Original Article

Free Flow-through Anterolateral Thigh Flaps for Wrist High-tension Electrical Burns: A Retrospective Case Series*

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Abstract

Objective The objective of this report was to demonstrate the clinical application of free flow-through anterolateral thigh flaps for the treatment of high-tension electrical wrist burns.

Methods We collected the data of 8 patients with high-tension electrical wrist burns admitted to Beijing Jishuitan Hospital from January 2014 to December 2018. The clinical and pathological data were extracted from electronic hospital medical records. We obtained follow-up information through clinic visits.

Results The injury sites for all 8 patients were the wrists, specifically 5 right and 3 left wrists, all of which were on the flexor side. Five patients had ulnar artery embolism necrosis and patency, with injury to the radial artery. Two patients had ulnar and radial arterial embolization and necrosis. The last patient had ulnar arterial embolization and necrosis with a normal radial artery. After debridement, the wound area ranged from 12 cm × 9 cm to 25 cm × 16 cm. The diagnoses for the eight patients were type II to type III high-tension electrical wrist burns. Free flow-through anterolateral thigh flaps (combined with great saphenous vein transplantation if necessary) were used to repair the wounds. The prognosis for all patients was good after six months to one year of follow-up.

Conclusion Treating wrist types II and III high-tension electrical burns is still challenging in clinical practice. The use of free flow-through anterolateral thigh flaps (combined with great saphenous vein transplantation if necessary) to repair the wound and to restore the blood supply for the hand at the same time is a good choice for treating severe wrist electrical burns.

Key words: High-tension electrical burns; Wrist flap surgery; Free flow-through anterolateral thigh flaps

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INTRODUCTION

Burns from high-tension electricity (current over 1,000 volts) frequently result in amputations, renal failure, and sometimes death due to cutaneous injuries and severe damage to underlying nerves, blood vessels, muscles, and bone[1,2]. High-tension electrical burns frequently involve the hand and wrist as these are the most common entry and exit points of the current[3].

High-tension electrical burns in the wrist often cause damage and necrosis of the tendon, nerves, blood vessels, and bones of the wrist, resulting in high disability and amputation rates[1,3,4]. For patients with wrist vascular injury, the great saphenous vein is usually transplanted to restore the circulation of the hand[3]. For patients with wrist vascular injury with skin and soft tissue defects, a variety of bridge flap blood flow is adopted to not only cover the wound but also restore blood circulation, such as

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flow-through radial artery flap, flow-through peroneal artery flap, and flow-through anterolateral thigh perforator flap[5-7]. However, there have been few reports on the use of flow-through anterolateral thigh perforator flap to repair the wrist blood flow for high-tension electrical burns.

The objective of this report is to demonstrate the use of free flow-through anterolateral thigh flap for high-tension electrical wrist burns. This patient report was exempted from an ethics review by the Beijing Jishuitan Hospital ethics committee as this was an anonymous chart review study.

METHODS

We retrospectively analyzed data for eight patients with high-tension electrical wrist burns admitted to Beijing Jishuitan Hospital from January 2014 to December 2018. All 8 patients underwent fasciotomy of the wrist midline at the local hospital to relieve tension due to early wrist tension and hand vascular crisis. Formal operations were performed after the patients were transferred to our unit for 2 to 3 d when their general conditions were deemed relatively stable. We obtained follow-up information through medical records of clinic visits and the follow-up period ranged from 6 to 12 months. The diagnosis, treatment, and follow-up for a representative patient are described in detail.

Diagnostic Assessment

According to physical examinations, medical histories, and auxiliary examinations, the clinical diagnosis at admission was level III°-IV° high-tension electrical burns for all patients evaluated.

Therapeutic Intervention

Surgery was performed in two stages. For the first-stage operation, the wrist wounds were thoroughly debrided, the eschar was removed, and the necrosis in the tendons, muscles, and nerves of the wrist was cleared. Viable tendon and nerve stumps were retained when possible. Free tendons and nerve grafts are not recommended at this stage. The necrosis and the injured ulnar and radial arteries were removed up to the normal part of the blood vessel and the end of the blood vessel was temporarily clamped with a blood vessel clamp. Before the second-stage operation, we first needed to design the anterolateral thigh flap according to the soft tissue defect of the wrist. The location of the perforating branch(es) of the lateral circumflex femoral artery descending branch was determined using an ultrasound Doppler flow detector and marked.

According to the design location and area of the flap, the medial thigh incision was made first and the flap was lifted from the surface of the rectus femoris. We next identified the perforating branch(es) of the lateral circumflex femoral artery descending branch in the space between the rectus femoris and the vastus lateralis muscle. After confirming the existence of one or two relatively thick perforating branches, lateral, upper, and lower thigh incisions for the flap were performed. The flap was lifted from the deep fascia of the thigh and dissected gradually to the perforating branch, then dissected along the perforating branch to the descending trunk of the lateral circumflex femoral artery. According to the length of the blood vessel to be bridged, the length of the descending branch of the lateral femoral artery was determined and the anterolateral thigh flap was dissociated. The flap was then transferred to cover the wrist wound and was simply fixed to the wound edge. The proximal and distal ends of the descending branch of the lateral circumflex femoral artery were respectively anastomosed to the proximal and distal ends of the ulnar artery. The accompanying vein of the proximal descending branch of the lateral circumflex femoral artery was anastomosed with the accompanying vein of the ulnar artery or the superficial forearm vein.

RESULTS

All 8 patients were male, aged from 20 to 42 years old, with an average age of 28 years old. The injury voltage was 10–100 kv and the patients were admitted to our hospital 6 to 15 d after the injury. The clinical characteristics of the patients can be found in Table 1.

Clinical Finding

The injury sites for all 8 patients were the wrists, specifically 5 right and 3 left wrists, all of which were on the flexor side. The patients had a wide range of skin and soft tissue necrosis. The wounds led to the exposure and necrosis of the superficial and deep flexor tendons, flexor pollicis longus tendon, several muscles, pronator quadratus, median nerve, and ulnar nerve. Four patients had ulnar artery embolism necrosis and patency but an injured radial artery with a weak pulse. For these patients, arteriography showed the absence of the ulnar artery and the expansion of the radial artery. Three patients had ulnar and radial arterial embolization and necrosis.

Table 1. Clinical characteristics of the eight patients with wrist high-tension electrical burns

Cases	Age	Gender	Admission days after injury	Electric voltage (kv)	Injured wrist	TBSA of the wrist burn (%)	Injured side hand blood supply examination	Diagnosis	Operation time after injury (d)	Operation procedure	Follow-up time (month)	Prognosis
Patient 1	27	male	10	10	Right side	1	Pale, low temperature	III°-IV° high-tension electrical burn	12	Debridement, Ulnar artery reconstruction left flow-through anterolateral thigh flap grafted	6	the shape of the flap and the blood supply of the hand were good
Patient 2	28	male	6	10	Right side	1	Pale, low temperat ure	III°-IV° high-tension electrical burn	8	Debridement, Ulnar artery reconstruction left flow-through anterolateral thigh flap grafted	6	the shape of the flap and the blood supply of the hand were good
Patient 3	32	male	3	100	Left side	1	Pale, low temperature	III°-IV° high-tension electrical burn	6	Debridement, Ulnar artery reconstruction left flow-through anterolateral thigh flap grafted	12	the shape of the flap and the blood supply of the hand were good
Patient 4	38	male	12	10	Right side	1	Pale, low temperature	III°-IV° high-tension electrical burn	14	Debridement, Ulnar artery reconstruction left flow-through anterolateral thigh flap grafted	6	the shape of the flap and the blood supply of the hand were good
Patient 4	38	male	12	10	Right side	1	Pale, low temperature	III°-IV° high-tension electrical burn	14	Debridement, Ulnar artery reconstruction left flow-through anterolateral thigh flap grafted	6	the shape of the flap and the blood supply of the hand were good
Patient 5	33	male	4	10	Right side	1	Pale, low temperature	III°-IV° high-tension electrical burn	7	Debridement, Ulnar artery reconstruction left flow-through anterolateral thigh flap grafted	12	the shape of the flap and the blood supply of the hand were good
Patient 6	20	male	15	10	Right side	1	Pale, low temperature	III°-IV° high-tension electrical burn	17	Debridement, Ulnar artery reconstruction left flow-through anterolateral thigh flap grafted	12	the shape of the flap and the blood supply of the hand were good
Patient 7	42	male	10	20	Left side	1	Pale, low temperature	III°-IV° high-tension electrical burn	12	Debridement, Ulnar artery reconstruction left flow-through anterolateral thigh flap grafted	6	the shape of the flap and the blood supply of the hand were good
Patient 8	30	male	9	30	Left side	1	Pale, low temperature	III°-IV° high-tension electrical burn	11	Debridement, Ulnar artery reconstruction left flow-through anterolateral thigh flap grafted	12	the shape of the flap and the blood supply of the hand were good

Note. TBSA stands for the percent total body surface area.

The last patient had ulnar arterial embolization and necrosis but with a normal radial artery. The hands of the injured side were pale, low temperature (2 °C below) compared with the normal hands. The range of the wound areas after debridement was 12 cm × 11 cm to 25 cm × 16 cm.

Therapeutic Intervention

For the cases described here, the flap areas ranged from 14 cm × 14 cm to 28 cm × 18 cm and the length of the bridged blood vessel ranged from 12 cm to 24 cm. Patient 1 had ulnar and radial artery embolization, though we found one normal arterial anastomosis at the distal end of the wrist. Patient 2 had ulnar artery embolization and necrosis, but the radial artery was normal. We used the flow-through anterolateral thigh flap to repair the wound and reconstruct the ulnar arteries. Patients 3 to 8 had ulnar artery embolization and necrosis as well as radial artery injury. The contralateral saphenous vein was first grafted to reconstruct the radial artery. The proximal and distal ends of the saphenous vein were respectively anastomosed to the proximal and distal ends of the radial artery to reconstruct the artery. The flow-through anterolateral thigh flap was used to reconstruct the ulnar artery and repair the wrist wound. The donor site was repaired with a median-thickness skin graft obtained from the ipsilateral thigh.

Postoperative treatment included the use of low molecular weight heparin, low molecular weight dextran, papaverine, and prostaglandin E_1 to improve blood circulation and closely paying attention to flap and hand blood supply. Postoperative ultrasound Doppler flow examination or angiography was routinely performed to examine the vascular condition. The free flow-through anterolateral thigh flaps for all eight patients survived well and the wounds of seven patients had healed by the first follow-up. The eighth patient developed an infection under the flap three days after the surgery but the infection healed within two weeks after dressing change and expansion debridement. All patients had good blood supply to the hands and were discharged from the hospital in 12 to 35 d.

Follow-up

After 6 months to one year of follow-up, the shape of the flaps and blood flow in the hands were good. However, flexion of the fingers was dysfunctional and the distal end of the fingers lacked a sense of touch, which subsequently had to be repaired through tendon and nerve transplantation. The shape of the thigh donor site was better restored, the thigh muscle strength was good, and the knee joint activity was regular.

Details for Patient 1

A 25-year-old man was burned by 10-kilovolt high-voltage electricity on June 1, 2017. The patient was treated at a local hospital with fasciotomy of the wrist midline, simple debridement, moist burn ointment, and acellular xenogeneic dermal matrix treatment. On June 11, 2017, the patient was transferred to our department as there was no apparent improvement in his wounds.

Admission examination showed extensive necrosis of the skin on the right wrist (Figure 1). Pulsation could not be detected in the ulnar artery, the radial artery pulsation was weak, and the right hand was slightly swollen. The percent total body surface area (TBSA) for the burns on the right wrist and feet was 5%, and the right wrist burn area was 1% TBSA. The feet had III° burns, which were treated with a skin graft. On the day of admission, right wrist angiography showed the absence of the ulnar artery and a slight expansion of the radial artery (Figure 2). The diagnosis was right wrist III°-IV° high-tension electrical burns.

On the third day of admission when the patient's condition was relatively stable, his right wrist wound was debrided and the left flow-through anterolateral thigh flap was grafted. During surgery, the soft tissue of the flexor skin of the wrist was found to be extensively deficient. There were defects on the superficial and deep flexor tendons as well as the flexor pollicis longus tendon. The defect on the median nerve was 13 cm long and the necrosis of the ulnar artery and nerve was 12 cm long. The radial artery was intact, but 8 cm of the artery was bulging, dark red in color, with weak pulsation and no contraction upon touch, which was considered radial artery injury (Figure 3). The necrotic ulnar nerve, necrotic ulnar artery, and injured radial artery were removed. A small thrombus was found after the incision of the radial artery wall (Figure 4). The size of the right wrist wound was 20 cm × 12 cm after debridement and the size of the flow-through anterolateral thigh flap was 22 cm × 13 cm with an 17 cm lateral femoral artery descending branch (Figure 5). A 14-cm contralateral great saphenous vein was grafted to repair the radial artery. The distal part of the great saphenous vein was anastomosed to the proximal end of the radial artery, and the proximal end of the great saphenous vein was anastomosed to the distal end of the radial artery to reconstruct the radial artery (Figure 6). The proximal and distal ends of the descending branch of the lateral circumflex femoral artery were respectively anastomosed to the proximal and distal ends of the ulnar artery. The accompanying vein of the proximal descending branch of the lateral circumflex femoral artery was anastomosed with the basilic vein using 9–0 prolenes (Figure 7). We used papaverine injection 4 times a day to prevent thrombosis after operation for 7 d. After anastomosis of the blood vessels, the flap and hand blood were well transported, and the temperature of the hand was normal (Figure 8). The donor site was repaired with median-thickness skin grafts obtained from the ipsilateral thigh.

The flaps survived well after the operation and the wound healed by the first follow-up. Right wrist angiography showed that the blood vessels had

Figure 1. Wound from right wrist high-tension electrical burn at the time of admission.

Figure 2. Image of angiograph. Preoperative angiography showed the absence of the ulnar artery and slight dilatation of the radial artery.

Figure 3. After debridement of the right wrist wound, flexor tendons and nerve defects as well as ulnar arteriovenous necrosis were found. The radial artery was dark red in color and swollen. A great saphenous vein graft was prepared.

Figure 4. A small thrombus was found after an incision in the radial artery wall.

Figure 5. The left flow-through anterolateral thigh flap.

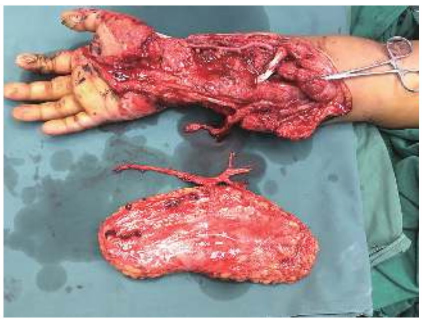

Figure 6. Radial artery reconstruction was performed with the great saphenous vein graft and the left flow-through anterolateral thigh flap was ready to be transplanted.

patency (Figure 9). The graft healed well, and the feet also healed after being cut and transplanted. The shape of the flap and the blood supply to the hand were good after six months of follow-up (Figure 10). However, the flexion of the fingers was dysfunctional, and the distal end of the fingers lacked a sense of touch, which had to be repaired later with tendon and nerve transplantation.

DISCUSSION

According to the extent and severity of the devitalized tissues of the wrist as well as the degree of damage to the wrist arteries, electrical wrist burns can be categorized into four types[4]. Type I burns are mostly confined to the volar side of the wrist and blood flow in the hands is not affected, making them easy to treat. Type IV burns are accompanied by hand necrosis, which requires amputation surgery. For types II and III wrist electrical burns, the treatment is extremely difficult due to the wide range of wounds and vascular injuries. The disability and amputation rates for types II and type III wrist electrical burns are very high[4]. Early debridement and transplantation of blood-rich tissue flaps, especially free flaps to repair wrist electrical burn wounds, has become a consensus in the field of burns, which has greatly promoted the treatment of electric burn wounds[8-11]. However, due to insufficient attention to the degree of vascular injury after electrical wrist burns, the amputation rate is still high[12,13].

It is essential for the management of patients with wrist electrical burns to pay close attention to vascular injury during the preoperative, intraoperative, and even postoperative periods for a long time[3,13,14]. For the preoperative period, knowledge of the patient's medical history should be combined with wrist and hand examinations to determine the vascular injury from the wrist electrical burns. For instance, cold hands and slow capillary reaction can confirm a primary vascular injury of the wrist. Deep eschar burns on the skin above the ulnar or radial arteries are highly indicative of ulnar or radial artery injury, which can be judged or pre-judged using modern detection examinations such as ultrasound Doppler flow detection, ultrasound angiography, computerized tomography (CT) angiography, or magnetic resonance angiography[13]. For the intraoperative

Figure 7. The flow-through anterolateral thigh flap was transplanted to the wrist wound.

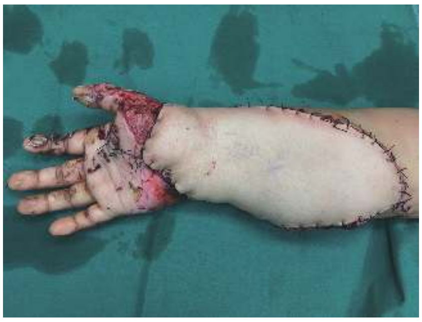

Figure 8. After anastomosis of the blood vessel, the flap and hand blood were well transported and the temperature of the hand was normal.

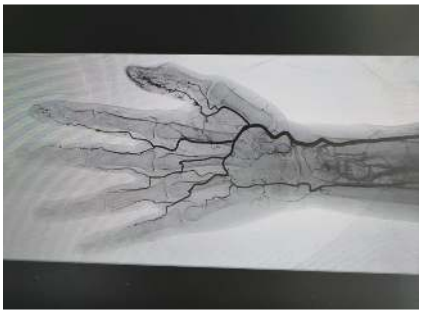

Figure 9. After six months of follow-up, postoperative angiography showed the ulnar artery and the radial artery were unobstructed.

Figure 10. After six months of follow-up, the shape of the flap and blood flow to the hand were good.

period, the condition of the ulnar and radial artery can be directly observed after debridement and eschar excision. If the artery is grayish white, has no pulsation and/or blood flow, arterial necrosis may occur. Vascular injury is highly likely if the artery is dark red or silted up, the blood vessel wall shrinks upon touching, or arterial pulsation is lacking despite blood vessel patency. There is an ongoing debate about the treatment of such blood vessel injuries due to the existence of blood vessel patency and arterial pulsations. Most scholars believe that as long as the arteries are patent and pulsating, even if there are necrotic tissues around the arteries, conservative debridement is the only therapy needed, and it is not necessary to probe blood vessels to avoid aggravating vascular injury and thrombosis[13]. In clinical practice, for patients with wrist burns treated with the traditional flap (not flow-through anterolateral thigh flap), there is still a high probability of massive hemorrhage under the flap or arterial thrombosis, which increase the risk of amputation and may be life-threatening[4]. Therefore, we believe that if the patient has a blood vessel that can be anastomosed and the blood vessel is suspected to be injured, vascular exploration and reconstruction should be performed. In the present report, we performed a repair for four patients with damaged but patent arteries of the wrist and the clinical outcomes were excellent.

In our department, we used free abdominal flaps combined with the saphenous vein to reconstruct the radial artery, treat wrist electrical burns, and protect patients from amputation. Soutar et al.[15] first introduced the concept of the flow-through flap in 1983, using the flow-through radial artery flap to repair soft tissue defects in the oral cavity and for head-neck revascularization. Afterward, flow-through flaps were widely adopted in the reconstruction of limbs and fingers. There are special characteristics for the flow-through flaps used for wrist high-tension electrical burns. High-tension electrical burns have a wide range of vascular damage, which requires long blood vessels to be anastomosed. The blood vessel anatomy is very complicated. The condition of the injured blood vessels requires accurate judgment and injuries can involve the intima, vascular middle layer or adventitia. Improper selection of anastomosis can result in anastomotic thrombosis or bleeding rupture. It has been reported that the low success rate of free flaps for repairing electrical burn wounds may be due to the improper choice of blood vessels to anastomose at the flap receipt site[11]. Some surgeons have used flow-through medial calf flaps or flow-through forearm flaps to repair wrist electrical burns. Although the blood supply of the hand could be reconstructed with these flaps, the main trunk artery of the posterior tibial artery and the radial artery were sacrificed, which led to unnecessary injury to the donor site[16].

Yokota et al.[10] first reported the repair of limb defects and vascular reconstruction with flow-through anterolateral thigh flaps in 2011. Since then, although flow-through anterolateral thigh flaps have been widely used in clinical practice, reports of their use for repairing wrist high-voltage electric burns with blood vessels are rare. Five patients with upper extremity electrical burns were treated with flow-through anterolateral thigh flaps in a previous study. While the treatment was successful for four patients, the fifth patient later required amputation[17]. In the present study, we used flow-through anterolateral thigh flaps to treat eight patients with severe wrist high-tension electrical burns, repairing the wrist wound and reconstructing the ulnar artery. In addition, three of the patients had a radial artery injury and were treated with a saphenous vein graft.

The main advantages of flow-through anterolateral thigh flaps for repairing wrist electrical burns are as follows: first, the descending branch of the lateral femoral artery has a large vascular pedicle and large diameter, which can satisfy the requirements for wrist electrical burn reconstruction. For example, the longest blood vessel we used for the 8 patients was 21 cm and it was difficult for other non-main trunk blood vessels to satisfy this requirement. Second, the donor site had sufficient skin cutting range to meet the needs of wrist wound repair. Third, there was no need to change the patient position during surgery, which is ideal for operations by two groups of surgeons. Lastly, the donor site was relatively concealed, and the damage was relatively small. Because the main trunk blood vessel was not used, blood supply to the limb was not adversely affected by the graft.

The blood supply to the main trunk blood vessels plays a vital role in limb survival and function. After main vascular injury, the blood supply at the distal end of the limb will be compensated by the dorsal or collateral vessels of the bone. The distal part of the limb may have weaker arterial pulsations compared to the normal condition. There may still be blood flow, but it will not be enough to provide sufficient blood supply for the limb. For patients with high-tension electrical burns to the wrist, regardless of whether the ulnar, radial, or both arteries are injured, the injured blood vessel should be reconstructed as much as possible to restore blood supply to the hand. In this paper, there were three patients with wrist ulnar artery necrosis and injured but patent radial arteries. In addition to the flow-through anterolateral thigh flap reconstruction of the ulnar artery, the saphenous veins were used to reconstruct the radial artery. This procedure not only resulted in a double blood supply but also avoided the risk of significant bleeding and embolism beyond the radial artery after the operation.

There are several issues that require attention for this procedure. First, it is necessary to accurately determine whether vascular anastomosis of the wrist is healthy or not. The preferred position for vascular anastomosis is about 3 cm from the vascular injury. Under the microscope, the intima of the vascular end should be smooth and free of shedding, with no prominent edema. Second, there is a possibility of postoperative infection, major bleeding, and thrombosis under the flap. Once major bleeding or hand circulatory disturbance occurs, vascular exploration and reconstruction should be performed in a timely manner. Additionally, medication to improve blood circulation (e.g., low molecular weight heparin, low molecular weight dextran, papaverine, and prostaglandin) should be administered after the operation to prevent thrombosis in the vascular anastomoses or other small blood vessel damage and improve blood flow to the hands and flaps.

CONCLUSION

Treating wrist type II and III high-tension electrical burns in clinical practice is still highly challenging. The use of flow-through anterolateral thigh flaps combined with great saphenous vein transplantation to restore the dual blood supply for the hand is a good choice for treating severe wrist electrical burns.

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