THE ROLE OF NEGATIVE PRESSURE WOUND THERAPY IN THE TREATMENT OF FOURTH-DEGREE BURNS. TRENDS AND NEW HORIZONS

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SUMMARY. The term “fourth-degree burn” is not very often found in the literature because it is often associated with lethal injury. These injuries are characterized by exposure of viable tissue such as tendon or bone and are associated with challenging wound closure. The goal of reconstruction is to provide adequate soft tissue coverage and restoration of function. Several treatment modalities have been used to serve this purpose. We present four male patients with fourth-degree burns of the extremities, treated with negative pressure wound therapy. The patients’ age ranged from 15 to 49 yr (mean, 28 yr). The total body surface area burned ranged from 3 to 60% (mean, 34.25%). Negative pressure wound therapy was applied for 16-30 days (mean, 23.75 days). Three split-thickness skin grafts and one bipedicled local flap were performed. Wound closure was completed in 28 to 50 days. The results were satisfactory for both physicians and patients. Our longest follow-up was three years. The results achieved in this group of patients revealed the negative pressure wound therapy was a reliable alternative method in the treatment of fourth-degree burns.

Keywords: negative pressure wound therapy; fourth degree burns; burn treatment

Introduction

The depth of burn injury has traditionally been divided into first-, second-, third-, and fourth-degree burns. A fourth-degree burn extends to fascia, bone, tendon, or other tissue beneath the subcutaneous fat. These injuries occur mostly after high-voltage electrical burns or severe fire burns and tend to result in challenging wound closure and partial or total loss of function. The reconstructive ladder is the rationale for the closure of soft tissue defects. In the case of such injuries, using the lower steps such as skin grafting is very difficult, often impossible and fairly often the local tissue is also burned or damaged, thus early performance moving of the reconstructive ladder is imperative. While a microsurgical reconstruction may look like a good option, these procedures are time-consuming, costly, and skill-demanding. Additionally, as the tissue resistance of the blood vessels is lower than that of muscle, skin, fat, tendon, and bone, it may be quite difficult to find appropriate recipient vessels for performing a microsurgical transfer after electrical injury. All these drawbacks have caused a decrease in the number of microsurgical procedures performed in many surgery services worldwide and a trend towards using simpler reconstruction procedures when possible.

Negative pressure wound therapy (NPWT) is a relatively new, nonpharmacological, wound management modality. The vacuum-assisted closure device, introduced by Argenta and Morykwas, has been used widely in many surgical services ever since. Its action mechanism is believed to be that of stimulation of angiogenesis and mitogenesis due to tissue microdeformations and evacuation of excessive fluid or oedema. The result is a well-perfused, ready-for-graft take, granulation tissue. The NPWT has been used for a broad indication spectrum ranging from eradication of infection and decrease of the depth in cavity wounds to stimulation of granulation tissue in areas with exposed tendon or bone, in order to choose a simpler reconstruction option at a later date.

In this study, we will present four cases of fourth-degree injuries of the extremities which were treated with the NPWT (VAC, Kinetics Concepts, San Antonio, Texas).
We will also share our experience and determine outcomes.

**Materials and methods**

The files of the patients admitted to the Gulhane Military Medical Academy Burn Center between the years 2007 and 2009 were reviewed retrospectively. The inclusion criteria were a fourth-degree burn and NPWT treatment. Patients who received NPWT but were later treated with a microsurgical reconstruction procedure and the patients who did not survive were excluded.

The files were reviewed retrospectively and data including the patient’s age, sex, aetiology of injury, injury site, duration of treatment, type of reconstruction, and complications were recorded. Outcomes, assessed 2-3 years post-operatively included the status of wound closure, additive surgeries, and ambulatory status.

**Case 1.** A 28-yr-old male patient (Fig. 1) was admitted to our centre three days after suffering a 49% TBSA high-voltage electrical burn. He presented fourth-degree burns on the upper and lower extremities which resulted in amputation above the elbow of the left arm. On admission a necrotic area was noticed over the left tibia at the entrance site. Time and serial debridement resulted in an almost complete exposure of the tibia. We decided to apply NPWT in order to decrease the size of the defect and increase the perfusion of the muscles by stimulating angiogenesis. NPWT was applied for 21 days with dressing changes twice a week. Two bipedicled local flaps were used for reconstruction when the defect size was sufficiently decreased.

A single surgical procedure was performed in this site, and resulting in complete closure of the defect. Wound closure was accomplished in 28 days. The patient is now ambulating independently and has had no further com-
plaints since. The follow-up is now three years.

Case 2. A 15-yr-old male patient (Fig. 2) was accepted in our centre after a 60% TBSA high-voltage electrical injury, sustained as a result of an accident involving a moving train. He suffered fourth-degree burns on the left lower extremity with nearly complete exposure of the tibia and a circumferential burn of the calf. We first offered the patient a microsurgical procedure option, but he and his family did not accept the procedure. We applied NPWT after trepanation of the outer table of the tibia bone, in order to stimulate granulation tissue as previously described. NPWT was applied for 30 days and the dressings were changed twice a week. The patient was ambulating independently and physiotherapy exercises were performed in the course of therapy. A well-perfused granulation tissue, covering the entire tibia developed, and the defect was covered with a split-thickness skin-graft. There was only one graft take failure due to infection. This was regrafted 10 days later and also resulted in complete take. The fourth-degree burn was treated for 50 days. The patient experienced no function loss: he is ambulating independently and riding his bicycle. His follow-up is now two and a half years.

Case 3. A 49-yr-old male patient (Fig. 3) was accepted to our centre with a 25% TBSA high-voltage electrical burn. He presented fourth-degree burns of the upper and lower extremities that resulted in amputation above the elbow of the left arm. NPWT was applied to both feet for 28 days. Healthy granulation tissue covering all of the exposed fascia and tendons developed and a split-thickness skin graft was used for covering. A single procedure was performed, resulting in complete graft take. Wound closure was completed in 35 days. The patient is now ambulating independently and has had no further complaints. His follow-up is now two years.

Case 4. A 20-yr-old male patient (Fig. 4) was accepted in our centre with a fourth-degree burn of the dorsum of the hand, owing to a hot press injury. He was referred to our centre on day 15 post-burn and on acceptance a fourth-degree burn of the hand dorsum with exposed central bands of the extensor system was noted. NPWT was applied for 16 days. Dressings were changed twice a week. After 16 days of NPWT, conventional wound care was applied for 14 days. Physical therapy exercises were performed daily. A split-thickness skin graft was used for wound closure after development of healthy granulation tissue. A single surgical procedure was performed and the wound closure was completed in 35 days. The patient now has very satisfactory use of the hand and is still working as a baker. His follow-up is now two and a half years.

Results

We treated four patients suffering fourth-degree burns of the extremities with NPWT. The patients’ ages ranged from 15 to 49 yr (mean age, 28 yr). All the patients were male. The TBSA ranged from 3 to 60% (mean TBSA, 34.25%). The aetiology of the burns was high-voltage electrical burn in three patients and hot press injury in one. Three patients suffered fourth-degree burns in the lower extremity and one in the upper extremity (Table I). We obtained complete closure of the fourth-degree burns in 28-50 days. Four skin grafts and one local flap reconstruction were performed. One of the patients experienced a graft loss due to infection, which was subsequently grafted after 10 days and resulted in complete take.
Table I - Patient data

<table>
<thead>
<tr>
<th>Case</th>
<th>Sex</th>
<th>Age (yr)</th>
<th>Aetiology</th>
<th>NPWT (day)</th>
<th>Reconstruction</th>
<th>Complication</th>
<th>Follow-up (yr)</th>
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<tr>
<td>1</td>
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<td>28</td>
<td>Electrical</td>
<td>21</td>
<td>Local flap</td>
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<td>2</td>
<td>M</td>
<td>15</td>
<td>Electrical</td>
<td>30</td>
<td>STSG*</td>
<td>Graft take failure (1)</td>
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<tr>
<td>3</td>
<td>M</td>
<td>49</td>
<td>Electrical</td>
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<td>STSG*</td>
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</tr>
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<td>M</td>
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<td>Hot press injury</td>
<td>16</td>
<td>STSG*</td>
<td>None</td>
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*STSG: Split-thickness skin graft

Discussion

The term “fourth-degree burn” is usually associated with lethal injury and it is rarely employed in the literature. An attempt was made by Zhu et al. to classify these deep burns, developing the Index of Deep Burn Injury. Their results showed that these kinds of injuries often resulted in prolonged morbidity and partial or complete loss of function. Though it is not widely used in clinical practice, this classification remains the only suggestion to classify fourth-degree burns.

Controversy also exists about the management of these injuries. The goal of reconstruction is to provide adequate soft tissue coverage of exposed tendon or bone and restoration of function. As with any open wound, the rationale for wound closure would be the reconstructive ladder. Before the development of microsurgical techniques, amputation rates were very high, as was the loss of function and overall cost. Although microsurgery has provided the trauma surgeon with new exciting options, these are difficult and long-lasting and require skill-demanding procedures. Their high cost, donor site morbidity, and complication rates are also other significant factors. Because of all these drawbacks there has lately been a significant decrease in microsurgical procedures with a concomitant increase in simpler reconstructive procedures such as skin grafts or local flaps.

Parrett et al. provided a review of their ten years’ experience with fourth-degree burns of the lower extremities. They created 14 local flaps, 6 free tissue transfers, 2 fillet flaps, and multiple skin grafts in 40 limbs. Other studies also indicated a trend towards using the lower rungs of the reconstructive ladder. Even though free flap transfers and complicated surgeries have decreased, the amputation rate remains the same.

NPWT was introduced by Argenta et al. and has since gained wide popularity. Its action mechanism is believed to be stimulation of mitogenesis and elaboration of growth factors, due to imposed tissue strain, evacuation of excessive tissue fluid or oedema, and reduction of bacterial colonization within the wound. The cost effectiveness of this modality has been described in two independent studies. NPWT has a wide range of use, ranging from open abdomen wounds, due to abdominal compartment syndrome, to fourth-degree burns with vital tissue exposure. Its clinical use has expanded and new indications are described.

In this study we applied NPWT after debridement in all cases. In high-voltage electrical burns, it is extremely difficult to recognize the borderline between vital and necrotic tissue. Quite often the tissue that appears vital at the time of debridement becomes necrotic a few days after, as the changes induced by electrical burns continue to affect the tissue. Even in these cases NPWT may help to increase the viability of the adjacent tissue by stimulating angiogenesis. We observed better viability of the adjacent areas and smaller sized necrotic areas in the NPWT group. Using this modality we obtained a soft tissue defect small enough in size to be covered with two bipedicled flaps.

On the other hand, in most of the patients, the adjacent tissue was also burned or damaged (as in Case 2), excluding the local flap option. In this patient we applied NPWT circumferentially in order to enhance the blood flow in adjacent tissue as well. We obtained an improvement in muscle tissue perfusion and observed better graft take.

NPWT may contribute to the stimulation of granulation tissue in fourth-degree burns even on exposed vital tissue. For this purpose, we performed NPWT and in selective cases when necessary trephened the outer table of the tibia as previously described. Using the NPWT modality, we accomplished the reconstruction using only the lower rungs of the reconstructive ladder.

In the case of high-voltage electrical burns such as our Case 2, reconstruction is not the only important objective. Most of these patients suffer severe burns and it would not be possible to perform a long-lasting, difficult, and time-consuming procedure while the life-threatening situation continues. On the contrary, NPWT can be applied freely in any patient starting from day 1 post-burn. NPWT will not aggravate the life-threatening situation and the pre-

None of the patients needed any further surgery during follow-up. They all maintained very satisfactory function and declared that they were very pleased and did not experience any donor area morbidity. As all of our patients also had burns in other parts of the body, we performed various debridement and skin grafting procedures while applying NPWT.

Case 2

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conditioning of the wound, provided by NPWT, will be beneficial for a reconstructive procedure performed at a later date.

All of our patients continued their physical therapy exercises throughout their treatment, an element they would not have accomplished had a microsurgical procedure not been performed. After the microsurgical procedures, lengthened immobilization and splinting were often necessary. We immobilized our patients only for five days after the grafting procedures. Physiotherapy of other areas was performed meanwhile when necessary.

As many fourth-degree burn patients experience severe burns, the donor area options may be limited. The nonaesthetic ‘patch effect’ of the bulky flap may also be a drawback. In an already grafted circumferential burned extremity (see Case 2), no patch effect will be produced using this modality. Also, very few options produce no bulk in a defect with no cavity in the dorsum of the hand or foot. Using the NPWT and STSG modalities we achieved the optimal aesthetic and functional outcome in Cases 3 and 4. All the patients declared that they were pleased with the aesthetic result and did not experience any donor area morbidity.

We accomplished the closure of the wound in 28-50 days and performed only one reconstructive procedure per patient. None of the patients needed any further surgery and they were all very pleased with the restoration of function. As all of our patients also had burns in other parts of the body, we performed various debridement and skin grafting procedures while applying NPWT, so that hospital stay was not limited to fourth-degree burn treatments. In the appropriate cases, the patient may be followed as an outpatient and may be hospitalized only for the graft procedure. This will decrease costs, save the patient from the trauma produced from a long stay in a burn centre, and decrease infection rates.

This study has several limitations requiring consideration: namely, the size of data is small and there was no control group. However, our positive results encourage us to use this modality. Even if complete wound closure is not achieved, the wound “preconditioning” effected by NPWT guarantees a smaller defect and a better recipient bed. There is certainly no doubt that NPWT cannot replace microsurgical tissue transfers. Nevertheless, as wound treatment concepts continue to evolve, combination of the modalities has become a reality. Thus, the performance of a microsurgical procedure on a granulated, infection-free bed will certainly guarantee better results.

Conclusion

We are firmly convinced that the indications for NPWT are going to expand in the future and combination of this modality with different treatment modalities should be encouraged. As a result we can say that NPWT is a valuable tool in the armamentarium of trauma and burn surgeons.

RÉSUMÉ. Le terme “brûlure de quatrième degré” n’est pas commun dans la littérature car elle est souvent associée à des lésions mortelles. Ces lésions sont caractérisées par l’exposition des tissus viables comme les os et les tendons et elles sont associées à une fermeture des lésions. L’objectif de la reconstruction est de fournir une couverture adéquate des tissus mous et la restauration de la fonction. Plusieurs modalités de traitement ont été utilisées pour servir à cette fin. Nous présentons quatre patients du sexe masculin atteints de brûlures de quatrième degré aux des extrémités. Ces lésions ont été traitées avec la thérapie des lésions moyennant la pression négative. L’âge des patients variait de 15 à 49 ans (moyenne, 28 ans). La zone corporelle totale surface brûlée variait de 3 à 60% (moyenne, 34.25%). La thérapie des lésions moyennant la pression négative a été appliquée pendant 16-30 jours (moyenne, 23.75 jours). Trois greffes de peau d’épaisseur variable et un lambeau local bipédiculé ont été exécutées. La fermeture des lésions a été complétée en 28 à 50 jours. Les résultats ont été considérés satisfaisants soit par les patients soit par les médecins. Le suivi le plus long parmi nos patients a été de trois ans. Les résultats obtenus par les patients dans ce groupe ont démontré que la thérapie des lésions moyennant la pression négative était une méthode alternative fiable dans le traitement des brûlures de quatrième degré.

Mots-clés: thérapie des lésions moyennant la pression négative, brûlure de quatrième degré, traitement de brûlure de quatrième degré

BIBLIOGRAPHY


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