

Original Article

McGregor inguinal flap for coverage of large soft tissue losses due to high-voltage electrical burns in the upper limb: a retrospective study

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Received February 14, 2019; Accepted June 13, 2019; Epub June 15, 2019; Published June 30, 2019

Abstract: High-voltage electrical burns are potentially devastating and they are associated with significant morbidity and mortality. Due to vascular damage and progressive tissue necrosis produced by electrical burns, there is a large controversy regarding the ideal reconstructive technique for cutaneous coverage of severe lesions in the upper limb. This study aims to analyze our experience using the McGregor inguinal flap technique, for the coverage of large soft tissue losses produced by high-voltage electric burns in the upper limb. We performed a retrospective descriptive study with patients diagnosed with high-voltage electric burns, in which the McGregor inguinal flap technique was used to cover severe lesions in the upper limb. This study was performed at the department of Reconstructive Plastic Surgery and Burns of the Specialist Hospital Eugenio Espejo, from January 2016 to December 2017. The flap technique was performed on twelve patients, out of which, nine were males with a mean age of 33 years old. Furthermore, nine out of the twelve cases occurred as a result of accidents at work. The mean time elapsed between the lifting of the flap, closure of the donor area, and fixation of the flap to the affected area was 56 minutes (44-72 minutes). In the immediate postoperative period, three patients presented signs of infection in the surgical area. No total dehiscence, total necrosis, and/or hematoma were reported in all patients. The success limb salvage rate was 100%. In our experience, the McGregor inguinal flap technique presented a favorable postoperative evolution with complete closure of the lesions and a low rate of complications. Due to the limitations of this study, more studies are needed to prospectively evaluate this flap.

Keywords: McGregor inguinal flap, high-voltage, electrical burns, upper limb, reconstructive surgical procedures, Ecuador

Introduction

Burns are an important public health issue, especially in low- and middle-income countries, which account for 95% of deaths from this cause. According to the World Health Organization (WHO), burns are among the main causes of death adjusted to disability. Furthermore, burns are the main cause of morbidity, including prolonged hospitalization, disfigurement and disability, stigmatization and social rejection [1].

Electrical burns constitute a special type of thermal injury that require a clear understanding of the physical properties of electricity, the regional and systemic physiopathology of elec-

trical lesion, the characteristics of local wounds and the wide range of complications that can occur [2]. In a study conducted by Navarrete et al., 49.5% of mortality related to burns was due to electrical injuries [3].

Extremities are the body parts most prone to this type of injury, especially the arms and hands [4]. The most common entry point for electricity is the hand [5]. The intensity of the injury is inversely proportional to the transverse surface of the tissue capable of carrying the current, consequently, the most serious injuries are seen in the wrists and ankles [4].

The intensity of the electric burn is determined by the voltage, the current (amperage), the type

of current (alternating or continuous), the path of the current flow, the duration of contact, the resistance at the point of contact, and the susceptibility of the individual [4]. High-voltage burns are characterized by exposure to an electric source greater than 1000 volts.

Historically, remote flaps were first used in cases of large losses of substance from the hand [6]. In 1972, McGregor and Jackson proposed a vascularized inguinal flap for the superficial iliac circumflex artery in the reconstruction of large cutaneous losses [7]. However, the development of new reconstruction techniques that use vascularization close to the lesion (e.g. local or free micro-surgical flaps) cease the use of remote flap techniques [8].

Vascular damage and progressive necrosis of tissues produced by electrical burns generate controversy over the ideal reconstructive technique for cutaneous coverage of severe lesions in the upper limb.

This study aims to analyze our experience using the McGregor inguinal flap, for the coverage of large soft tissue losses produced by high-voltage electric burn in the upper limb.

Methods

We performed a retrospective descriptive study with patients diagnosed with high-voltage electric burns, in which the McGregor inguinal flap technique was used to cover severe lesions in the upper limb. This study was performed at the department of Reconstructive Plastic Surgery and Burns in the Specialist Hospital Eugenio Espejo, from January 2016 to December 2017.

Inclusion criteria were patients older than 15 years, without sex restriction, with or without comorbidities, large lesions in the upper limb, defined according to the classification of Shimpel et al., as located on the forearm or hand, with three or more postoperative controls after the release of the flap (immediate postoperative period, at three and six months, up to two years) [9].

Exclusion criteria involved patients with other etiologies of burn, under 15 years old, upper limb with complete vascular damage, and patients who did not attend scheduled post-surgical controls.

Data was collected according to age, sex, work activity, wound size, number of days from the incident until the flap surgery, and the time elapsed between the lifting of the flap, closure of the donor area, and fixation of the flap.

In the three postoperative controls, dichotomous variables were evaluated: partial flap necrosis, total flap necrosis, infection of the surgical wound, presence of hematoma in the surgical site, and dehiscence of the sutures. Qualitative variables to describe closing of the donor site (total/partial/open) and final integration of the flap (total/partial/non-integrated) were also evaluated.

The variable return to work was evaluated in the time between discharge from the hospital and the control at two years.

Descriptive analysis of the data is shown as mean or median (continuous variables) or as a percentage (categorical). Data used in this study has been obtained from the hospital database (Hosvital).

Surgical procedure

The surgery started by marking the flap limits, which are typically wide. In this way, the axial pedicle allows that the length-width relationship does not have a direct influence on the survival of the flap. The marked site included the area that is irrigated by the superficial iliac circumflex artery, which directly arises from the common femoral artery. The iliac circumflex artery has an upward and outward course, parallel to the crural arch, and it travels proximal to the anterior superior iliac spine where it branches into three terminal arteries. Extreme caution had to be taken to safely dissect the flap around the area where the iliac circumflex artery becomes more superficial and pierces the aponeurosis in front of the medial edge of the sartorius muscle. It has been reported that with extreme caution, it is possible to safely dissect the flap up to 8 cm above and outside the anterior superior iliac spine without risk of necrosis [6].

The flap dissection was initially dermal from outside to inside, but if it was necessary to extend its dimension, the dissection became fasciocutaneous, including the Sartorius muscle fascia. The flap was then fixed with simple

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Table 1. Patient demographics

No.	Age/Sex	Localization	Anatomical position	Largest diameter cm	Complication
1	24/M	Right wrist	Volar	6	2 nd digit amputation
2	23/M	Left hand	First space	7	5 th digit amputation
3	31/M	Right hand	First space	6	No
4	24/M	Left wrist	Volar	6	4 th , 5 th digits amputation
5	19/M	Right wrist	Dorsal	7	No
6	39/M	Right wrist	Volar	12	No
7	37/M	Right wrist	Dorsal	10	No
8	71/M	Right wrist	Volar	9	No
9	20/M	Right wrist	Volar	11	No
10	48/F	Right wrist	Dorsal	10	No
11	47/F	Right wrist	Volar	8	No
12	16/F	Right wrist	Volar	6	No

All cases were considered third degree burns, with cutaneous, muscular, tendinous, vascular, nervous, and bone involvement. The size of the wound was evaluated by its largest diameter, with a mean size of 8.16 cm (range: 6-11 cm).

The mean number of days from the incident up to the flap surgery was 49 days (range: 14-71 days). The mean time elapsed between

points of skin to the affected area, which had to be previously sterilized. The limb had to be immobilized with adhesive bandage to avoid tension on the flap and any unintentional detachment.

The limb had to be immobilized for three weeks, during which the patient could carry out normal activities and rehabilitation. Furthermore, strict observation of the vitality of the flap and cleanliness was needed to maintain asepsis. After three weeks, the release of the flap was performed in a second surgery, after applying a simple clamping test of the pedicle to assess vascular autonomy.

Ethical considerations

The study was approved by the Deputy Directorate of Teaching and Research at the Specialist Hospital Eugenio Espejo. The databases that were obtained and analyzed for this research were previously anonymized, so there was never contact with the patients and no additional procedure was performed on any patient.

Results

Skin coverage technique using the McGregor inguinal flap was performed on twelve patients. Nine of these patients were male and three were female. The mean age was 33 years old (range: 16-71 years old). Nine out of the twelve cases occurred as a result of an accident at work (**Table 1**).

the lifting of the flap, closure of the donor area, and fixation of the flap to the affected area was 56 minutes (range: 44-72 minutes).

During the immediate postoperative period, three patients presented signs of infection in the surgical area, which were confirmed by culture results, the most commonly isolated bacteria were: *Pseudomona aeruginosa* multi-resistant in two cases, *Klebsiella Pneumoniae*-producing carbapenemase in two cases, and *Proteus mirabilis* in one case. All cases were resolved with antibiotic therapy.

Two patients who reported infections, also presented partial dehiscence that accounted for less than 15% of the open wound. Furthermore, these two patients showed signs of distal necrosis, which in one case, closed by secondary intension, and in the other case, it had to be surgically re-operated without complications during the control periods. No total dehiscence, total necrosis and/or hematoma were reported in all patients.

The wound from the donor site was totally closed. There was no difficulty in closing the donor site's wound in any control period. A total integration of the flap to its recipient bed was achieved in all twelve patients during the control period from the 6th month up to the 2nd year. The successful limb salvage rate was 100%. Three out of twelve cases presented some type of amputation in the operated limb, while five out of twelve patients suffered amputations in other extremities.

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Figure 1. 39-year-old male patient diagnosed with high-voltage electric burns on the right wrist. A. This resulted in significant loss of soft tissue, necrosis of the flexor tendons, loss of the ulnar artery, median, and ulnar nerves. B. The result after debridement, cleaning of devitalized tissue, and use of a negative pressure system. C. Tenorrhaphy with tendinous allografts for deep flexors and end-to-end anastomosis of median and ulnar nerves, requested from a tissue bank. D. Skin coverage with the McGregor inguinal flap. E. Immediate postoperative period after vascular pedicle release. F. Result after 6 months of evolution. G. Result after 12 months of evolution. H. Result after 12 months index thumb opposition.

Of the twelve patients evaluated, one patient did not return to work. Of the remaining eleven patients who returned to work, three switched employers, while eight returned to the same employer.

Representative cases of the McGregor inguinal flap technique for coverage of large soft tissue losses due to high-voltage electrical burns in the upper limb are presented in (Figures 1A-H and 2A-H).

Discussion

Twelve patients were admitted to the Unit of Reconstructive Plastic Surgery and Burns, Specialist Hospital Eugenio Espejo from January 2016 to December 2017. All patients presented serious injuries and loss of soft tissue in the upper limb as product of high-voltage electrical burns. Most patients were men and most injuries were related to work accidents. The McGregor inguinal flap technique was used as a reconstructive surgical technique. During the surgical procedure, no complications were reported. In the immediate postoperative period, most complications were infection-related complications at the surgical site, and partial dehiscence of the flap. In the postoperative evaluations at month three and six, up to year two, all cases reported complete integration of the flap.

These findings were similar to the review carried out by Shih et al., who reported that high-

voltage electrical burns are more frequent in men, 93.9% of all cases, and that 75% of all cases occurred at the workplace [10]. Arnoldo et al., in the United States, reported an incidence of 700 consecutive electric burns over a 20-year period; according to this report, electric burns also occurred more frequently in men, they were incidental and work-related [11]. The average participants' age in our study was 33 years, which was similar to other studies [5, 10, 11].

There is still no consensus on the appropriate time for cutaneous coverage of high-voltage electrical burns. Karimi et al., compared between early flap surgery (≤ 3 weeks) and late flap surgery (> 3 weeks), results demonstrated that rates of infection and amputation were lower in the early flap surgery [12]. However, in the study performed by Mene et al., results showed that all free flaps performed after a debridement session suffered tissue necrosis, and they concluded that the early fasciotomy followed by repeated debridement remains as the procedure of choice [13]. In our study, skin coverage was delayed (> 3 weeks) in 11 out of 12 patients, since multiple debridements were required to provide definitive coverage.

The McGregor inguinal flap technique avoids the use of local vascularization in cases of high-voltage electrical burns. In the study of Zhao et al., authors concluded that free anterolateral thigh flaps with a single-perforator pedicle were effective and reliable therapeutic interventions

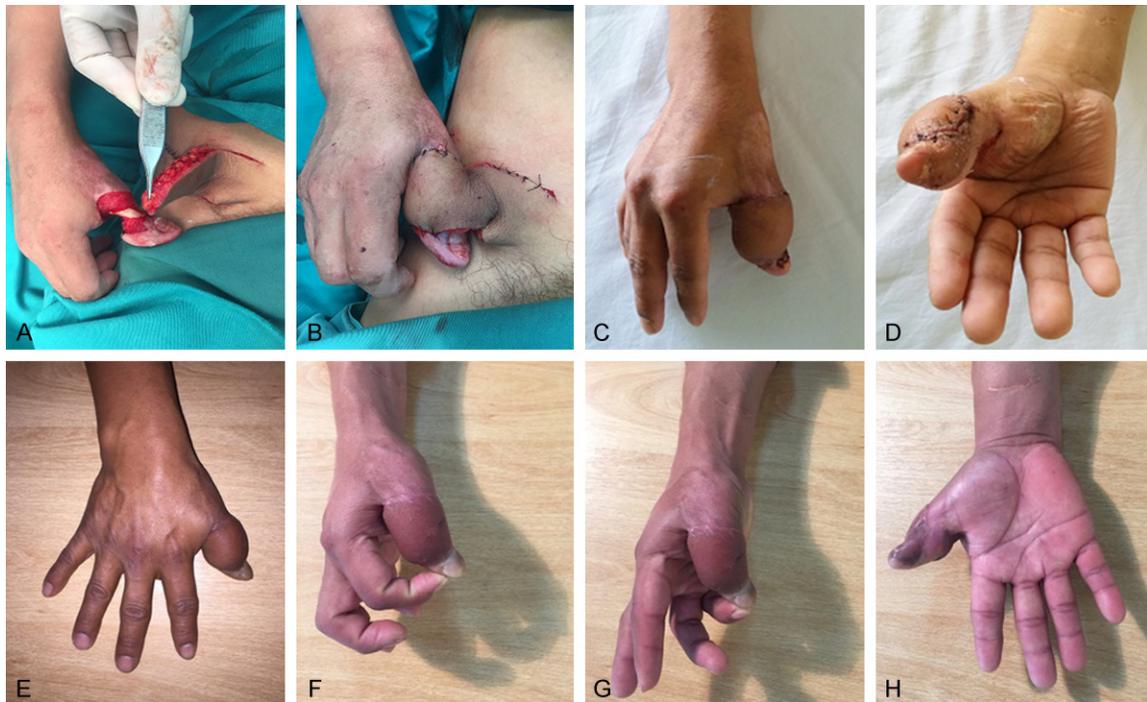


Figure 2. 31-year-old male patient diagnosed with high-voltage electric burn on the first finger of the right hand. A. Inguinal flap lift, loss of soft tissue and bone exposure, conservation of the flexor pollicis longus and thumb main artery. B. Fixation of flap over affected area. C. Immediate postoperative dorsal view. D. Immediate postoperative palmar view. E. Dorsal view results 6 months. F. Index thumb opposition. G. Thumb opposition. H. Palmar view.

for the management of severe high-voltage electrical injuries on the extremities. However, they emphasized that the use of an exhaustive microsurgical technique with a prolonged time of surgery is essential to achieve optimal results (average time of the surgical operation was 314.6 minutes). Only 7 out of 12 patients presented lesions in the upper limbs and not all donor sites could directly close, resulting in grafts of skin directly [10]. In our study, most cases of flap lifting, closure of the donor area, and fixation of the flap did not last more than one hour; the average time was 56 minutes. There was no problem in closing the donor area.

Hsiao et al., reported that flow-through antero-lateral thigh flaps provide for the simultaneously reconstruction of blood vessels and soft tissue in electrical injuries of the severely damaged upper extremities. Nevertheless, they reported that the risk of flap failure is higher than in other etiologies of burn, its success rate was only 80% [14]. In our study, the successful limb salvage rate was 100%.

Remote flap with axial pedicle and inguinal flap present great reliability in their performance.

Moreover, it is imperative to know the anatomy of the superficial iliac circumflex artery thoroughly to perform a successful flap [6, 15]. Kimata et al., followed up 74 cases in which they performed anterolateral free thigh flap; in this study, they stated that the two main disadvantages of this technique were the pedicle's anatomical variation and the surgeon's long learning curve [16].

As reported by other authors, advantages of the McGregor inguinal flap are: 1) The presence of a long pedicle that allows the coverage of large tissue losses in the hand, 2) The possibility of early mobilization, 3) Greater reliability, 4) Low difficulty in carrying out the procedure, 5) Scar concealment, 6) Primary closure of the donor site, and 7) Integration security due to an excellent vascularization, which helps to avoid possible amputations [6, 17]. Disadvantages of according to this study were: 1) Discomfort of the patient, 2) Performance of two surgical times, 3) Increase in hospital stay, and 4) Increase in the risk of infections [17].

Returning to work after suffering an electrical injury can be challenging due to the physical, cognitive, and emotional disabilities [18].

Rehabilitation services and advocacy were viewed as extremely beneficial for a successful return to work after a workplace electrical injury [19].

In Ecuador, since 1986, regulation of workers' health and safety, and the improvement of the working environment have been enforced in order to protect workers' safety and to promote their welfare. However, informal and illegal work is the main cause of these types of work accidents.

As reported in the present study, the McGregor inguinal flap technique used to cover large soft tissue losses caused by high-voltage electric burns in the upper limb is an alternative technique to avoid limb's amputation. Especially in scenarios like ours, a public hospital where there is a lack of facilities and sophisticated technology to provide quick results.

The strengths of this study included: 1) Its performance at one of the most important national referral hospitals for the management of patients with electrical burns; 2) To be the first study in the country to report the results of this technique, with a 2-years follow-up. On the other hand, limitations of our study were: 1) The lack of evaluation of important variables such as sensitivity and functionality of the hand, however, this could not be possible as this was a retrospective study; 2) A possible risk of attribution bias for extracting information from an existing database.

Conclusion

In our experience, the use of the McGregor inguinal flap technique for the coverage of lesions with large cutaneous losses in the upper limb produced by high-voltage electric burns presented a favorable postoperative evolution with complete closure of the lesions, a low complication rate, and other advantages such as hiding the scar and primary closure of the donor site. Due to the limitations of this study, more studies are needed to prospectively evaluate the McGregor inguinal flap technique, including the assessment of impairment over similar timeframes where more complete patient histories available.

Acknowledgements

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and Research at the Specialist Hospital Eugenio Espejo.

Disclosure of conflict of interest

None.

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