Microsurgical Flaps in High-Voltage Electrical Burns: Experience at the Chilean National Burn Reference Center

Roberto Macchiavello Macho, Nicolas Flores Moltedo, Marco Rios Vergara, Carolina Soto Diez

ABSTRACT

OBJECTIVES: Microsurgical flaps in high-voltage electrical burns are commonly used in response to a scarcity of remaining local tissues. Here, we share our experiences with microsurgical flaps in patients with high-voltage electrical burns at the National Burn Reference Center in Chile.

MATERIALS AND METHODS: We conducted a descriptive retrospective study of patients with high-voltage electrical burns reconstructed with microsurgical flaps who were seen at our center between 2019 and 2021. Demographic and surgical data were obtained from clinical records. Preoperative studies were performed with computed tomography angiography and Doppler ultrasonography. Surgeries were performed by staff plastic surgeons, who used the same techniques and instruments. Postoperative monitoring was performed using conventional clinical methods.

RESULTS: During the study period, 16 patients received a total of 19 flaps. Mean age was 41.5 years (range, 20-69 years). All were men with mean percentage of total body surface area of 11.8% (range, 1% to 45%). Mean days from burn to flap surgery was 40 days (range, 28-68 days). The most frequent defects to be covered were foot and forearm, the most used flap was the anterolateral thigh flap, and the mean surgical time was 7.36 hours (range, 4.5-10.83 h). Overall success of the flaps was 94.7%. Four patients had flap complications, with need for reoperation in 3 patients. Mean hospital stay was 53 days (range, 16-98 days).

CONCLUSIONS: The use of microsurgical flaps in patients with electrical burn is a safe option for defects in different anatomic locations, considering an adequate debridement, the use of healthy receptor vessels, a trained microsurgical team, and adequate timing.

KEY WORDS: *Burn center, Electric burns, Microsurgical free flap*

From the National Reference Center for Adult Major Burn, Hospital de Urgencia Asistencia Pública (HUAP), Santiago, Chile

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CORRESPONDING AUTHOR: Roberto Macchiavello Macho, National Reference Center for Adult Major Burn, Curico 345, PO Box 8330075, Santiago, Chile

E-mail: robertomac89@gmail.com

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INTRODUCTION

High-voltage electrical burns are characterized by extensive tissue damage in the burned patient. These injuries tend to be more common at contact points, also known as entrance and exit wounds. The extent of burn damage is related to the magnitude, frequency, and duration of the electrical current, as well as the resistance of the tissues.

In deep burns with exposure of structures such as blood vessels, bones, and nerves, adequate skin coverage can be through a locoregional, distant, or microsurgical flap. The frequent indication for reconstruction with microsurgical flaps is mainly because of a scarcity of local tissues (especially in the case of extremities), as well as destruction of the remaining local tissue options secondary to the electrical burn. The first data on free flaps in burns were published by Sharzer, Harii, and colleagues in 1975.[1] Since then, several studies have demonstrated the safety of microsurgical reconstruction in victims of electrical trauma.[2]

Here, we have shared our experiences with the use of microsurgical flaps in patients with high-voltage electrical burns seen at the Public Assistance Emergency Hospital, which works as the main reference center for patients with large burns in Chile.

MATERIALS AND METHODS

We conducted a descriptive retrospective study of patients with high-voltage electrical burns who required reconstruction with microsurgical flaps. Patients were seen at the Burns Service of the Public Assistance Emergency Hospital of Santiago, Chile, between January 2019 and December 2021. Approval of the corresponding ethics committees was obtained, and the protocols conformed to the ethical guidelines of the 1975 Helsinki Declaration. Informed consent was obtained from patients or their guardians.

Relevant data were obtained from clinical and surgical records of the patients; data included sex, age, date of burn, extent of the burn, anatomic location of the defect, type of flap, type of anastomosis, postoperative complications, surgical times, and hospital stay, among others. Patients underwent preoperative studies with computed tomography angiography and Doppler ultrasonography to identify perforators and receptor vessels. Surgeries were performed by 3 different staff plastic surgeons as the first surgeon. Procedures used 9-0 and 10-0 polypropylene sutures for arterial and venous anastomoses under a Leica M530 OHX microsurgical microscope view. Postoperative monitoring was performed using conventional clinical methods (color, temperature, perfusion time, and bleeding pattern).

RESULTS

During the study period, 16 patients received a total of 19 microsurgical flaps. The mean age was 41.5 years (range, 20-69 years). All were men with comorbidity rate of 87.5%, with the most frequent being polydrug use. Mean total body surface area was 11.8% (range, 1% to 45%) (Table 1).

Mean number of previous surgeries was 3.4 (range, 0-9), mean time from the burn to flap procedure was 40 days (range, 28-68 days), and mean number of subsequent surgeries was 0.7 (range, 0-4). The most frequent defect to be covered was the foot, followed by the forearm. The most used flap was the anterolateral thigh flap, and the mean number of perforators was 1.52 (range, 1-3), with 14 myocutaneous versus 3 septocutaneous. The most common recipient vessels were the radial and dorsalis pedis arteries, end-to-end arterial anastomosis was performed in 13 of 19 anastomoses, mean number of venous anastomoses was 1.73 (range, 1-2), and need for intraoperative anastomosis revision was 10.53% (2 cases). Six cases required complementary procedures from hand trauma and/or neurosurgery teams. The mean surgical time was 7.36 hours (range, 4.5-10.83 h), and flap dimensions varied from 11 × 5 cm (the smallest) to 12 × 28 cm (the largest) (Table 2).

The overall success rate of the flaps was 94.7% (there was 1 intraoperative loss due to irreversible acute arterial thrombosis). In addition, there were 4 patients with flap complications (Table 3). However, there were no complications in the donor areas. Of the 4 patients with

TABLE 1. Demographic Characteristic of the Study Patients

Characteristic	Result
No. of men/women	16/0
Mean age (range), years	41.5 (20-69)
Percent with comorbidities (1 or more), %	87.5%
Arterial hypertension, No. (%)	3 (18.7%)
Coronary cardiopathy, No. (%)	1 (6.25%)
Diabetes, No. (%)	1 (6.25%)
Polydrug use, No. (%)	7 (43.75%)
Associated head trauma, No. (%)	5 (31.25%)
%Total body surface area (range)	11.8 (1-45)

TABLE 2. Surgical Features of the Study Patients

Surgical Feature	Result
Mean No. of previous surgeries (range)	3.4 (0-9)
Mean No. of subsequent surgeries (range)	0.7 (0-4)
Mean time from burn to flap (range), days	40 (28-68)
Defect to be covered, No.	
Head	1
Elbow	1
Forearm	5
Hand	4
Leg	3
Foot	9
Flap type, No. (%)	
Anterolateral thigh flap	17 (89.47%)
Gracilis	1 (5.26%)
Radial	1 (5.26%)
Mean flap size area (range), cm^2	197.6 (55-336)
Mean No. of perforators (range)	1.52 (1-3)
Myocutaneous	14
Septocutaneous	3
Recipient vessels, No.	
Internal plantar	1
Dorsalis pedis	5
Radial	6
Posterior tibial	2
Anterior tibial	2
Ulnar	2
Temporal	1
Type of arterial anastomosis, No.	
End to end	13
End to side	6
Mean No. of venous anastomosis (range)	1.73 (1-2)
Mean surgical time (range), hours	7.36 (4.5-10.83)

TABLE 3. Surgical Complications

Complication	Number
Flap hematoma	1
Flap dehiscence	1
Flap infection	1
Flap arterial thrombosis	1

complications, 3 patients required a reoperation secondary to complications, with mean hospital stay of 53 days (range, 16-98 days). All patients were able to start an early compression and rehabilitation protocol, and all were discharged with adequate functional results.

Figures 1, 2, and 3 show representative cases from our series of patients.

DISCUSSION

Reconstruction after an electrical burn, especially of the distal extremities, is an extremely challenging task. There are often no good or reliable sources of local tissues, as irrigation and venous drainage areas are made up of small-diameter terminal vessels. Microsurgical flaps are used when locoregional options are not available.

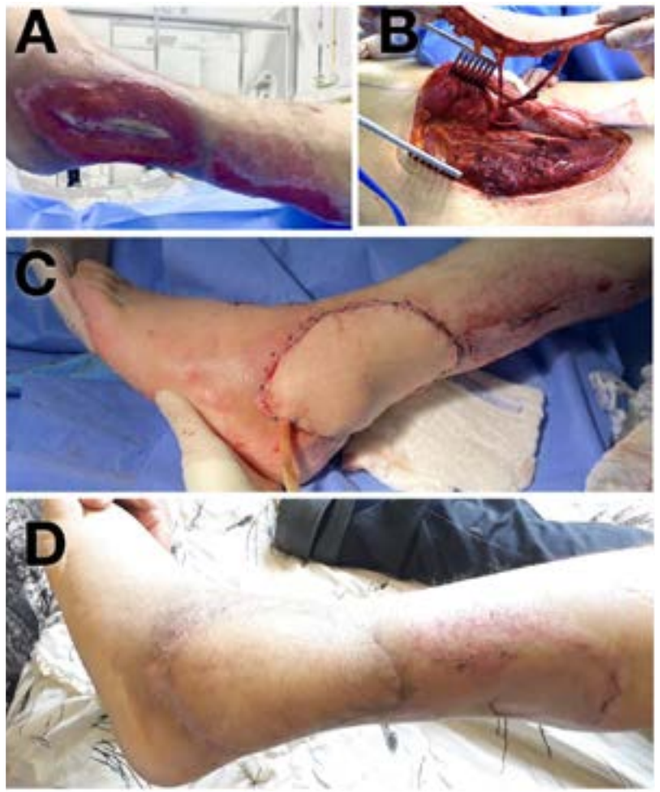
The main indications for microsurgical flaps in burned patients are (1) preservation or restoration of function, (2) coverage of exposed noble structures (vessels, nerves, bones, tendons, and joints), and (3) salvage of the limb from the imminence of amputation (mainly in electrical trauma).

To optimize results, it is essential to debride devitalized tissues (until a viable wound bed is obtained), select the appropriate recipient vessels, and have an experienced and trained microsurgical team. Sheng and colleagues stated that the most reliable indicator of vessel viability in electrical burn is intraoperative inspection under a microscope.[3]

Because of microvasculature damage caused by electrical trauma, many studies have proposed avoiding the use of early microsurgical flaps since it would cause more complications and the risk of triggering an anastomotic thrombosis.[4-6]

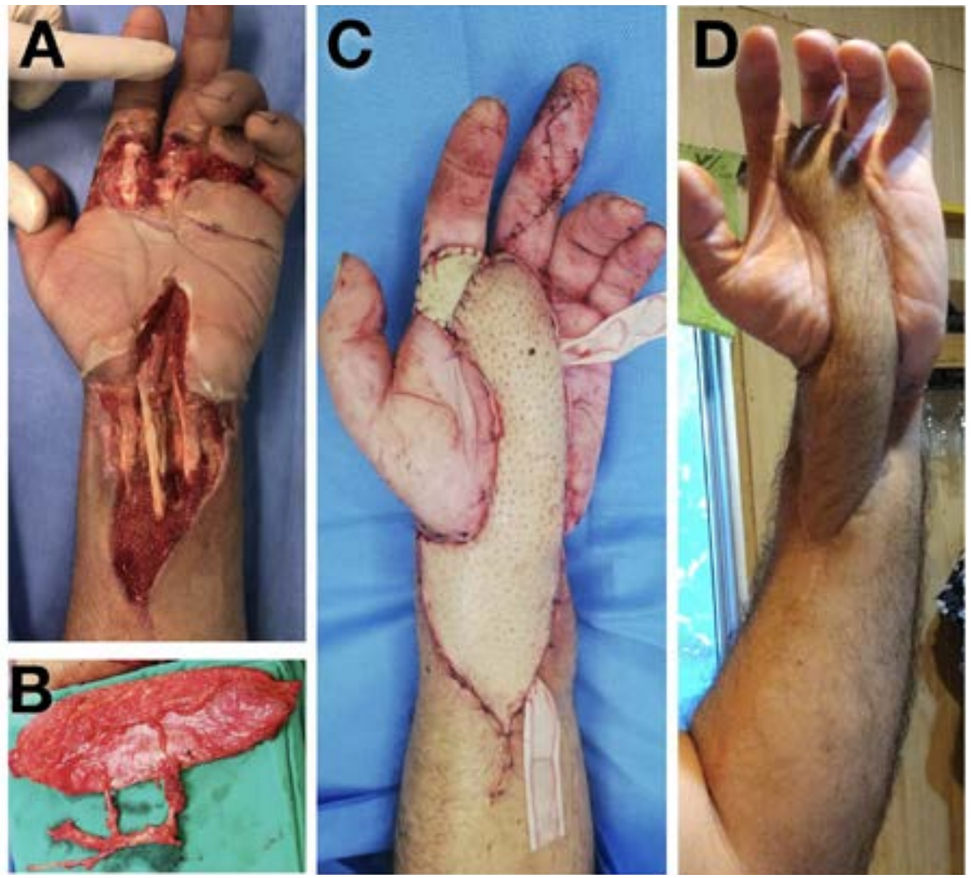
With regard to the temporality of reconstruction in patients with burns, the moment of coverage with the free flap can

FIGURE 1. Case Number 1



(A) 68-year-old male patient with a high-tension electrical burn and a distal defect of the left leg and foot exposing peroneal tendons. **(B)** Right anterolateral thigh flap with 2 perforants being retrieved and anastomosed to the dorsalis pedis artery. **(C)** Final inset of the flap, achieving an adequate coverage of the defect. **(D)** Flap at 6 months postoperative.

FIGURE 2. Case Number 2



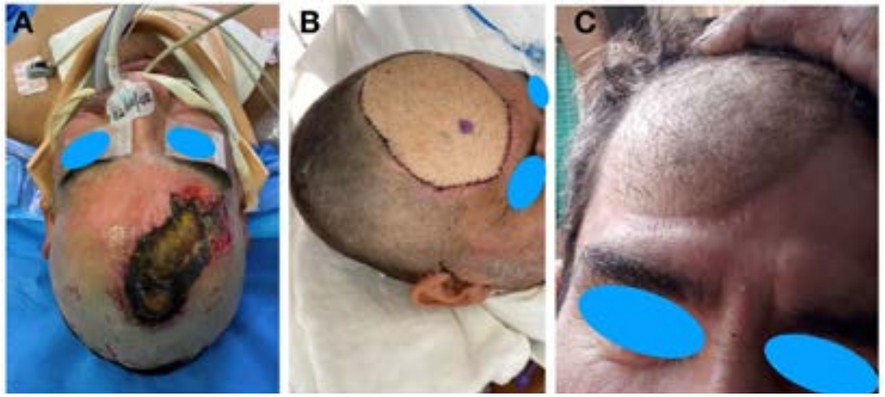
(A) 44-year-old male patient with a high-tension electrical burn with a defect in the volar aspect of the left hand (zone 2) and wrist (zone 5), with section of the median nerve and deep and superficial D3 flexor. **(B)** Anterolateral thigh flap with 2 perforants retrieved and anastomosed to the radial artery; neurorrhaphy with femoral nerve was performed to repair the median nerve. **(C)** Final inset of the flap achieving an adequate coverage of the defect. **(D)** Flap at 6 months postoperative.

be classified into 2 main groups: primary reconstruction and late or secondary reconstruction (reconstructive phase). Primary reconstruction involves 3 categories: immediate (<5 days), early (5-21 days), and intermediate (>21 days to 6 weeks). Secondary reconstruction for flaps is performed beyond 6 weeks.

The highest flap failure rate is during the early stage (after 5 days to 21 days).[7,8] This is because of the greater risk of infection, greater tendency for thrombosis, and unresolved vascular trauma. Reconstruction in this phase may be justified in situations with exposure of noble tissues in head and neck and to prevent limb amputation.

On the other hand, conducting immediate coverage procedures before the 5 days, which should have better results, is a difficult decision, since the patient may not be stable or the indication for coverage may not yet be clear. In this acute period, there are many phenomena occurring simultaneously that can have a negative impact on the results of the flap. There are large fluid movements that occur during resuscitation (which are sometimes excessive) and during initial burn eschar excision, and debridement of nonviable tissue can lead to local or systemic inflammatory reactions, including microvascular thrombosis, systemic infections such as pneumonia, acute renal failure and need

FIGURE 3. Case Number 3



(A) 42-year-old male patient with high-voltage electrical burn and forehead region defect with exposure of the calvarium. **(B)** Final inset of a left fasciocutaneous anterolateral thigh flap anastomosed to the temporal artery, achieving adequate coverage of the forehead defect. **(C)** Flap at 6 months postoperative

for dialysis, and blood loss requiring multiple transfusions, which may ultimately lead to not performing a microsurgical flap at this stage. In certain cases, early coverage may be an alternative, such as in head and neck injuries with exposure of critical structures like a nonviable external table, loss of orbit, or other full thickness defects that expose vital structures.[9]

Baumeister and colleagues described a lower complication rate after 45 days of reconstruction.[7] This delay was based on waiting for the vascular trauma to stabilize and the objectives of going beyond the mere salvage of a limb and rather ensuring the restoration of the intrinsic functions of the limb. Other groups, such as Castro and colleagues,[2] evaluated the use of microsurgical flaps in the early phase, where they conducted coverage procedures between days 21 and 27 after the burn. In their small experience of 5 patients, they described no loss of flaps, with no patients requiring revision for reanastomosis. Ozkan and colleagues[10] described 26 free flap procedures, where 15 were performed in the first 21 days postburn. Two free flaps for this early-phase reconstruction and 1 free flap for postburn contracture release were lost; all of these patients had high-voltage electric burns. In any case, it seems that as important to the timing of the reconstruction is the medical and surgical stabilization of the patient.

In our series, all flaps were performed in the intermediate phase (an average of 41 days after the burn), with a success rate of almost 95%, which is consistent with the above descriptions. For us, conducting reconstructions at the immediate or early phase is difficult because our patients tend to be referred from hospitals from other regions of the country. The initial evaluation and previous debridement surgeries have already been performed in these local hospitals before transfer to our referral center, which means also that the aggressiveness of the initial debridement is an element that we can only partially control. Our protocol is then to ensure that we have a clean receptor bed with viable tissue before indicating a microsurgical flap. Among the patients in our present series, there was a mean of 3.4 previous debridement surgeries, and no early reconstructions were conducted in the present series, with the earliest reconstruction at 28 days after the burn. We frequently use vacuum therapy for wound bed preparation, in at least one-third of the cases described here.

It is important to highlight that, at our center, we carry out multidisciplinary work with the hand trauma and neurosurgery teams for concomitant procedures at the time of microsurgical flap coverage to ensure the best functional outcome for the patient. In our series, 6 of 19 flaps underwent joint surgery with hand trauma and 1 with neurosurgery teams. The most common complementary procedures were tenolysis and tendon grafts in the hand, arthrodesis of fingers and toes, and neurorrhaphies and nerve grafts (sural nerve and femoral nerve branch) for reconstruction of the median nerve.

The only case of flap loss (from a foot defect) was due to intraoperative thrombosis of the flap perforator, generating ischemia of the flap. In this case, it was decided to remove the flap and graft the defect on the back of the foot, which was complemented in a second stage with the placement of a dermal matrix. The remaining cases had good evolutions, with an acceptable rate of complications (20%), in which 3 cases required reoperations to resolve them.

The most frequent defects to be covered in our series described here were the foot and then the forearm, which were associated with the entrance and exit wounds. For these defects, the most used flap was the fasciocutaneous anterolateral thigh flap, offering us the greatest versatility.

All of our patients were men of working age with a high prevalence of polydrug use but without a greater presence of other comorbidities, thus displaying the typical characteristics of the population with electrical burns that we treat at our public hospital. In this context, we considered these patients suitable for a prolonged intervention such as a microsurgical flap, since, in patients with multiple comorbidities, minor or serial alternative procedures should be considered.

In the literature, there are other variants in the use of free flaps in the coverage of high-voltage injuries, such as the flow-through free flaps. Hsiao and colleagues[11] suggested that, in cases of large soft tissue defects with destruction of main arteries, the objective of reconstruction is to provide tissue coverage and revascularization at the same time. As a consequence, a flow-through free flap transfer would offer the best solution for such situations; in their study, the anterolateral thigh flap had a successful limb recovery rate of 80%. Gencel and colleagues[12] used a cross flow-through flap, using the concept of a free cross flap to reduce the risk of amputation of traumatized limbs that maintain a single vessel irrigation. They used the cross-legged pedunculated latissimus dorsi muscle flow-through flap in a series of cases of electrical burns of a single recipient vessel. The pedicle was cut at about 39 days, and there was no flap loss or major amputation during follow-up, with computed tomography angiography showing vessel continuity in the recipient's vascular system.

CONCLUSIONS

In our described experience of the use of microsurgical flaps in patients with high-voltage electrical burns seen at the National Burn Reference Center, a public hospital in a developing country as Chile, microsurgical flaps provided a safe and effective option for reconstruction of defects in different anatomic locations, respecting the principles of adequate debridement, use of healthy receptor vessels, a trained microsurgical team, and a suitable timing for coverage.

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