Case Report

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Functional and cosmetic reconstruction of palmar heat press injury following wound bed preparation combined with artificial highly concentrated carbon dioxide bathing: A case report

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Abstract

Background: The effect of artificial highly concentrated carbon dioxide bathing on heat-press-injured wounds has been clinically observed.

Case presentation: A 46-year-old male patient with a heat press injury of the right palmar region achieved complete necrotic tissue removal and sufficient granulation of the skin graft by continuous hand bathing in a solution containing highly concentrated carbon dioxide for four weeks. The patient successfully underwent a full-thickness skin graft from the plantar to the palmar region, and his right hand function improved to the extent that it did not interfere with daily life.

Conclusions: Heat press injuries are often refractory to treatment owing to the synergistic effects of heat and crush injuries. Highly concentrated carbon dioxide bathing has long been known to increase skin and muscle blood flow, and its clinical applications in ischemic limbs, skin ulcers, and osteomyelitis have already been reported. In this case, the results suggest an effect of improved blood flow leading to maturation of the graft bed at the heat-press injury site.

Keywords

Carbon dioxide bathing, eschar debridement, hand burn, heat press injury, wound bed preparation

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Lay Summary

Highly concentrated carbon dioxide bathing is not only clinically applicable to ischemic extremities, skin ulcers, and osteomyelitis, due to increased cutaneous and muscular blood flow, but also to the reliable debridement of heat press injury wounds and the granulation of graft beds. We successfully used this novel combination of procedures to establish a graft bed with a good blood flow despite the deep heat press injury occurring in the palmar region, leading to an excellent functional recovery. The cost per procedure is low, at about $1 (USD), making it a wound care option that should be considered from a healthcare economic perspective.

Introduction

In the case of heat-press injuries, the synergistic effects of thermal and crush injuries cause the area of damage to continuously expand, which is very difficult to treat.[1] Highly concentrated carbon dioxide bathing (highly concentrated carbon dioxide bathing with the optimal carbon dioxide gas concentration adjusted to 1000–1300 ppm for medical use) has been reported as a therapeutic intervention to improve the cutaneous circulation of ischemic skin ulcers.[2] The effect of artificial highly concentrated carbon dioxide bathing on heat-press-injured wounds was clinically investigated.

Case presentation

A 46-year-old man sustained a heat press injury when his right hand was caught in a roller heated to 180°C for crimping fabric products for approximately 30 s. There was only slight heat damage to the dorsum of the hand and no obvious fractures on the right hand. However, the palmar skin was severely indurated owing to deep burn damage, and the active motion of the fingers was severely limited (Figure 1). The area of injury was approximately 1% of the body surface. From the day after the injury, a 15-min hand bath in highly concentrated carbon dioxide bathing at 37 °C (AS Care®; Asahi Kasei Medical Co., Ltd, Tokyo, Japan) was performed daily to gradually eliminate necrotic tissue and continue finger rehabilitation (Figure 2). The depth of the burn on the pulps of all digits was classified as superficial dermal burn (SDB), and sensation at the fingertip was maintained. Continuous anesthesia was not required from the initial stage of the procedure, and debridement was performed step-by-step during bathing. Four weeks after the injury, the palmar necrotic tissue had been completely eliminated, and sufficient granulation tissue had grown; therefore, the patient underwent skin grafting using plantar glabrous skin grafts (Figure 3). The right hand was cast in the intrinsic plus position and a domino graft from the inguinal area was applied to the skin defect in the right plantar region. Palmar skin can only be replaced by plantar skin owing to its characteristics. Therefore, it is necessary to graft the skin from other sites to the plantar region, which is commonly known as domino grafting. One week after surgery, the cast was removed and rehabilitation was initiated by a physical therapist to improve hand movement. One year after the injury, the color, texture, and skin extensibility of the grafted skin were acceptable, and the intrinsic muscles and mechanisms of the fingers functioned normally without any residual damage. There was no pigmentation on the palms, but slight speckled depigmentation was observed (Figure 4). The treatment results were satisfactory for both the surgeon and patient. The patient did not have chronic pain or

Figure 1. The palmar skin was severely indurated due to deep burn damage, and the active motion of the fingers was severely limited.

Figure 2. Highly concentrated carbon dioxide bathing at 37 °C was performed daily to gradually eliminate necrotic tissue and continue finger rehabilitation.

Figure 3. Four weeks after the injury, sufficient granulation tissue had grown, so the patient underwent skin grafting using plantar glabrous skin grafts.

cold intolerance, but had hyperesthesia of the right hand and a mild hypertrophic scar at the margin of the skin graft. The patient was followed for one year. The patient did not develop psychiatric complications or post-traumatic stress disorder during that period. Donor skin to the palms was harvested from the bilateral medial plantar areas, and skin defects on the feet were replaced with skin grafts from the bilateral inguinal areas (domino skin grafts). Epithelialization of the donor area took two weeks. The patient was able to return to work and his previous level of activity four months after the injury.

Discussion

Exhaustive debridement of necrotic tissue from deep hand burns and immediate covering with autologous skin grafts leads to early wound healing and restores optimal postoperative hand function.[3] However, in the case of heat-press injuries, the synergistic effects of thermal and crush injuries cause the area of damage to continuously expand, which is very difficult to treat.[1] Because the depth of injury tends to be underestimated in heat press injuries, it is often difficult to accurately debride the necrotic tissue and establish a graft bed with good blood flow in the early stages of injury. In our case, it was determined that there was no tendon or nerve damage, and this treatment method was applied. The surgeon must have sufficient clinical experience to be able to comprehensively estimate the extent of deep tendon damage based on hand movement, impaired blood flow, and skin stiffness. Therefore, skin grafting procedures sometimes fail, and the methods and timing of

Figure 4. One year after the injury, the color match, texture match, and skin extensibility of the grafted skin were acceptable.

surgical intervention remain controversial.[4] In a report of 56 heat press injuries of the hand, 86% of cases required surgical intervention; 50% required 2-stage nerve, bone, or joint-related surgery; and the return-to-work rate was only 68%.[2]

In the present case, we applied a highly concentrated carbon dioxide bathing treatment to a heat press injury, an approach that has not been previously reported. The main effects of this treatment have previously been reported, including improved skin and muscle blood flow, decreased blood pressure, and amelioration of bradycardia.[5] The clinical applications of highly concentrated carbon dioxide bathing for ischemic extremities, skin ulcers, and osteomyelitis have already been reported.[6–8] The biochemical mechanism involves conversion of transdermally absorbed carbon dioxide to bicarbonate ions, which act directly on endothelial cells to increase nitric oxide (NO) production through phosphorylation of endothelial nitric oxide synthase (eNOS), a process that is considered to improve blood flow.[9] The optimal conditions for improving skin blood flow were as follows: carbon dioxide gas concentration, 1000–1300 ppm; water temperature, 37 °C; bathing time, 15 min; and application interval, once a day.[10]

The advantages of incorporating this bathing regimen into the treatment for heat press injuries include the facilitation of accurate debridement of necrotic tissue and the establishment of a graft bed with good blood flow. Although it is unclear whether this method is better than the standard treatment with wet-dry or negative-pressure wound therapy, hand bathing allows the wound to be cleaned daily, essentially reducing the risk of wound contamination. Enzymatic debridement therapy has the disadvantage of being more expensive and requiring anesthesia, while negative pressure wound therapy and wet-dry therapy are not only more labor-intensive for the therapist, but also carry the risk of wound infection complications. Carbon dioxide bath tablets are already commercially available in Japan, making it easy to take highly concentrated carbon dioxide baths at home. The drug tablets used for each carbon dioxide bathing session are equivalent to approximately $1 (USD) per tablet, and the only other cost is for the 37°C water, making it a wound care option that should be considered from an economic healthcare perspective.[8] We successfully used this combination of procedures to establish a graft bed with good blood flow despite deep heat press injury occurring in the palmar region, leading to excellent functional recovery. There have been no similar reports in the past; therefore, this report is novel and educational.

Conclusion

Highly concentrated carbon dioxide bathing is not only clinically applicable to ischemic extremities, skin ulcers, and osteomyelitis due to increased cutaneous and muscular blood flow, but also to the reliable debridement of heat press injury wounds and granulation of graft beds.

Author contributions

MH, KT, and TM performed the surgery. MH, NK, and AK designed and directed the treatment. All authors read and approved the final manuscript.

Consent for publication

Written informed consent was obtained from the patient for publication of this case report and accompanying images.

Declaration of conflicting interests

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