rui participated in the operations and was the team leader. All authors have no conflicts of interest to disclose. All authors have read and approved the final submitted manuscript.

Funding

This work was supported by Construction target of clinical medical center in Wuxi (LCZXJS001)

Availability of data and materials

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

Ethics approval and consent to participate

The study protocol was approved by the ethics committee of The Ninth People's Hospital of Wuxi affiliated to Soochow University.

Consent for publication

Not applicable.

Competing interests

All authors have no conflicts of interest to disclose. All authors have read and approved the final submitted manuscript.

Contributor Information

Yongqiang Kang, Email: kang123qiang@126.com

Xiaoyun Pan, Email: panxiaoyun89@163.com

Yongwei Wu, Email: 15151515157@163.com

Yunhong Ma, Email: mayh2006@126.com

Jun Liu, Email: liujun_jiangyin@163.com

Yongjun Rui, Email: wxswkryj@163.com

References

1. Koshima I, Soeda S. Inferior epigastric artery skin flaps without rectus abdominis muscle. *Br J Plast Surg.* 1989;42(6):645-8.
2. Vitse J, Bekara F, Bertheuil N, Sinna R, Chaput B, Herlin C. Perforator-based propeller flaps reliability in upper extremity soft tissue reconstruction: a systematic review. *J Hand Surg Eur Vol.* 2017;42(2):157-64.
3. Wang HD, Alonso-Escalante JC, Cho BH, DeJesus RA. Versatility of Free Cutaneous Flaps for Upper Extremity Soft Tissue Reconstruction. *J Hand Microsurg.* 2017;9(2):58-66.
4. Godina M. Early microsurgical reconstruction of complex trauma of the extremities. *Plast Reconstr Surg.* 1986;78(3):285-92.
5. Kolbenschlag J, Klinkenberg M, Hellmich S, Germann G, Megerle K. Impact of Timing of Admission and Microvascular Reconstruction on Free Flap Success Rates in Traumatic Upper Extremity Defects. *J Reconstr Microsurg.* 2015;31(6):414-9.
6. Haas NA, Kock L, Bertram H, Boekenkamp R, De Wolf D, Ditkivskyy I, et al. Interventional VSD-Closure with the Nit-Occlud((R)) Le VSD-Coil in 110 Patients: Early and Midterm Results of the EUREVECO-Registry. *Pediatr Cardiol.* 2017;38(2):215-27.
7. Derderian CA, Olivier WA, Baux G, Levine J, Gurtner GC. Microvascular free-tissue transfer for traumatic defects of the upper extremity: a 25-year experience. *J Reconstr Microsurg.* 2003;19(7):455-62.
8. Kumar AR. Standard wound coverage techniques for extremity war injury. *J Am Acad Orthop Surg.* 2006;14(10 Spec No.):S62-5.
9. Hallock GG. The utility of both muscle and fascia flaps in severe upper extremity trauma. *J Trauma.* 2002;53(1):61-5.
10. Qing L, Wu P, Yu F, Zhou Z, Tang J. Use of a sequential chimeric perforator flap for one-stage reconstruction of complex soft tissue defects of the extremities. *Microsurgery.* 2019.
11. Miyamoto S, Fujiki M, Nakatani F, Sakisaka M, Sakuraba M. Free flow-through anterolateral thigh flap for complex knee defect including the popliteal artery. *Microsurgery.* 2015;35(6):485-8.
12. Jensen M, Moran SL. Soft tissue coverage of the elbow: a reconstructive algorithm. *Orthop Clin North Am.* 2008;39(2):251-64, vii.
13. Zhang Y, Pan X, Yang H, Yang Y, Huang H, Rui Y. Computed Tomography Angiography for the Chimeric Anterolateral Thigh Flap in the Reconstruction of the Upper Extremity. *J Reconstr Microsurg.* 2017;33(3):211-7.
14. Steiert AE, Gohritz A, Schreiber TC, Krettek C, Vogt PM. Delayed flap coverage of open extremity fractures after previous vacuum-assisted closure (VAC) therapy - worse or worth? *J Plast Reconstr Aesthet Surg.* 2009;62(5):675-83.
15. Moues CM, Heule F, Hovius SE. A review of topical negative pressure therapy in wound healing: sufficient evidence? *Am J Surg.* 2011;201(4):544-56.
16. Mundi R, Chaudhry H, Niroopan G, Petrisor B, Bhandari M. Open Tibial Fractures: Updated Guidelines for Management. *JBJS Rev.* 2015;3(2).
17. Arnez ZM, Papa G, Ramella V, Novati FC, Ahcan U, Stocco C. Limb and Flap Salvage in Gustilo IIIC Injuries Treated by Vascular Repair and Emergency Free Flap Transfer. *J Reconstr Microsurg.* 2017;33(S 01):S03-S7.

Table 1. Patient anterolateral thigh(ALT) flap reconstruction											
Sex	Age (Year)	Cause of injury	Associated Fracture	Associated Injury	Time to debridement (Hours)	fracture fixation	Number of Washouts	Time to Flap (Days)	Type Flap	Flap Failure/Comments	Infecti
Male	45	Machine strangulated	Radius Ulna	Radial artery ulnar artery	7	Internal	1	6	Radial flow- through		None
Male	27	Machine strangulated	Carpals	Radial artery ulnar artery	6	Internal External	1	8	Radial flow- through		None
Male	24	Machine strangulated	Radius Ulna Metacarpal		3	Internal	2	21	single		None
Male	54	Machine crushed	Ulna		2	Internal	1	18	single		None
Male	32	Machine crushed	Radius Ulna Carpals	Radial artery Radial nerve	4	Internal External	4	13	single		None
Male	57	Machine strangulated	Radius Ulna		10	External	4	5	split skin paddles flap	Partial flap loss	Superf infecti
Female	43	Machine crushed	Radius Ulna	Radial artery	7	Internal	3	29	single	microvascular re- exploration	None
Female	48	Machine strangulated	Radius		4	Internal	3	22	Radial flow- through		None
Male	23	Machine strangulated	Carpals Radius	Radial artery	2	Internal External	1	7	single		None
Male	52	Hot machine crushed	Radius Ulna	Radial artery Radial nerve	5	Internal	4	26	single	microvascular re- exploration	Superf infecti
Male	54	Machine strangulated	Radius Ulna Carpals		4	Internal	1	9	Single Without fascia lata		None
Male	26	Machine strangulated	Humerus Radius Ulna		6	Internal	1	27	split skin paddles flap		None
Male	42	Machine crushed	Ulna		4	Internal	1	15	Single		None
Male	45	Machine strangulated	Humerus	brachial plexus brachial artery Radial artery	3	Internal	0	8	Radial flow- through		None
Female	45	Machine strangulated	Radius Ulna		8	Internal	0	7	Single		None

Male	65	Machine strangulated	Humerus Radius Ulna	Radial never	6	Internal	1	24	Single	None
Male	50	Machine strangulated	Radius Ulna		9	Internal	1	17	Single	None
Female	65	Machine crushed	Radius Ulna	ulnar artery	2	Internal External	1	11	Single Without fascia lata	None
Male	69	Heavy bruised	Humerus	brachial artery Radial artery Ulnar artery	6	Internal	0	10	Radial flow-through	None
Female	62	Machine crushed	Humerus Radius Ulna	Radial never	5	Internal	1	12	Single Without fascia lata	None
Male	42	Machine strangulated	Radius Ulna Carpals	Radial artery	3	Internal External	0	8	split skin paddles flap	None
Female	46	Machine crushed	Radius	Radial artery	8	Internal	0	6	split skin paddles flap	None
Male	27	Machine strangulated	Radius Ulna		2	Internal	1	12	Single	None
Male	31	Machine strangulated	Radius Ulna		5	Internal	0	5	Single	None

Table 2. Patient latissimus dorsi flap reconstruction											
Sex	Age (Year)	Cause of injury	Associated Fracture	Associated Injury	Time to debridement (Hours)	fracture fixation	Number of Washouts	Time to Flap (Days)	Type Flap	Flap Failure/Comments	Infection
Female	52	Hot machine crushed	Ulna	ulnar artery ulnar never	2	internal	3	21	Free flap	microvascular re-exploration	None
Male	59	Hot machine crushed	Humerus Ulna		6	internal	3	28	island flaps		None
Male	42	Machine strangulated	Humerus Ulna Radius		2	Internal External	1	16	island flaps	Partial flap loss	None
Male	37	Machine strangulated	Radius Ulna	Radial artery ulnar artery	5	Internal	1	6	island flaps		None
Female	41	traffic accidents	Humerus Ulna Radius	brachial artery	8	Internal External	3	27	island flaps		Superficial infection

Table 3. Patient lateral arm flap reconstruction											
Sex	Age (Year)	Cause of injury	Associated Fracture	Associated Injury	Time to debridement (Hours)	fracture fixation	Number of Washouts	Time to Flap (Days)	Type Flap	Flap Failure/Comments	Infection
Female	54	Machine crushed	Ulna	ulnar artery ulnar nerve	2	internal	3	21	Free flap		None
Male	59	chainsaw	Radius	Radial artery	6	internal	1	8	island flaps		None
Male	40	chainsaw	Ulna Carpals	ulnar artery ulnar nerve	2	Internal External	1	6	Free flap		None
Male	38	Machine crushed	Radius Ulna	Radial artery ulnar artery	5	Internal	1	14	island flaps		None
Male	47	traffic accidents	Metacarpal Carpals		4	Internal	2	10	Free flap		None
Female	52	Machine strangulated	Radius	Radial artery	3	Internal	1	12	Free flap		None

Figures

Figure 1

Case 1, a 48-year-old woman. A: The defect on the right was on the forearm with the size 7 × 28 cm². B-D: According to the guide points (black cross) marked on the patient's right thigh, an appropriate flow-through flap (size 7 × 28 cm²) was designed. E: Primary closure of donor site. F: Flap covered the wound after anastomoses were complete. G-H: Appearance at 15-month follow-up.

Figure 2

Case 2, a 43-year-old woman. A: Left arm crush injury with soft-tissue defect. B: Both ulnar and radial fractures. C: The defect on the left was on the forearm with the size 7×27 cm². D: The distal radius is connected to the proximal ulna with internal fixation using dynamic compression plates. E-G: Flap covering the reconstructed soft-tissue. H-I: Appearance at 27-month follow-up.