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Original Article

A Practical Flap Solution for Electric Burn Wounds of the Upper Limb

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Abstract

Background: High-voltage electrical burns often result in extensive soft tissue damage to the upper limb, particularly the hand and forearm. These injuries demand prompt and reliable reconstruction to restore function and minimise complications. In many centres, advanced microsurgical facilities are not readily available, making paraumbilical perforator-based flaps a practical and accessible solution for hand and forearm coverage. This study aims to assess the effectiveness of paraumbilical perforator flaps for reconstructing hand and forearm defects after electrical burns.

Methods: This prospective observational study included 48 patients with post-electric burn injuries to the hand and forearm. The study was conducted at the Sheikh Hasina National Institute of Burn and Plastic Surgery, Dhaka, and the Department of Plastic Surgery and Burn Unit, Dhaka Medical College Hospital, Dhaka, Bangladesh, between August 2017 and June 2019. All patients underwent reconstruction using paraumbilical perforator-based flaps. Data on flap design, operative technique, complications, flap survival, and clinical outcomes were collected and analyzed.

Results: The age ranged from 1-50 years. Total number of male patients was male 39 and female 9. Right hand involved in 31 cases, left hand involved in 16 cases and both hand in 1case. After excision, the wound length was ranged from 5cm to 20cm and wound width was ranged from 3cm to 8cm. The flap length was ranged from 10cm to 21cm and flap width was ranged from 4cm to 8cm. Primary closure of donor site done in all cases. All flaps survived, marginal necrosis was found in 3(6.25%) cases, all managed conservatively. Time of flap division was between 18-21days in 37(77.08%) cases and between 22-28days in 11(22.91%) cases. On assessment of the flap 45(93.75%) cases had good outcome and 3(6.25%) satisfactory.

Conclusion: The paraumbilical perforator flap is a reliable, practical option for upper limb reconstruction after electrical burns, especially in resource-limited settings.

Keywords: Paraumbilical perforator flap, electrical burn, upper limb reconstruction, hand and forearm reconstruction, soft tissue coverage.

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Introduction

Electrical injuries to the hand often result in severe damage, leading to long-term functional impairment. These injuries pose significant challenges in both immediate management and subsequent reconstructive procedures[1].

High-voltage electrical injuries, typically exceeding 1000 volts, cause extensive tissue damage primarily due to the amperage of current rather than voltage alone. The injury pathway often extends from the point of contact to a grounded exit site, with severe destruction occurring near exit points. These burns are deceptive; as superficial wounds rarely reflect the depth of underlying damage. Along the current's path, thermal injury and progressive vascular thrombosis lead to devascularization over several days, often resulting in compartment syndrome and pressure necrosis. Muscle necrosis is common near entry and exit sites and along bones, where resistance generates significant heat. Secondary complications include infection, delayed aneurysm formation, and neurological deficits linked to endothelial injury. The progressive nature of tissue loss over 4–5 days underscores the complexity of managing electrical burns[2].

High-voltage electrical burns are among the most devastating injuries to the upper limb, often resulting in deep tissue damage and exposure of vital structures. The hand and forearm are particularly vulnerable due to their functional significance and limited soft tissue coverage. While various reconstructive options exist—including local, regional, and free flaps—many are constrained by donor site limitations, technical demands, or inadequate reach. Low-voltage electrical burns to hand frequently cause localized, deep tissue damage in these regions. Reconstruction of complex soft tissue defects involving the thumb and first web space remains a significant challenge. Sometimes, first dorsal metacarpal artery flap offers a local option for addressing such defects[2].

In emergency settings, especially where microsurgical facilities are unavailable, pedicled flaps remain essential and often serve as lifeboat options for coverage of upper limb defects[3]. The abdominal flap is a versatile and simple solution for hand and forearm reconstruction[4], though its random blood supply and limited flap dimensions pose challenges[5]. Groin and superficial inferior epigastric artery (SIEA) flaps may be insufficient for large or multiple defects involving the hand and forearm[5,6].

The paraumbilical perforator (PUP) flap, based on perforators from the deep inferior epigastric artery, overcomes these limitations. It can reliably cover defects of the hand, wrist, forearm, and elbow[7], offering ease of harvest, low donor site morbidity, and dependable vascularity[5,7–11]. This study evaluates the effectiveness of the PUP flap in managing post-electric burn soft tissue defects of the upper limb and highlights its role as a practical reconstructive solution.

Materials and Methods

This prospective observational study included patients with post-electric burn injuries to the hand and forearm. The study was conducted at the Sheikh Hasina National Institute of Burn and Plastic Surgery, Dhaka, and the Department of Plastic Surgery and Burn Unit, Dhaka Medical College Hospital, Dhaka, Bangladesh, between August 2017 and June 2019. All admitted patients with soft tissue defects of the hand and forearm due to electrical burns were considered for inclusion. A total of 48 patients meeting the eligibility criteria were selected using purposive sampling. All patients underwent reconstruction using paraumbilical perforator-based flaps. Data on flap design, operative technique, complications, flap survival, and clinical outcomes were collected and analyzed.

Data Collection: After providing all the necessary information regarding the research study informed written consent for surgery as well as pre-operative & post-operative photographs were taken. Data were collected from the selected patients using a pre-designed structured questionnaire.

Data Analysis: All data had been compiled in a master table first. Standard statistical formula has been used and statistical analysis of the results has been obtained by using window-based computer software devised with Statistical Packages for Social Sciences (SPSS-22). I have taken assistance from professional experts when necessary, during study.

Surgical Anatomy of the flap: The skin island of the paraumbilical perforator (PUP) based flap is vascularized by perforators from the deep inferior epigastric artery, centered around the periumbilical region[5,12]. This “perforator plus” flap benefits from robust vascularity, with the largest perforator typically located about 2 cm from the umbilicus, coursing toward the inferior angle of the ipsilateral scapula[5,12]. These perforators form anastomoses with posterior intercostal vessels and run at a 45-degree angle to the midline[5,12]. They travel as musculocutaneous perforators through deep subcutaneous fat and then superficial to the Scarpa’s fascia before reaching the skin island[5,12].

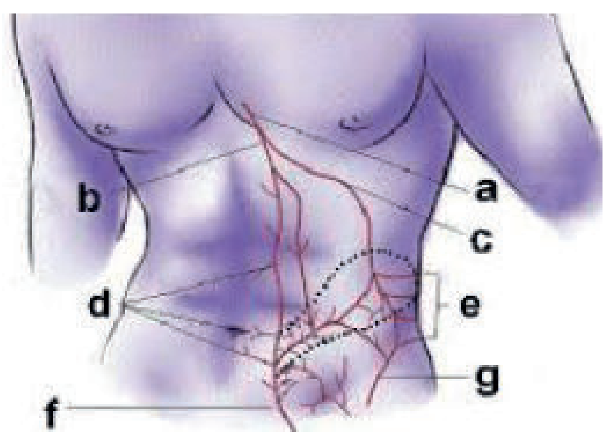

Figure 1: The design of the paraumbilical perforator based flap (a, b, c, d, e, f, and g mean the internal mammary artery, superior epigastric artery, musculophrenic artery, periumbilical perforating arteries, subcostal and lumber arteries, inferior epigastric artery, and ascending branch of deep circumflex artery, respectively)[10].

Technique for flap dissection: Under general anesthesia and tourniquet control, wound excision was performed with haemostasis ensured. The defect size was measured, and the axis of the paraumbilical perforator (PUP) flap was marked from the umbilicus to the inferior angle of the ipsilateral scapula[5,13]. Mid and posterior axillary lines were marked to define the lateral flap limit[5,13]. Perforators were identified using a handheld Doppler[13], and flap marking was done with skin pinching to assess elasticity for primary closure. The flap was elevated from lateral to medial in a relatively avascular plane, preserving key perforators[13]. Dissection was stopped upon identifying perforators or achieving adequate flap length[5]. Donor sites were closed primarily, and flap inset was done with the hand positioned to avoid pedicle kinking. Immobilization was

Figure 2 (Case no-18): Post electric burn soft tissue defect of right wrist: **A.** Before wound excision **B.** After wound excision. **C.** Flap marking. **D.** Flap elevation. **E.** Primary closure of donor site. **F.** Flap inset. **G.** 5th Postoperative day. **H.** 14th Postoperative day. **I, J.** Follow up after 3 month. **K, L.** Follow up after 6 month.

achieved using cotton rolls, bandages, and a pillow under the ipsilateral elbow. Flap division was typically performed at 3 weeks, with delays up to 4–5 weeks in select cases.

Results

This study included 48 patients with post-electric burn soft tissue defects of the hand and forearm, with ages ranging from 1 to 50 years, highlighting vulnerability across all age groups. A pronounced male predominance (39 males, 9 females) was observed, likely reflecting higher occupational exposure and risk behaviours among males. The right hand was involved in 64.59% of cases, left in 33.33%, and both hands in 2.08%. The pattern of injuries reflected diverse anatomical involvement across the hand and forearm (Table I). Wound dimensions ranged from 5–20 cm in length and 3–8 cm in width and the flap dimensions ranged from 10–21 cm in length and 4–8 cm in width (Table II). Primary closure was achieved for all donor sites (Table III). Donor site morbidity was negligible, with only three young patients developing hypertrophic scars, treated conservatively. Overall flap survival was 100%. Complete survival was achieved in 93.75% of cases, while marginal necrosis was noted in 6.25% and treated conservatively (Table III). Flap division occurred between 18–21 days in 77.08% and 22–28 days in 22.91% of cases (Table III). Overall, 93.75% of patients had good outcomes and 6.25% had satisfactory results (Table III).

Table I : *Location of Defects (n = 48)*

Location of Defects	Frequency	Percentage
Hand	3	6.25%
Wrist	6	12.50%
Wrist (Bilateral)	1	2.08%
Hand and Wrist	3	6.25%
Wrist and Forearm	31	64.59%
Hand, Wrist and Forearm	3	6.25%
Forearm and Cubital fossa	1	2.08%

Table II : Size of Defect After Wound Excision and Size of Flap (n = 48)

Parameter	Measurement	Minimum (cm)	Maximum (cm)
Defect Size	Length	5	20
	Width	3	8
Flap Size	Length	10	21
	Width	4	8

Table III : *Summary of Donor Site Closure, Flap Survival, Division Time and Outcome (n = 48)*

Parameter	Category	Frequency	Percentage
Donor Site Closure	Primary closure	48	100%
Flap Survival	Complete flap survival	45	93.75%
	Marginal necrosis	3	6.25%
Time of Flap Division	18–21 days	37	77.08%
	22–28 days	11	22.91%
Outcome of the Flap	Good	45	93.75%
	Satisfactory	3	6.25%

Discussion

Electrical burns to the upper limb typically cause extensive, full-thickness tissue destruction that extends beyond the skin into muscles, tendons, nerves, and vessels, often leaving these vital structures exposed and severely compromising limb function. The hand and forearm are particularly vulnerable due to their functional significance and limited soft tissue coverage. While various reconstructive options exist—including local, regional, and free flaps—many are constrained by donor site limitations, technical demands, or inadequate reach. The paraumbilical perforator (PUP) based flap has emerged as a reliable and versatile option for reconstructing complex upper limb defects, particularly following electrical burns. Its consistent vascularity, ease of harvest, and ability to reach the hand and forearm without the need for microsurgical techniques make it especially valuable in resource-limited settings.

Compared to free flaps, the PUP flap significantly reduces operative time and eliminates the requirement for specialized microsurgical expertise. Additionally, the minimal donor site morbidity and favorable aesthetic outcomes further support its role as a workhorse flap in burn reconstruction.

Several studies have explored the etiology of soft tissue defects in the hand and forearm. A 2016 study reported vehicular accidents as the most common cause (46.7%), followed by electrical burns (26.7%), machinery injuries (13.3%), and post-surgical causes (13.3%)[5]. Similarly, a 2017 study found electrical injuries in 28.6% of cases, with crush and avulsion injuries each accounting for 21.4%, and severe and hot crush burns each at 14.3%[10]. Another study in 2009 observed electrical burns in 30.1% of cases, second only to vehicular accidents (33.7%) and followed closely by machine injuries (28.9%)[11]. These findings underscore the significant role of electrical burns in upper limb trauma.

In our study, electrical burn injuries predominantly affected the right hand in 64.59% of cases, the left hand in 33.33%, and both hands in 2.0%. All patients were right-hand dominant. The wrist and forearm were the most common defect sites (64.59%). The PUP flap was harvested from the right side in 64.59% of cases, the left in 33.33%, and bilaterally in 2.0%. This bilateral harvesting capability offers a distinct advantage over traditional flaps. A 2007 study also demonstrated the successful use of bilateral PUP flaps to cover defects in both hands[6].

Post-excisional wound dimensions ranged from 5–20 cm in length and 3–8 cm in width. Correspondingly, flap dimensions ranged from 10–21 cm in length and 4–8 cm in width. A 2017 study reported flap lengths of 16–20 cm and widths of 6–8 cm[10], while a 2015 study found lengths of 28–30 cm and widths of 6–8 cm, maintaining a 3:1 length-to-width ratio[13]. Similarly, a 2010 study reported average flap dimensions of 28 cm by 8 cm, also with a 3:1 ratio[14]. These findings confirm the feasibility of harvesting large flaps with favorable proportions.

In this study, all 48 donor sites were closed primarily. This is consistent with findings from a 2009 study where all donor sites were closed primarily[11]. In contrast, a 2016 study reported primary closure in 86.7% of cases, with 13.3% requiring split-thickness skin grafts[5]. A 2007 study noted that 28.6% of donor sites required grafting[6], while a 2005 study reported primary closure in 90.9% of cases[8]. The ability to achieve primary closure in most cases highlights the low donor site morbidity associated with the PUP flap, offering a clear advantage over traditional abdominal flaps.

All flaps in our study survived, with marginal necrosis observed in 3 cases (6.25%), which were managed conservatively. In comparison, a 2016 study reported partial flap loss in 6.7% and wound infection in 26.7% of cases [5], while the 2017 study documented marginal necrosis in 21.4% of cases[10]. Similarly, the 2009 study involving 83 patients noted partial flap loss in 2.4%, marginal necrosis in 6.02%, complete flap detachment in 2 cases, partial detachment in 7 cases, and recipient site infection in 13.25%[11]. These findings indicate that the PUP flap demonstrates a favourable complication profile relative to previously reported techniques.

Flap division in our study was performed between 18–21 days in 77.08% of cases and between 22–28 days in 22.91%. This aligns with other studies: flap division was done between 16–21 days in 2017[10], at three weeks in 2015[13], between 18–21 days in 2007[6], and between 13–20 days in 2005[8]. Typically, pedicle division is performed around three weeks postoperatively, though extended timing may be necessary in cases of large flaps, infection, or delayed healing due to comorbidities.

On assessment of the flap 93.75% cases had good outcome and 6.25% satisfactory. In our anatomical assessment, the large perforators were located within 2–5 cm of the umbilicus. This is consistent with a 2002 study that identified the largest perforator approximately 2 cm from the umbilicus 15.

Overall, the paraumbilical perforator-based flap demonstrates excellent reliability, versatility, and safety, making it a practical and effective solution for managing complex upper limb defects following electrical burns, particularly in settings with limited resources.

This study is limited by a small sample size, inclusion of only two centers, and absence of a control group, which restricts generalizability and comparative analysis. Functional outcomes and long-term follow-up were not assessed. Future research should involve larger, multicenter randomized trials with control groups, comprehensive functional assessments, and extended follow-up to establish long-term efficacy and guide clinical practice.

Conclusion

The paraumbilical perforator (PUP) flap is a reliable, versatile, and practical option for reconstructing post-electric burn soft tissue defects of the upper limb. Its consistent vascularity, ease of harvest, low donor site morbidity, and ability to reach the hand and forearm without microsurgical techniques make it especially valuable in resource-limited settings. This flap offers a dependable solution for complex upper limb reconstruction, reinforcing its role as a workhorse in burn injury management.

Patient Consent

Written and informed consent was obtained from patient.

Conflict of Interest

None declared.

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