



Management of Crush Injury's Complications Using Hyperbaric Oxygen Therapy: Case Series

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Abstract: Crush injury occurs due to an external trauma mechanism that directly affects the skin, muscle, and bone tissue. Crush injuries can involve several parts of the body at the same time. When accompanied by handling, wound healing in crush injury can be long-term, so that it can affect the function of the patient. Various complications that can occur ranging from secondary infection, necrosis, recurrent bleeding, to compartment syndrome. We reported serial cases of crush injury with various clinical presentations and complications, varying in the age range of 16-65 years. All four patients were given multiple managements, such as open reduction external fixation and extensive debridement. There were complications such as secondary infection and delay in the wound healing process in patients who did not on time for follow-up. The four patients received additional treatment in the form of wound dressings hyperbaric oxygen therapy (HBOT) with 5-10 90-minute sessions under 2.4 ATA pressure for 10 consecutive days. Follow-up was carried out again within a period of one month to compare the wound condition before and after HBOT. The clinical condition was getting better, marked by the formation of granulation tissue. The state of hyperoxia in HBOT accelerated the inflammatory process and angiogenesis during the wound healing process characterized by the eradication of bacteria in the wound tissue and accelerated neovascularization formation. In conclusion, adequate therapy, wound dressing, and patient compliance affect patient outcome. Moreover, the addition of hyperbaric oxygen therapy has shown to accelerate the wound healing process and restore the patient's limb function.

Keywords: crush injury; hyperbaric oxygen therapy; oxygen; wound healing

INTRODUCTION

Crush injury is defined as compression of the extremities or other parts of the body that cause muscle swelling and or neurological disorders in the affected areas of the body.¹ In addition, crush injuries will have decreased blood flow related to the damage of tissues and edema.² Hyperbaric oxygen therapy acts through the ideal gas laws and is effective as an adjunctive therapy in the treatment of crush injuries. Oxygen is considered as a drug in this case, and hyperoxygenation could affect the reduction of edema, infection control enhancement, as well as blood vessel and collagen formation.³ In this study we discussed about four patients of crush injuries in serial cases.

CASE SERIES

Case 1, a 64-year-old female, came to the hospital with a fibula fracture and Achilles tendon rupture. The patient also suffered from diabetes mellitus. The base of the tendon and bone wound showed an extensive wound of approximately 10x12 cm with pus on it (Fig. 1A). Wound cleaning and open reduction external fixation (OREF) were carried out (Fig. 1B). Patient underwent one-month treatment with 15 sessions of hyperbaric oxygen therapy (HBOT) successfully (Fig. 1C).



Figure 1. A, 64-year-old female with fibula fracture and tendon Achilles rupture; B, After wound cleansing and OREF; C, Post operation with 15 sessions of HBOT

Case 2, a 16-year-old male, came to the hospital with crush injury on the knee region and the distal part of left femur. Wound base was tendon to the bone with irregular edge. Patient suffered from the injury due to falling from a motorcycle two hours before being admitted to the hospital (Fig. 2A). Open reduction external fixation and wound dressing were performed (Fig. 2B) added with 15 sessions of HBOT therapy (Fig. 2C)

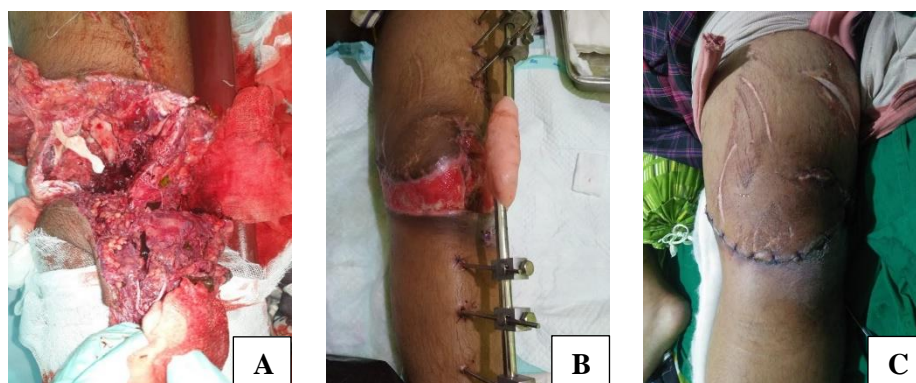


Figure 2. A, 16-year-old male with crush injury of knee region and distal part of left femur; B, post OREF; C, HBOT of 15 sessions

Case 3, a 52-year-old male, came to the hospital with a crush injury on the right forearm and hand due to his hand entering the coconut crushing machine. A saturation examination was carried

out on the patient's fingertip showing a decrease in oxygen fraction (Fig 3A, B). When X-ray examination was carried out on the patient, it was found that there was a fracture of the proximal to the medial phalanx of digit 4 of right hand (Fig. 4) From the field of plastic surgery, wound dressing was performed. The patient's wounds also experienced significant improvement after 10 sessions of HBOT (Fig. 3C)

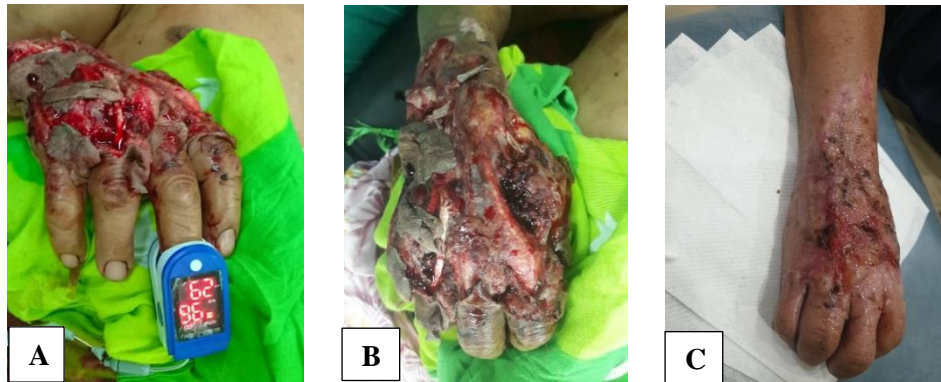


Figure 3. A and B, 52-year-old male with crush injury on right forearm – hand; C, Post 10 sessions of HBOT



Figure 4. Fracture of proximal – medial phalanx digiti 4 of right hand

Case 4, a 21-year-old female came with a crush injury on her left leg as a result of a traffic accident (Fig.5A). Wound cleaning was carried out and X-ray examination showed tibia and fibula fractures. OREF and wound dressing were performed on the patient's wound, added with 10 sessions of HBOT (Fig. 5B).



Figure 5. (A) 21 years old, female with crush injury, (B) Post 10 sessions of HBOT

DISCUSSION

Destructive wound in the extremities or other body parts resulting from a direct contact with an object is called crush injury.⁴ In this modern era, there is increased utilization of motor vehicles and construction equipment.⁵

The underlying pathophysiology of crush injuries and skeletal muscle compartment syndrome (SMCS) is trauma with tissue hypoxia, which may lead to the continued evolution of the injury to an irreversible state or a self-perpetuating progression of edema, forming a vicious circle. Visible tissue damage, injury at the cellular level, and biochemical alterations are included as the consequences of trauma. Immediate necrosis occurs in high-energy trauma cases and the only option in these circumstances is debridement or amputation.⁶ Interactions between oxygen free radicals and cell membrane lipids is interrupted by HBOT, perturbing lipid peroxidation of the cell membrane and inhibiting the sequestration of neutrophils on postcapillary venules.⁷

Secondary effect of tissue hyperoxygenation is edema reduction. Hyperbaric oxygen induces precapillary vasoconstriction, which reduces blood flow by 20%.^{8,9} The four patients received additional treatment in the form of wound dressing and HBOT with 5-10 90-minute sessions under 2.4 ATA pressure for 10 consecutive days. Follow-up was carried out again within a period of one month to compare the condition of the patients' wounds before and after HBOT. Their clinical conditions were getting better, marked by the formation of granulation tissue. After HBOT, cells in the wound area exhibit increased growth factor production and neovascularization, as well as improved cell migration and collagen synthesis. A separate, free radical-based mechanism for the augmentation of neovascularization by HBOT is through circulating stem/progenitor cells (SPCs). Hyperoxia stimulates mobilization of bone marrow SPCs and improves their function once they home to peripheral sites.⁸⁻¹⁰

Hyperbaric oxygen therapy also has anti-inflammatory properties. When ischemic tissue is reperfused (for instance, after reattachment of a flap or graft) inflammatory cells paradoxically "attack" the previously ischemic tissue, leading to what is known as ischemia-reperfusion injury. Reperfusion injury involves leukocyte margination and extravasation from capillaries, a process mediated by endothelial cell expression of intercellular adhesion molecule 1 which is tightly controlled by endothelial cell-derived nitric oxide in inverse fashion; nitric oxide concentration increases in the presence of HBOT. This is because HBOT upregulates endothelial derived nitric oxide synthetase.¹¹

CONCLUSION

Adequate therapy, wound care, and patient compliance affect patient outcomes. In addition, hyperbaric oxygen therapy has shown to accelerate wound healing process and restore the patient's limb function.

Conflict of Interest

The authors affirm no conflict of interest in this study.

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