EARLY AND LATE TERM MICROSURGICAL FREE FLAP RECONSTRUCTION AND RISKS IN HIGH VOLTAGE ELECTRICAL INJURY

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ABSTRACT

The aim of the study is to discuss and compare the early and late micro vascular flap reconstruction's outcomes, importance, risks, advantages and disadvantages with review of our 13 high voltage electrical burn injury cases. Medical records have been reviewed for electrical burns in last three years. 13 cases fitting the criterion were included into the study. Four of them have been hospitalized for late complication such as severe contracture; nine of them have been hospitalized for acute treatment. Five patients had latissimus dorsi muscle flap, three patients had parascapular flap, two patients had latissimus dorsi and scapula osteomusculocutaneous flap, two patients had rectus abdominis musculocutaneous flap, and one patient had parascapular and scapular flap. Early reconstruction applied group showed a significant difference regarding to flap failure rates. Electrical injuries are more complex than regular burn injuries related with heat, and the reconstruction of these cases also should be special. One of the most important factor for free flap viability in electrical injury cases is surgery timing. All of the complications were seen in the patients who had surgery at 12th and 19th days after the electrical injury. No complication has seen in the group of patients who had surgery on late term period. However microsurgical reconstruction should be considered to cover exposed bony tissues on the extremities in the short term period in order to prevent possible limb shortening procedures.

***Key words**: Free Flap Reconstruction, High Voltage, Electrical Injury.*

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Introduction

Electrical injuries consist of 3-4% of patients admitted to the burn unites and the extremities are affected in more than 70 % of the cases[(1)]. Generally current entry point is located on the upper extremity and exit point is located on the lower extremity. Tissue damage decreases from distal to proximal. The damage developing after the electrical injury has two underlying causes: 1) electrical currency change cell membranes directly, and cause cell injury and death; 2) damage produced by heat during the electrical flow. Cases with electrical burn may also have accompanying injury from height fall.

Reconstruction of the soft tissue defects should follow the rule of simple options comes first[(2)]. For example skin grafting should be chosen first in order to do simplest surgical procedure if it possible. However if there is a defect with open bony or vascular structure and no local flap options, reconstruction with free flaps would be the one and only option for those patients[(3-5)]. According to the Ohm rule (Current = voltage / resistance), current increase in the tissues have less resistance such as vascular structures in case of electrical burn injury[(6)]. Therefore the damage would be in the possible recipient vessels for free flaps in case of micro vascular reconstruction candidates. This makes reconstruction of electrical injury cases with tissue

defect require free flap quite challenging if there is an accompanying vascular injury.

We reviewed electrical burn injury cases which required primary (in early and immediate time period) and secondary micro vascular free flap reconstruction in last three years' patient records regarding to the flap failure rate in this study, and discussed the risks and advantages.

Patients and method

Charts were reviewed for past three years to reveal patients had burn injury and subsequent reconstruction of soft tissue with free flap in short term or long term period (early and immediate reconstruction in primary period, and secondary period). Patients had high voltage electrical injury and got free flap reconstruction in the first six month period are included to the study, and patients had skin grafting, local flap reconstruction are excluded from the study. Patients are classified regarding to their reconstruction period of time. The choice of reconstruction and complications were recorded. Statistical analyses were performed with PASW version 18 (SPSS). Fisher's exact test was used for the analyses regarding to existence of flap failure complications. $P<0.05$ accepted as significant.

Results

Total 13 patients were fitted with the inclusion criterions. Mean age of the patients were 28.4(13-59). All of the patients were male, and none of had accompanying systemic disease. Two patients were reconstructed in early (5 - 21 days) and seven patients were treated in intermediate period (21 days - 6 weeks) in primary reconstruction cases (Total 9 patients). Four patients were reconstructed with secondary reconstruction (Table 1, Fig 1).

	Primary reconstruction		Secondary reconstruction
	Early	Immediate	
Number of case	2	7	4
Number of flap failure	2	0	0

Table 1: Distrubition of the cases.
Distribution of the cases and flap failure in different groups were summarized in the table.

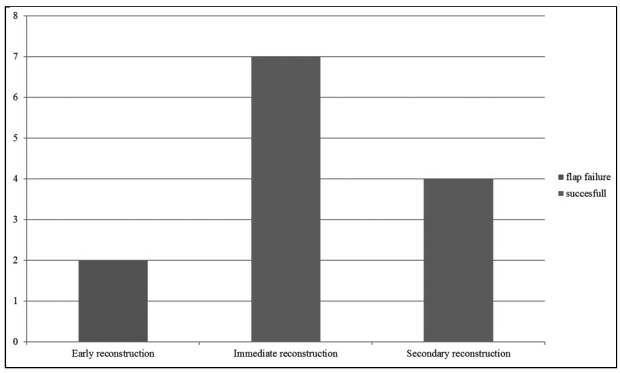

Figure 1: Survival of the free flaps were summarized in the graphic.

All of the patients had a soft tissue defect which have exposed bone, tendon and vascular structures after debridement of necrotic or scar tissues. So free flap options were mandatory in all patients. Flap opsitons used in the reconstruction of the soft tissue defects were summarized in the Figure 2.

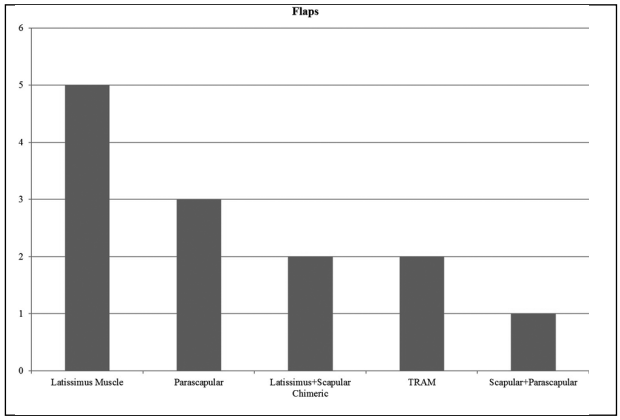

Figure 2: Free flap choices were summarized in the graphic.

One patient had latissimus dorsi muscle - scapular osseofasciocutaneous chimeric flap reconstruction in early reconstruction period group. Another patient had reconstruction with parascapular flap in early period. There were three latissimus dorsi muscle (Fig 3), one latissimus dorsi muscle – scapula osseofasciocutaneous chimeric (Fig 4), one combined scapular-parascapular fasciocutaneous flap and two parascapular fasciocutaneous (Fig 5) flap reconstructions in intermediate reconstruction period group. Lastly, there were two transvers rectus abdominis musculocutaneous (Fig 6) and two latissimus dorsi musculocutaneous (Fig 7) flap reconstructions in secondary reconstruction period group. Two of two cases had early reconstruction had flap failure complication on the other hand none of the other cases had flap failure in other groups (Figure 1).

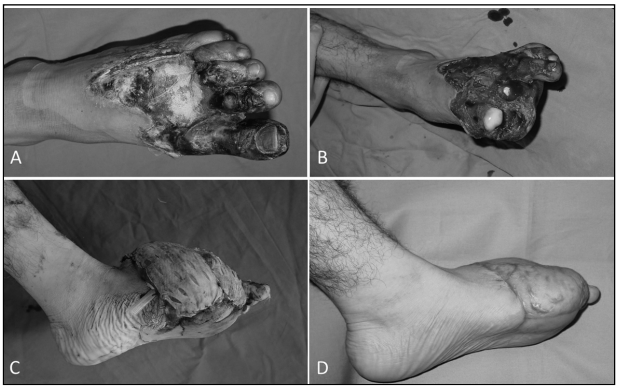

Figure 3: 28 years old male patient had an high voltage electrical injury. He had full thickness skin, subcutaneous tissue, tendon and bone necrosis on the left foot dorsum and great and second toes, and demarcation become prominent on three weeks of the burn injury (A). After an aggressive debridement of the devitalized tissues (B), free latissimus dorsi muscle flap reconstruction with split thickness skin graft was applied to cover exposed bones (C). Four week after the surgery the wound was healed without any complication (D).

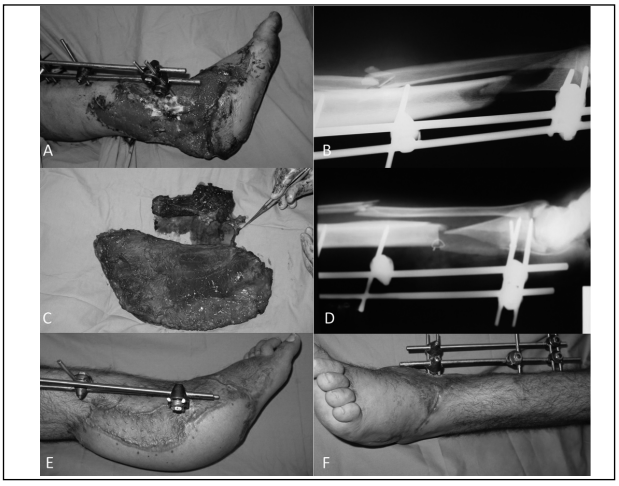

Figure 4: 25 years old male patient had electrical injury on his left foot, and he had accompanying distal tibial and fibular fractures due to falling from high. He had full thickness tissue and exposed tendons and bone on the fracture site after debridement of devitalized tissues (A). There was a bone defect on the distal tibial fracture site (B). Scapular bone with latissimus dorsi musculocutaneous combined (chimeric) flap were elevated on the subscapular pedicles (C). Scapular bone was fixed with wires to the tibial bones and compression was achieved with the external fixator (D). After four week from the surgery, acceptable wound healing was achieved (E,F).

Comparison of early and immediate reconstruction groups' flap failure rates revealed significant difference regarding to the Fisher's Exact test (p=0.03) (Table 2). Comparison of primary reconstruction and secondary reconstruction groups revealed no significant difference (p=1.0) (Table 3).

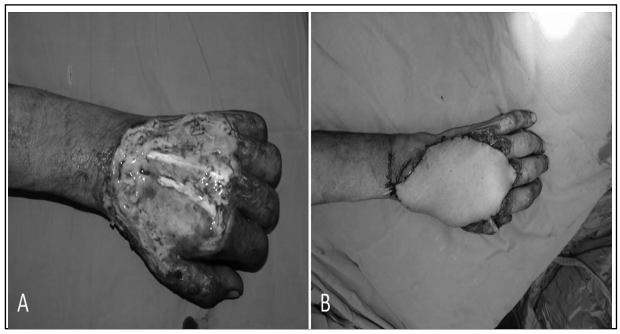

Figure 5: 32 years old male patient had a full thickness tissue lost after debridement of the nectotic tissues on three weeks of the injury with exposed extensor indisus and communis tendons (A). A free scapular flap was applied for reconstruction of the defect (B).

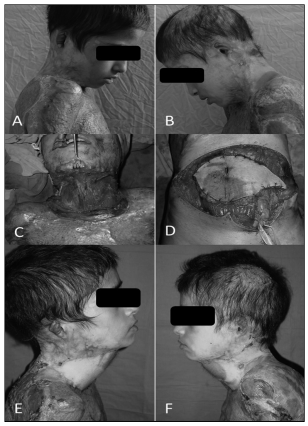

Figure 6: A nine years old boy had a high voltage electrical injury two months ago, and he had initial treatment in another center. He presented with severe neck contracture and skin defects on his back (A, B). He had a wide defect with exposed vessels after releasing the contracture on the neck (C). A transversus rectus abdominis musculocutaneous flap was raised (D). After three weeks from the surgery, he had adequate extension on his neck (E,F).

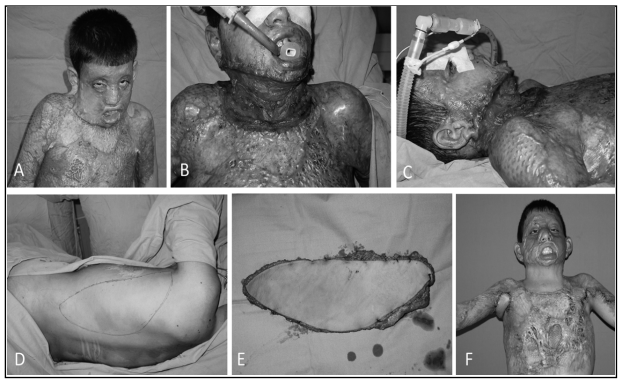

Figure 7: An eleven years old boy had a high voltage electrical injury six month before presented to our clinic with severe neck contracture (A). He had a defect with exposed vessels after the releasing of the contracture (B, C). A latissimus dorsi musculocutaneous free flap was elevated on the toracodorsal pedicle (D, E). Successful neck extension was achieved after one month of the surgery (F).

	Early reconstruction	Immediate reconstruction	Total
Successful	0	7	7
Failure	2	0	2
Total	2	7	9

Table 2: The contingency table for early and immediate reconstruction.
There were a significant relation between early and immediate reconstruction regarding to flap failure (p=0.03).

	Early reconstruction	Immediate reconstruction	Total
Successful	7	4	11
Failure	2	0	12
Total	9	4	13

Table 3: The contingency table for primary and secondary reconstruction.
There was no significant relation between primary and secondary reconstruction regarding to flap failure rate. Fisher's exact test' two-tailed P value equals 1.0 for the contingency table.

Discussion

Reconstruction of electrical burns is classified as primary and secondary reconstruction (Table 4)[7]. Primary reconstruction is divided into three groups as immediate, early and intermediate reconstruction groups regarding to the day reconstruction performed. Results with a short group of electrical burn injuries were presented and complications were compared regarding to reconstruction period of time. Small sample size is the main limitation of the study.

1- Primary reconstruction	a. İmmediate	< 5 days
	b. Early	5 - 21 days
	c. İntermediate	21 days - 6 weeks
2- Secondary reconstruction		>6 weeks

Table 4: Classification of the timing of the reconstruction.
Classification of the reconstruction of the electrical burn injury regarding to timing of the surgery was summarized in the table.

We believe the most important factor for free flap viability in electrical burn injury is the timing of the reconstruction. However it is controversial and there is no data in the literature specifically focusing the timing of the surgery and its effect on the free flap failure for high voltage electrical injuries[8-11]. Shen et all showed no significant relationship between flap failure and timing of the surgery in their series with 54 patients (17% flap failure) consist of mix cases of burn, electrical burn and trauma[5]. Sauerbier et al also concluded that although primary reconstruction with free flaps have slightly higher complication rates in their mix burn and high power electrical burn injury series, it is worthwhile to do complex microsurgical procedures in order to salvage extremities[7]. On the contrary we showed significant difference in our small series but still further studies needed with homogenous patient groups of electrical burn injury and free flap reconstruction due to limitation of very small sample size. Similarly Hold et al are also advocated to not use flap in the period between the 6th and the 21st day but their presented a mix burn patients, and included both free and local flap reconstruction in their series[10]. Handschin et al recommended to be cautious for first 4 weeks of the trauma and advocated that this four week period is likely has a progressive intima lesion, and potentially hazardous for free flap survival[9]. The flap failures in our cases are similarly occurred in the first three weeks.

Lorenzi, Abramson and Baumeister's studies showed free flap application and success rate in burn cases but they didn't give any information of the effect of timing on the success rate[12, 13, 3]. Lorenzi's study have only secondary cases and other authors have mix patient groups with electrical and heat burns. We had the result of both early and late reconstruction of electrical burn injuries and it is clear that further studies needed for definitive conclusion for the effect of the timing on the flap failure for electrical burn injuries.

Baumeister at al showed a relationship between flap failure rate and timing of the procedure[13]. They showed less complication in secondary reconstruction cases. Similarly we had successful results in four cases presented with severe contracture as secondary cases and we had complication on the cases operated on 12th and 19th days of electrical burn injury. However the difference between primary cases' complication rate and secondary cases' complication rates were not significant in our series due to small sample size.

Saint-Cyr and Daigle showed overall flap survival rate was 80% in 15 free flap cases for reconstruction of defects due to high voltage electrical injury[14]. They also compared free flap reconstruction with conventional treatment and find free flap

reconstruction option significantly better regarding to the number of surgeries, time required to achieve wound closure, and length of hospitalization. We had survival rate of 69% in our 13 free flap cases.

Severe contractures developed after a high voltage electrical injury is a common problem and may require free flap reconstruction if there is an exposed vascular structure after releasing the contracture. Various types of free flaps have been used for cervical contracture which developed after healing an electrical injury[15]. We had four cases need a free flap in secondary time period after releasing a contracture developed after a high voltage electrical injury, and all of them healed without any complication.

German et al were presented their 36 cases of chimeric (combined) free flap series from subscapular system[16]. They demonstrated 97% success rate and three of the cases they present were electrical burn injury defects. Electrical burn injuries may have a falling down trauma, complex defect and may require more complex reconstruction. Chimeric flaps' versatility makes it a great option for those cases. We had two cases which we used chimeric free flap from the subscapular system for the reconstruction of electrical burn injury (Fig 4). Both cases have accompanying trauma due to falling down.

Microvascular flap transplantation had a great risk in early period of electrical burn injury. However, it is very important to plan a reconstruction with free flaps as early as possible in case of exposed bone on the upper extremity related to an electrical burn injury. Early reconstruction in the extremity with a case with exposed bone, tendon and vascular structure may often salvage the injured extremity[17, 7].

Meticulous wound debridement around the possible free flap recipient vessels is another crucial issue when considering the reconstruction of the electrical burn injury defect. Since the necrotic tissue may not be superficial or may not has constant depth as heat burn injury may has, a careful debridement of the irregular three dimensional necrotic areas around the vascular structure is mandatory to ensure performing anastomosis well away from the zone of trauma[18]. However, Koul et al concluded that there is no reason to believe that free flaps may success differently in trauma and electrical burn cases[18]. We believe free flaps fate may not be same in case of electrical burn injury since electrical burn injury may evoke damage far away from the initial necrotic area. So we should be do more careful and aggressive debridement when planning a reconstruction in those cases to have the microsurgical choices safely.

Herter et al suggested that radical debridement and primary free flap coverage within 24 hour in complex upper extremity traumatic injury cases should be regarded as the golden rule[19]. Even though it has been named and classified as a burn, electrical burn injuries are more complex injuries than pure burn injuries which related only a thermal injury on the skin and subsequent possible systemic response. Electrical burn injuries have additional typical deep tissue burns which may un-proportionally extensive to the area of the damaged tissue on the skin and treatment may become challenging[20]. Due to electrical currency tend to follow vascular structures in the body during the initial injury, future candidate vessels for microvascular anastomosis with free flap pedicle may possibly injured with the heat produced with electrical currency. The injury in the pedicle either may from the effect of the direct high voltage on the cell membranes or the heat injury to the endothelial and media layer of the donor artery and veins. These injuries may result with occlusions, arteritis, aneurisms, thrombosis and segmental narrowing in the major vessels of the extremity. So that it is expected to have unsuccessful result with microvascular reconstruction options than local flap or secondary late solutions. We had two cases with a tissue defect due to electrical burn injury had primary reconstruction in early period with free flap and failed on the other hand, seven patient had primary reconstruction in intermediate period with free flap had no complication. However free flap transfer is still crucial option especially distal tissue defect with exposed bone and vascular structures in order to prevent infection, further necrosis and shortening of the extremity.

Conclusion

Free flap reconstruction is still the workhorse for the defect of high voltage electrical burn injuries in order to achieve early debridement of necrotic tissues, and closure of exposed bone, tendon and neurovascular structures. Primary reconstruction, especially early primary reconstruction had high risk of free flap failure. It is advisable to be cautious when doing free flap reconstruction for a defect for high power electrical burn injuries on early period of time. Further studies with larg-

er samples are needed for definitive conclusion regarding to risks of reconstruction time for high power electrical injuries regarding to free flap failure.

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