TURKISH JOURNAL OF PLASTIC SURGERY
www.turkjplastsurg.org

Original Article / Özgün Araştırma

DOI: 10.5152/TurkJPlastSurg.2017.2141

Management of High-Voltage Burns of the Hand and Wrist with Negative Pressure Dressing

Yüksek Voltaj El ve Bilek Yanıklarının Negatif Basınçlı Pansuman ile Yönetimi

Nazım Gümüş

Department of Plastic, Reconstructive and Aesthetic Surgery, Mersin University School of Medicine, Mersin, Turkey

Abstract

Objective: Negative pressure dressing stimulates wound healing by promoting cellular proliferation and regeneration. It also removes interstitial edema and increases local blood flow, resulting in rapid growth of the granulation tissue. We used the dressing method in deep hand and wrist burns caused by high-voltage electrical current, which leads to progressive tissue necrosis, elevated compartment pressure, and deep tissue edema, to reveal if subatmospheric pressure could limit the zone of injury or ongoing tissue necrosis after electrical burn.

Material and Methods: Six hands of five patients, who came in contact with high-voltage electrical wire carrying more than 1000 volts, are presented in this study. Hands and wrists were seriously injured and contracted. After the initial treatment involving fluid resuscitation, fasciotomy, carpal tunnel release, and debridement, a negative pressure dressing was applied to the wounds of hand, wrist, and forearm with 125 mm Hg continuous pressure, and maintained for 20 days.

Results: When negative pressure dressing was stopped on the 20th day, significant granulation tissue developed over the hand and forearm wounds. However, wrist wounds needed more debridement and repeated dressings because of the presence of necrosis. Edema of the hands subsided significantly during the use of negative pressure dressing. Time to closure for hand and forearm wounds decreased considerably. Moreover, in one wrist, spontaneous closure was achieved at about one month. All hands except one treated with negative pressure dressing could be saved from amputation; however, significant tissue loss developed, needing complex reconstruction procedures. One hand was amputated because of the permanent loss of blood perfusion.

Conclusion: The management of high-voltage burns of hand and wrist with subatmospheric pressure appears to be capable of reducing hand edema and accelerating closure of the wounds. It seems that negative pressure has an important effect on reducing the severity of the electrical damage to the extremity, leaving more tissue in the limb possibly by protecting the tissue from necrosis, which can help considerably in salvaging the hand.

Keywords: Hand, salvage, high-voltage, negative pressure, dressing

Öz

Amaç: Negatif basınçlı pansuman, yara iyileşmesini hücresel çoğalma ve yenilenmeyi artırarak uyarır. Ayrıca doku arasındaki ödemi azaltır ve bölgesel kan akımını artırır, bu da granülasyon dokusunun hızlı gelişimi ile sonuçlanır. Biz, bu pansumanı ilerleyici doku nekrozu, yükselmiş kompartman basıncı ve derin doku ödemine yol açan yüksek voltaj elektrik akımına bağlı derin el ve bilek yanığında subatmosferik basıncın hasar sınırını veya ilerleyici nekrozu sınırlayıp sınırlamadığını açıklamak için kullandık.

Gereç ve Yöntemler: Bu çalışmada, 1000 volttan fazla akım taşıyan yüksek voltaj teli ile temas eden beş hastanın altı eli sunulmaktadır. Eller ve bilekler ciddi olarak hasarlanmış ve büzüşmüştü. Sıvı yerine koyma, fasiyotomi, karpal tünel gevşetmesi ve debridmandan oluşan başlangıç tedavisinin ardından, 20 gün süre ile el ve önkol yaralarına 125 mmHg sürekli negatif basınçlı pansuman uygulandı.

Bulgular: Yirminci günde negatif basınçlı pansuman sonlandırıldığında, el ve önkolda belirgin granülasyon dokusu gelişti. Ancak bilek yaraları nekroz varlığı nedeniyle tekrarlayıcı pansuman ve daha fazla debridmana ihtiyaç gösterdi. Pansumanın kullanımı süresince ellerin ödemi belirgin olarak yatıştı. El ve önkol yaralarında kapanma zamanı ciddi olarak azaldı. Hattâ, yaklaşık birinci ayda bir bilekte kendiliğinden kapanma sağlandı. Biri hariç negatif pansuman ile tedavi edilen tüm eller ampütasyondan kurtarıldı, fakat kompleks rekonstrüksiyon işlemleri gerektiren ciddi doku kayıpları gelişti. Bir el kalıcı kan akımı kaybı nedeniyle ampüte edildi.

Sonuç: El ve bileğin yüksek voltaj yanıklarının negatif basınç ile takibi, el ödemini azaltma ve yara kapanmasını hızlandırma kapasitesine sahip görünmektedir. Negatif basınç, ekstremitede, muhtemelen elin kurtarılmasında ciddi şekilde yardımcı olabilecek, dokuları nekrozdan koruyarak, ekstremitede daha fazla doku bırakarak, elektrik hasarının şiddetini azaltmada önemli bir etkiye sahip görünmektedir.

Anahtar Sözcükler: El, kurtarma, yüksek voltaj, negatif basınç, pansuman

Cite this article as: *Gümüş N. Management of High-Voltage Burns of the Hand and Wrist with Negative Pressure Dressing. Turk J Plast Surg 2017; 25(4): 188-95.*

Correspondence Author / Sorumlu Yazar: Nazım Gümüş **E-posta / E-mail: gumus1970@hotmail.com**

Received / Geliş Tarihi: 26.09.2017
Accepted / Kabul Tarihi: 03.10.2017

INTRODUCTION

To date, many advances have been introduced in burn management, particularly in early resuscitation, respiratory care, treatment of inhalation injury, control of infection, modulation of hypermetabolic response, and nutritional support. Additionally, recent developments in wound care have had significant effect on patient survival, morbidity, hospital stay, and comfort, offering some important solutions in the management of burn wound, which is extremely challenging and is in need of placing a mechanical and biological barrier between the internal media and environment. Unlike dressings for scald, flush- and flame-burn injuries, soft-tissue coverage after high-voltage injury would provide sufficient protection for the local tissue reserves of the limb. After a high-voltage injury of the upper limbs, in most of the cases, there is a strong need for fasciotomy, carpal tunnel release, and early debridement of full-thickness burns; and wounds quite larger than the initial burn are created as a result of these surgical interventions, exposing healthy muscles, tendons, vascular and neural structures and burned tissues to infections and various environmental damages. The ideal dressing material for these limbs would protect all healthy tissues and structures from infection and mechanical trauma, provide a moist environment for the wound, ensure bacterial clearance, remove excess fluids, and help to reduce limb edema. It may also increase local blood perfusion and development of granulation tissue. Moreover, it may stimulate eschar separation and autolysis of necrosis. In view of these features, negative pressure dressing seems to be the most effective dressing in the present dressing modalities despite some drawbacks, such as the possibility of vascular injury over the major arteries and veins, and development of burn wound sepsis in case of infection and necrosis.[1-3]

Negative pressure dressing stimulates wound healing by removal of interstitial edema and increases in local blood flow, thereby forming the granulation tissue rapidly. With the mechanical tension, it promotes cellular proliferation and regeneration. Apart from the effect on growing the granulation tissue, it ensures better graft take and decreases bacterial levels in tissues. Therefore, it has widely been used for the treatment of pressure sores; stasis ulcers; chronic wounds, such as diabetic foot ulcers, post-traumatic, and postoperative wounds; infected wounds, such as necrotizing fasciitis or sternal wounds; soft-tissue injuries; injuries with bone exposure; and open abdominal wounds.[1] Also, it has been utilized successfully in the management of burn injuries, such as partial-thickness burns, deep dermal burns, extensive full-thickness burns, and burns with exposed bones.[2-9]

In this study, vacuum-assisted dressing was used in the soft-tissue coverage of hand and wrist burns caused by contacting high-voltage electrical current, which can lead to progressive tissue necrosis, elevated compartment pressure, and deep tissue edema; the experience is presented in detail.

MATERIAL AND METHODS

This study included six upper extremities of five patients who had come in contact with high-voltage electrical wire carrying more than 1000 volts. After written informed consent was obtained from the five patients who participated in this study as a study group, research was conducted according to the principles of the World Medical Association Declaration of Helsinki "Ethical Principles for Medical Research Involving Human Subjects." Patients had seriously injured their hands and wrists, resulting in contracted upper limbs, which involved deep tissue necrosis and elevated compartment pressure as a result of deep muscle edema. This study was designed to observe the effects of low pressure environment on the progression and healing of deep hand and wrist burns caused by high-voltage electrical contact. All of the patients who had experienced a severe work-related electrical injury, were male and their mean age was 27.8±8.6 years (range, 19-41 years), and average total body surface area (TBSA) burn was 16.4±8.9% (range, 11-32%).

After administration of fluid resuscitation and analgesics on the scene by paramedics, patients were referred to our emergency clinic. Initially, the treatment consisted of fluid resuscitation and replacement of colloid to maintain vital signs in nearly normal limits with adequate urinary output, and surgical decision for decompression was subsequently provided in all five patients because of clinical presentation of compartment syndromes, such as tense and swollen compartments, paresthesia, and passive stretch pain. Fasciotomy of the extremities and a carpal tunnel release were immediately performed on patients. Early debridement was also performed if tissue injury was significant and a full-thickness eschar was present. Following meticulous hemostasis, a vacuum-assisted dressing (Wound VAC; Kinetic Concepts International, San Antonio, Texas, USA) was applied to the wounds, and negative pressure was set to 125 mm Hg continuously (Figure 1). Wounds under vacuum-assisted dressing were followed carefully with daily examination for any signs of infection or other local complications. When necessary, extensive surgical debridement was performed again, while dressing was changed at three-day intervals. Negative pressure dressing was maintained for 20 days and then extremities were dressed with daily conventional dressing using silver sulphadiazine cream. In the following days, besides medical treatment, serial debridements were also performed for removing both superficial and deep necrosis of the extremities until granulation tissue became significantly apparent. When granulation tissue was sufficient for the closure of the wounds, they were covered with either a skin graft or flap. Wound healing and clinical course of the extremities were noted in each patient; all findings are detailed in Table 1. To provide a comparative group nearly similar to the study group, six upper extremities of five high-voltage burn patients who were previously treated using conventional dressing, were retrospectively analyzed (historic control). These patients had undergone the same surgical and medical procedures as the study group. In the historic control group, however, dressings were performed with only conventional approaches.

Statistical Analysis

All findings were compared statistically between the study and historic control groups. The number of the patients, their ages,

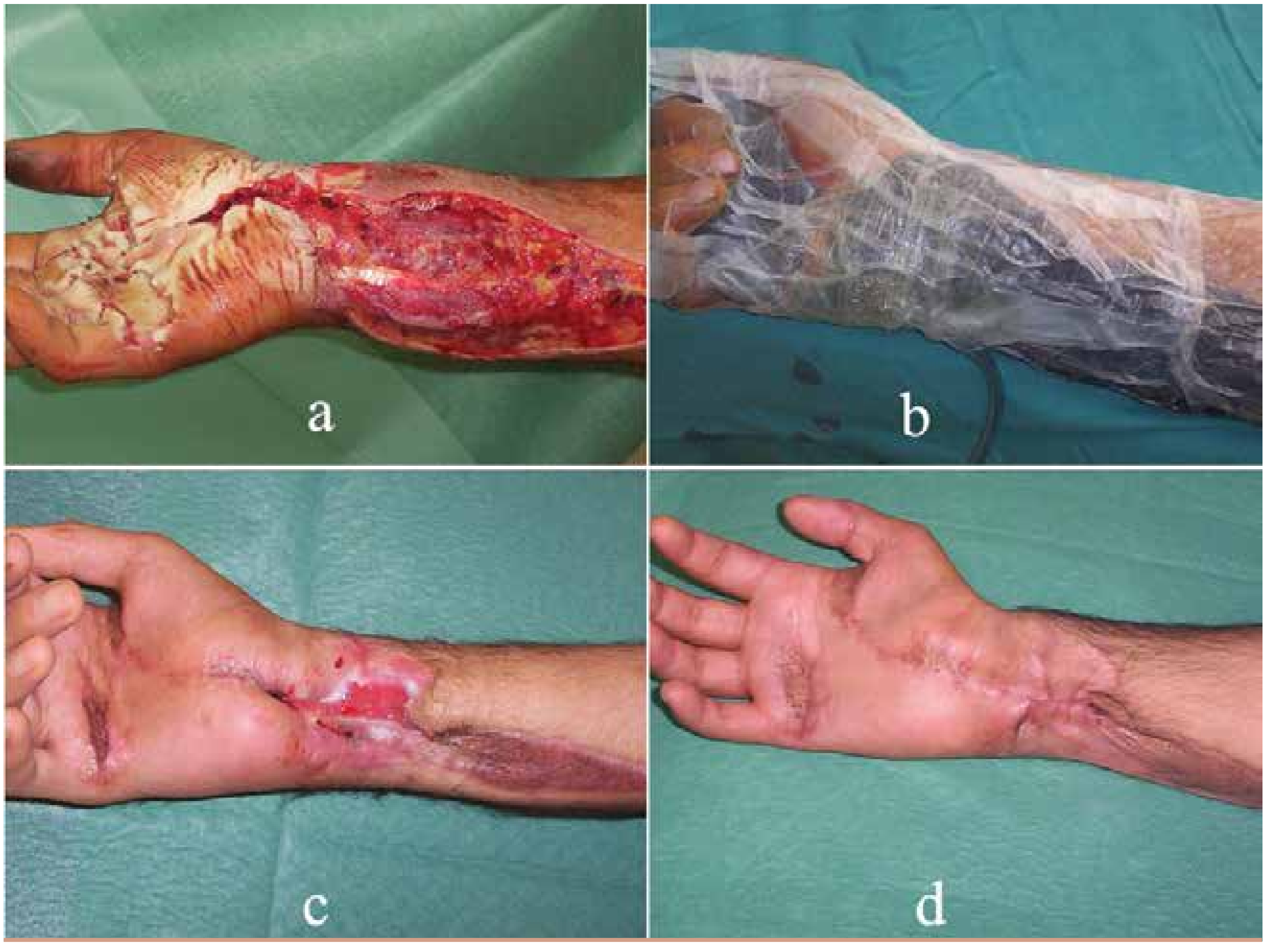

Figure 1. a-d. Patient one (a) Appearance of the right hand, wrist, and forearm on the fifth day after the burn injury. The contracted upper limb was released with early fasciotomy and carpal tunnel decompression. (b) Vacuum-assisted dressing was applied to the wounds. (c) Wrist wound two months after the injury. (d) View of hand and wrist 13 months after the injury

Table I. Detailed information on patients and surgical procedures

Patient	Sex	Age (year)	TBSA%	Number of surgeries	Type of surgical procedures	Time to closure (days)	Follow-up time (months)
1	M	26	11	7	Fasciotomy, debridement, skin grafting	50	13
2	M	31	12	2	Fasciotomy, debridement	30	12
3**	M	41	32	8	Fasciotomy, debridement, skin grafting, groin flap	51	14
3***	M	41	32	3	Fasciotomy, debridement, hand amputation	15*	-
4	M	19	11	3	Fasciotomy, debridement, skin grafting	18	12
5	M	22	16	6	Fasciotomy, debridement, skin grafting, groin flap	55	17
Mean		27.8±8.6	16.4±8.9	4.8±2.7		40.8±16.0	13.6±2.0

TBSA: total body surface area
*: Time to hand amputation. **: Information for the right hand, ***: Information for the left hand

percentage of TBSAs, number of surgical procedures, follow-up time, and time to closure were compared statistically between the study and historic control groups. For statistical analyses, the Statistical Package for the Social Sciences 14.0 (IBM Corp.; Armonk, NY, USA) was used. Mann-Whitney U test was used for statistical comparisons, and data were reported as mean±standard deviation (SD; Table 2). In the statistical analysis, a p value of <0.05 was regarded statistically significant.

RESULTS

The treatment protocols described above were used for the management of burns (Figure 1-6). By the time negative pressure dressing was stopped on the twentieth day, significant granulation tissue had developed over the hand and forearm wounds, appearing suitable for a definitive closure; hence, these wounds were covered completely by using a thin-thick-

Table II. Detailed information about the historical control

Patient	Sex	Age (year)	TBSA%	Number of surgeries	Type of surgical procedures	Time to closure (days)	Follow-up time (months)
1	M	23	9	10	Fasciotomy, debridement, skin grafting, groin flap	78	12
2	M	36	19	4	Fasciotomy, debridement, skin grafting	44	14
3	M	31	20	3	Fasciotomy, debridement	39	10
4	M	19	14	9	Fasciotomy, debridement, skin grafting, groin flap	68	15
5**	M	29	24	11	Fasciotomy, debridement, skin grafting, groin flap	77	17
5***	M	29	24	4	Fasciotomy, debridement, hand amputation	19*	-
Mean		27.6±6.6	17.2±5.8	6.8±3.5		61.2±18.4	13.6±2.7

TBSA: total body surface area
*: Time to hand amputation. **: Information for the right hand, ***: Information for the left hand.

Figure 2. a-d. Patient 2. (a) The hand damaged severely by high-voltage electrical burn. (b) View immediately after fasciotomy and carpal tunnel release. (c) On the day when negative pressure dressing was removed. (d) Nine months later

ness mesh skin graft. However, wrist wounds needed further debridement and repeated dressings because of the presence of necrosis (Figures 1, 3, and 6). By this time, the wrist wounds of one patient showed initiation of spontaneous epithelialization at the wound margins, and a few days later the wound closed spontaneously (Figure 2). The other four wrists had more extensive and deep burns, including severe necrosis of muscles, tendons, nerves, and soft tissues. Of these four, two required flaps to cover exposed bones, tendons, and wrist joints. In addition to skin grafting, a large groin flap was used for the closure of these wrists (Figures 3 and 6). In the other two wrists, definitive closure was achieved using only skin grafting (Figure 1). In the fifth extremity, by the tenth day after the injury, deep necrosis had developed with the permanent loss of blood perfusion, which made amputation inevitable. The left hand was amputated five days later (Figure 4).

Figure 3. a-d. Patient 3. (a) Hand and wrist burn on admission. (b) On the fifth day after the injury. (c) Coverage of wounds with negative pressure dressing. (d) View of hand 15 months later

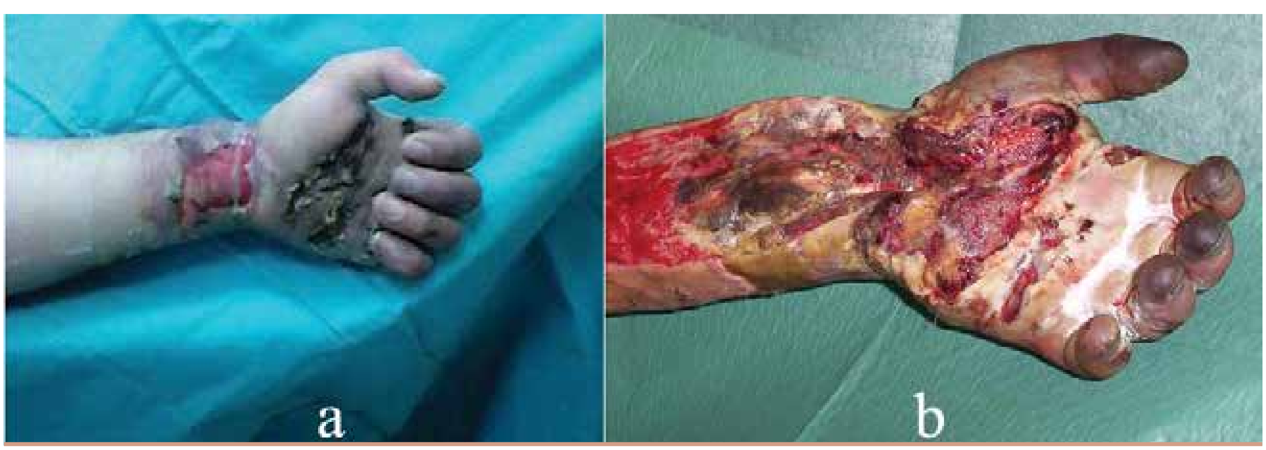

Figure 4. a,b. Left hand of patient 3. (a) Severe electrical burns of hand and wrist. (b) On the tenth day after injury, appearance of the left upper limb with significant deep necrosis of the extremity due to the permanent loss of blood perfusion that made amputation inevitable

Edema of the hands subsided significantly with the use of negative pressure dressing. Clinically, time to closure for hand and forearm wounds decreased considerably. Moreover, in one wrist spontaneous closure was achieved at about one month. Patients were followed from 12 to 17 months with an average of 13.6±2.0 months. After the follow-up of 12 months, hand functions were analyzed, and in two hands, nearly complete sensory loss and limitation in range of motion in all fingers with interosseous muscle atrophy were observed. There were also minimal extension and

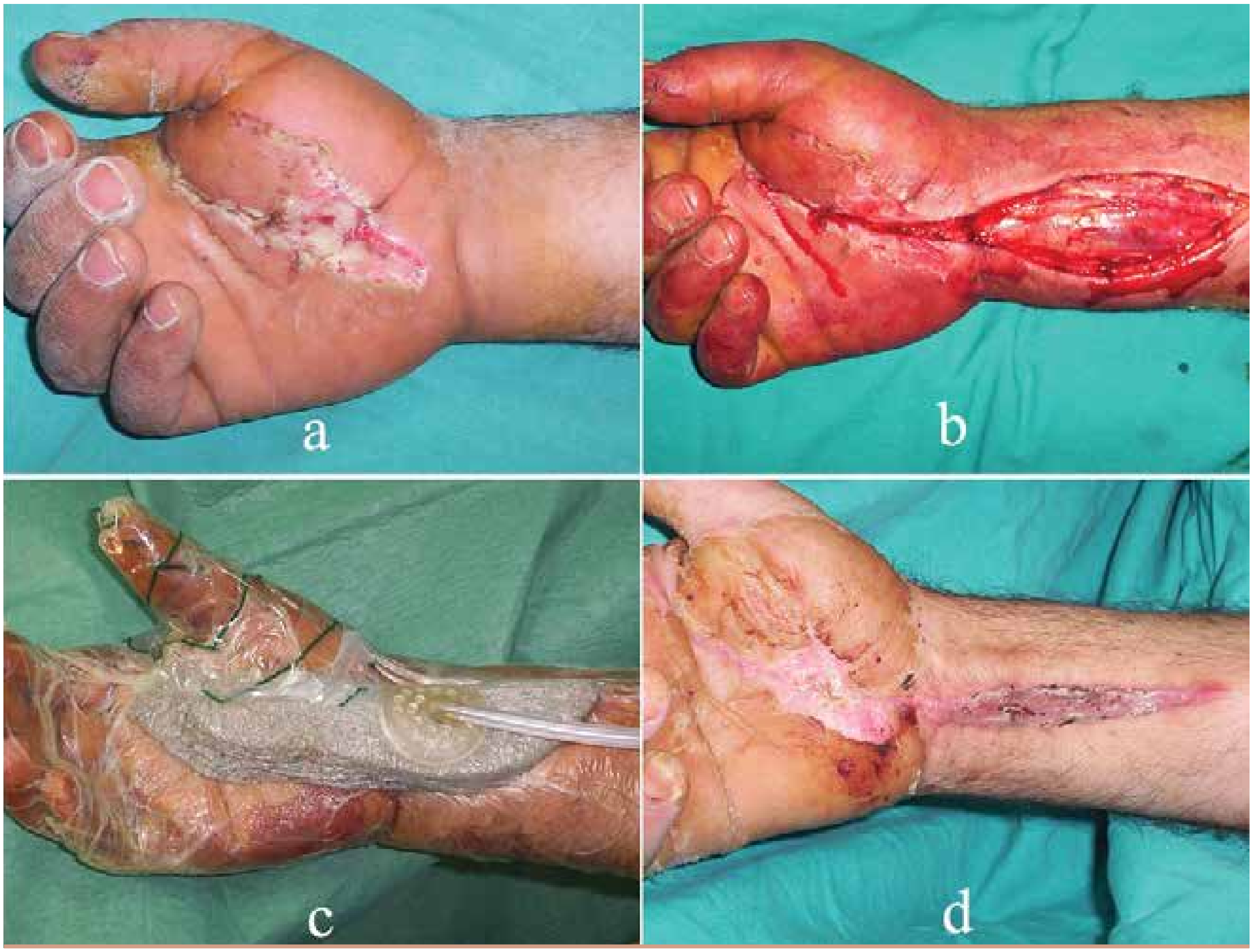

Figure 5. a-d. Patient 4. (a) Hand burn injury caused by high-voltage electrical current. (b) View immediately after fasciotomy and carpal tunnel release. (c) Negative pressure dressing application. (d) Two months later

flexion in the fingers and these two hands were not functional enough to perform daily activities or resume work. In the third hand, sensory deficit and complete loss of finger movements was seen, and stability of the wrist joint could be provided with a hand splint. In the other two hands, total recovery of hand functions occurred without any functional impairment or permanent sensorial deficit, except for temporary numbness of a hand for two months. The number of patients, their ages, percentage of TBSAs, number of surgical procedures, follow-up time, and time to closure were compared statistically between the study and historic control groups, and no differences were found between the two groups. However, a significant difference was observed in the mean time to closure between the groups. While mean time to closure was 61.2±18.4 days in the historic control group, it was 40.8±16.02 days in the study group, with a considerably shorter duration of treatment. Also, the time to closure ranged from 18 to 55 days in the study group, whereas this ranged from 39 to 78 days in the historic control group. During the application of vacuum-assisted dressing, a leak that appeared in the system of one patient was successfully sealed; and in skin maceration that occurred thrice on the hands, dressing application was discontinued for three days to allow for recovery.

DISCUSSION

Vacuum-assisted closure of wound is known as a method of increasing the rate of wound healing by secondary intention, and facilitating granulation tissue growth on the wound bed to allow for successful closure with either a skin graft or flap. It has been suggested that it removes edema and excess interstitial fluid from the region of the wound, leading to an increased localized blood flow, angiogenesis, and tissue growth.[1,2,4]

Negative pressure dressing has been used successfully in the treatment of burn wounds, such as partial-thickness burns, deep dermal burns, extensive full-thickness burns, and burns with exposed bones.[2-13] Some experience with high-voltage burns has also been reported in literature. Molnar JA et al.[4] presented the case of a 26-year-old male who suffered a flash burn to his right upper extremity and face from the heat of a high-voltage electrical arc. Vacuum-assisted dressing was applied directly to the deep partial-thickness burn at approximately 6 hours after injury and maintained at a continuous negative pressure of 125 mm Hg over 40 hours. The wound epithelialized completely within 10 days. The authors clearly demonstrated the beneficial effect of the dressing on the

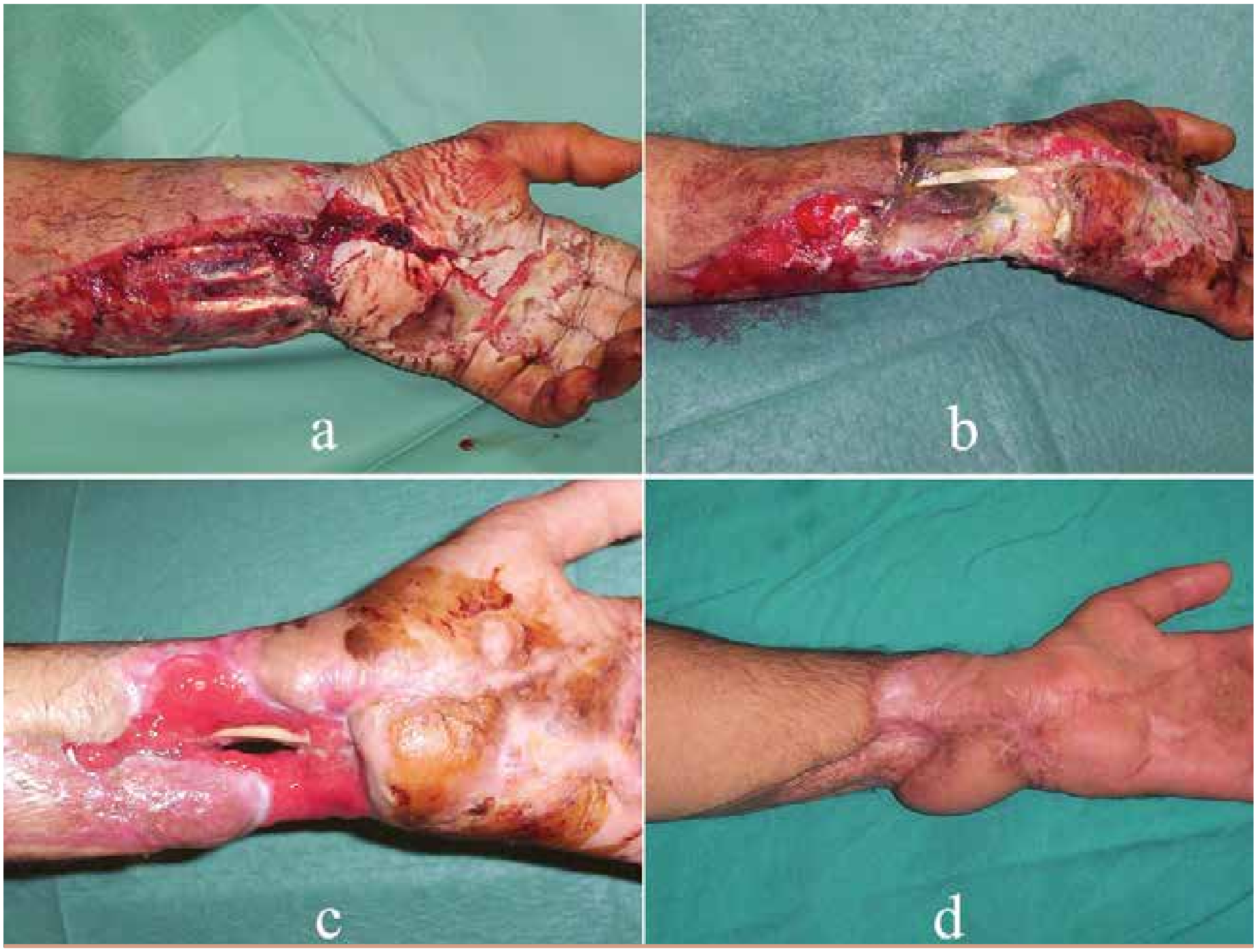

Figure 6. a-d. Patient 5. (a) View of hand, wrist, and forearm on the fifth day after fasciotomy and carpal tunnel decompression. (b) Ten days after using vacuum-assisted dressing, hand edema subsided significantly and palmar wounds were grafted with mesh skin. Forearm wound was also ready for skin grafting; however, wrist had a more extensive and deeper wound with severe necrosis of muscles, tendons, nerves, and soft tissues. (c) The appearance of the wrist and hand 40 days after the injury. (d) View of the hand 17 months later. The wrist wound was covered using a groin flap

treatment of partial-thickness thermal burn with only 40 hours of dressing application.[4]

Apart from scald and flame burns, high-voltage electrical burns are severely devastating injuries, which result in damage not only to the skin, but also to other tissues such as muscles, nerves, tendons, and bones. Electrical burns can occur in several forms, including injuries from the electrical current itself, flash burns, flame burns, and contact burns. Of these, the most devastating injury appears in high-voltage electrical current. Park C et al.[2] reported their experience with subatmospheric pressure treatment in acute electrical injury. Severe electrical injuries, 11 high-voltage electrical wire contacts, and one contact with 440 mV of home circuit breaker, were treated with early operative management including amputation, debridement, and release of compartments. Subatmospheric pressure was applied to the wounds postoperatively. In the conclusion, it was emphasized that patients with severe electrical injuries may be safely and successfully managed with subatmospheric pressure dressing. However, detailed information about patients, used techniques, results and severity of the extremity damage was not found.

Management of high-voltage burns in the extremities is often different from other burns, such as scald burns, flame burns and chemical injuries, because of the nature of the damage, which is deep, extensive, and particularly progressive. Ongoing tissue necrosis and severity of the initial tissue damage usually determine the fate of the hand in the treatment. This study aimed to reveal if subatmospheric pressure could limit the zone of injury or ongoing tissue necrosis after a severe electrical injury; however, this study includes a small number of cases without randomization and thus cannot provide definitive information about the efficacy of subatmospheric pressure treatment in electrical injury of limb. Nevertheless, this attempt has revealed encouraging results. In fact, a randomized and controlled research on this issue is extremely difficult due to the variability of injuries, asymmetrical damage, and limited number of cases. In the presented cases, the extremities were treated using negative pressure dressing with serial debridements, and apart from skin maceration, no severe complications occurred. Amputation could be avoided in all but one hand; however, significant tissue loss developed and required complex reconstruction procedures. In the hands, not only did the edema subside earlier, but also the wounds closed rapidly, suggesting that negative pressure dressing had a beneficial effect on electrical burns of the hand. It seems that this dressing modality protects the tissues in this area from desiccation and preserves the forearm tendons. It may have an added benefit of increasing blood flow to damaged tissue. In an experimental study, Morykwas et al.[10] used subatmospheric pressure for the coverage of a rabbit wound caused by prolonged crush/ischemia injury, and serum samples were subsequently analyzed for myoglobin content. Serum myoglobin levels demonstrated progressive increase with time in nontreated animals and were significantly elevated when compared with subatmospheric pressure-treated animals. In conclusion, it was emphasized that the application of subatmospheric pressure to an affected body part was associated with lower serum myoglobin levels. In view of these findings, it may be considered that in the presence of muscle injury, subatmospheric pressure can reduce muscle death and rhabdomyolysis, leading to the preservation of muscle tissue. Similarly, in the electrical burns of limbs, it may have a beneficial effect on avoiding hand amputation by reducing the muscle death and rhabdomyolysis.

In patients being treated with the dressing in proximity to forearm vessels, direct application of the foam to the radial and ulnar arteries can lead to disruption of the vascular wall due to the negative pressure; thus, major arteries and veins must be protected from the system to avoid severe bleeding.[10-13]

Statistically, to perform a prospective controlled study seemed difficult given the lower number of the cases; therefore, comparison was planned with a historic group of burn patients treated with conventional dressing. The historic group consisted of similar number of patients with comparable ages, percentage of TBSAs, and follow-up times to the study group; therefore, no statistical differences were observed between the groups ($p>0.05$). Although in the study group, mean time to closure (40.8±16.0 days) and number of surgical procedures (4.8±2.7) were considerably lower than those in the historic group (61.2±18.4 and 6.8±3.5, respectively), no statistical differences were found between the groups. This result might be due to the small number of patients; however, statistical analyses revealed the reduced mean time to closure and less number of surgical procedures, resulting in shorter treatment times and hospital stays.

CONCLUSION

The management of high-voltage hand and wrist burns using subatmospheric pressure appears to be capable of reducing hand edema and accelerating wound closure. Early coverage of hand and wrist wounds decreases the risk of desiccation and infection of tissues. Negative pressure appears to have an important effect on reducing the severity of the electrical damage to the extremity, leaving more tissue in the limb possibly due to the protection of tissues from necrosis, which can help considerably in salvaging the hand. Further studies enrolling a larger number of patients with nearly symmetric damage to their extremities will clarify the true effect of subatmospheric pressure on the electrical injury of the limb.

Ethics Committee Approval: Authors declared that the research was conducted according to the principles of the World Medical Association Declaration of Helsinki "Ethical Principles for Medical Research Involving Human Subjects" (amended in October 2013).

Informed Consent: Written informed consent was obtained from patients who participated in this study.

Peer-review: Externally peer-reviewed.

Conflict of Interest: No conflicts of interest were declared by the author.

Financial Disclosure: The author declared that this study has received no financial support.

Etik Komite Onayı: Yazar bu çalışmanın, Dünya Tıp Birliği'nin "İnsan Öznesi İçeren Tıbbi Çalışmalarda Etik Prensipler" Helsinki Deklarasyonu'na uygun olarak yapıldığını beyan etmiştir.

Hasta Onamı: Yazılı hasta onamı bu çalışmaya katılan hastalardan alınmıştır.

Hakem Değerlendirmesi: Dış bağımsız.

Çıkar Çatışması: Yazar çıkar çatışması bildirmemiştir.

Finansal Destek: Yazar bu çalışma için finansal destek almadıklarını beyan etmiştir.

REFERENCES

1. Argenta LC, Morykwas MJ, Marks MW, DeFranzo AJ, Molnar JA, David LR. vacuum-assisted closure: state of clinic art. Plast Reconstr Surg 2006; 117(7 Suppl): 127S- 142S. [CrossRef]
2. Park C, Molnar JA, DeFranzo AJ. Use of subatmospheric pressure in the management of electrical injuries. Burns 2007; 33(1): 34-S35. [CrossRef]
3. Kamolz LP, Andel H, Haslik W, Winter W, Meissl G, Frey M. Use of subatmospheric pressure therapy to prevent burn wound progression in human: first experiences. Burns 2004; 30(3): 253-8. [CrossRef]
4. Molnar JA, Simpson JL, Voignier DM, Morykwas MJ, Argenta LC. Management of an acute thermal injury with subatmospheric pressure. J Burns Wounds. 2005; 24; 4: e5.
5. Wasiak J, Cleland H. Topical negative pressure for partial thickness burns. Cochrane Database Syst Rev 2007; 18(3): CD006215. [CrossRef]
6. Nugent N, Lannon D, O'Donnell M. Vacuum-assisted closure - a management option for the burns patient with exposed bone. Burns 2005; 31(3): 390-3. [CrossRef]
7. Schintler M, Marschitz I, Trop M. The use of topical negative pressure in a paediatric patient with extensive burns. Burns 2005; 31(8): 1050-3. [CrossRef]
8. Adamkova M, Tymonova J, Zamecnikova I, Kadlcik M, Klosova H. First experience with the use of vacuum assisted closure in the treatment of skin defects at the burn center. Acta Chir Plast 2005; 47(1): 24-7.
9. Terrazas SG. Adjuvant dressing for negative pressure wound therapy in burns. Ostomy Wound Manage 2006; 52(1): 16-8.
10. Morykwas MJ, Howell H, Bleyer AJ, Molnar JA, Argenta LC. The effect of externally applied subatmospheric pressure on serum myoglobin levels after a prolonged crush/ischemia injury. J Trauma 2002; 53(3): 537-40. [CrossRef]
11. Taylor CJ, Chester DL, Jeffery SL. Functional splinting of upper limb injuries with gauze-based topical negative pressure wound therapy. J Hand Surg Am 2011; 36(11): 1848-51. [CrossRef]
12. Ogilvie MP, Panthaki ZJ. Electrical burns of the upper extremity in the pediatric population. J Craniofac Surg 2008; 19(4): 1040-6. [CrossRef]
13. Kidd M, Hultman CS, Van Aalst J, Calvert C, Peck MD, Cairns BA. The contemporary management of electrical injuries: resuscitation, reconstruction, rehabilitation. Ann Plast Surg 2007; 58(3): 273-8. [CrossRef]