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Hyperbaric oxygen therapy: Therapeutic role in various cases – A case series

Thenmozhi MD[1], Sivakumar S[2], Sethuraja K[3], Meera SS[4]

[1,3]Assistant Professor, [2]Associate Professor, Department of Plastic Surgery, [4]Associate Professor, Department of General Surgery, Priyam Multispeciality Hospital, Kondalampatti Bypass, Salem, Tamil Nadu, India

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ABSTRACT

Hyperbaric oxygen therapy (HBOT) is an adjuvant novel non-invasive treatment technique in the field of plastic surgery for treating different wounds. This technique utilizes 100% oxygen at pressures above the atmospheric pressure. In our study, we are discussing about eight different cases in the field of plastic surgery. HBOT plays an important role in the treatment for different pathological conditions. It involves a hundred percent breathing of oxygen in a closed chamber for a certain period of time. HBOT main mechanism of action is hyper oxygenation but also enhances the immunity by antimicrobial properties and improves stem cell production.

Key words: Hyper oxygenation; Wound healing; Compromised flaps; Diabetic ulcers; Burns; Fournier gangrene; Keloids; Osteomyelitis

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INTRODUCTION

Hyperbaric oxygen therapy (HBOT) is a novel and advanced treatment and a major tool in the armamentarium of clinical treatment, either as a primary or adjuvant therapy for several clinical conditions. The application of HBOT is on rise on recent times.[1]

Hyperbaric oxygen is a process by which providing pure oxygen under higher the normal atmospheric pressure, the pressure causes more oxygen to dissolve in the plasma besides the red blood cells.[2]

HYPER-increase baric-pressure

Hyperbaric oxygen is a process by which providing pure oxygen under higher the normal atmospheric pressure, the pressure causes more oxygen to dissolve in the plasma besides the red blood cells. HBOT applies the principles of "Henry's law."

"Henry's Law" states that, at constant temperature, the amount of dissolved gas in a liquid is directly proportional to its partial pressure above the liquid.[2]

A committee on hyperbaric medicine defines, HBOT as "A mode of medical treatment in which the patient is entirely encased in a pressure chamber and breathes 100% oxygen at PR >1 (ATA)-Atmospheric pressure.

In HBOT, the treatment pressure is between 2 and 3 atms (ATA) of pressure. According to undersea and hyperbaric medical society, currently approved indications, it is required a chamber pressurized to a minimum of 2 ATA.

Thus, a creation of a hyperbaric environment with pure oxygen permits a significant increment of the oxygen supply to blood (Hyperoxemia) and to the tissues (Hyperoxia) even without the contribution from hemoglobin.

Address for Correspondence:
Dr. Meera SS, Associate Professor, Department of General Surgery, Government Mohan Kumaramangalam Medical College Hospital, Salem, Tamil Nadu, India. **Mobile:** +91-9443421352. **E-mail:** drssmeera_vasu@yahoo.in

Figure 1: (a) Pre-operative (b) Post-operative (c) Before HBOT (d) After 15 session of HBOT

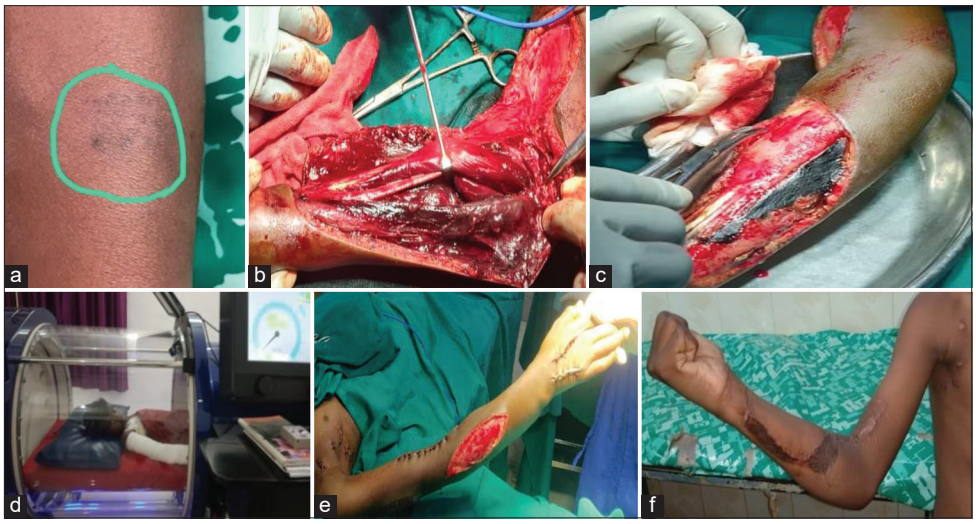

Figure 2: (a) Snake bite site (b) Post-snake bite wound exploration (c) After four sessions of HBOT (d) HBOT sessions (e) ten sessions of HBOT (f) Post SSG

Figure 3: (a) Day 1 burns (b) Day 2 HBOT (c) Post-HBOT (d) After five sessions of HBOT

MECHANISM OF HBOT

HBOT helps wound healing by bringing oxygen-rich plasma to tissue starved for oxygen. Wound injuries damage the body's blood vessels, which release fluid that leaks into the tissues and causes swelling. This swelling deprives the damaged cells of oxygen, and tissue starts to die. HBOT reduces swelling while flooding the tissues with oxygen. The higher pressure in the chamber increases the amount of oxygen in the blood. HBOT aims to break the cycle of swelling, oxygen starvation, and tissue death.[3]

HBOT prevents "reperfusion injury." This is the severe tissue damage that happens when the blood supply returns to the tissues after they have been deprived of oxygen. When blood flow is interrupted by a crush injury, for instance, a series of events inside the damaged cells leads to the release of harmful oxygen radicals. These molecules can do damage to tissues that cannot be reversed. They cause the blood vessels to clamp up and stop blood flow. HBOT encourages the body's oxygen radical scavengers to seek out the problem molecules and let healing continue.[3]

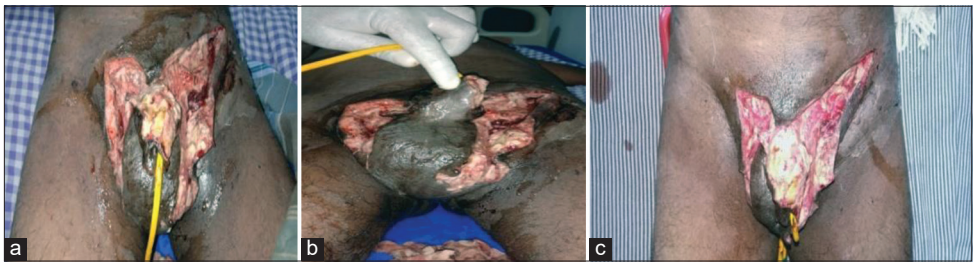

Figure 4: (a) After wound debridement (b) After wound debridement (c) After NPWT

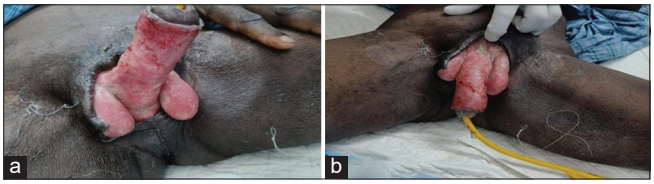

Figure 5: (a and b) After 11 sessions of HBOT

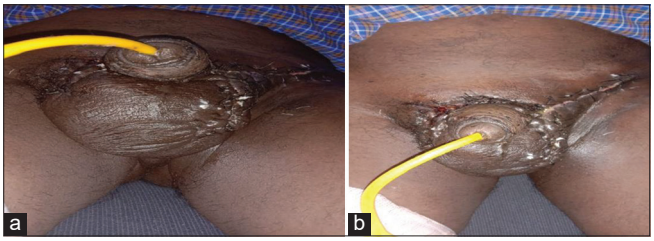

Figure 6: (a and b)After HBOT delayed primary wound closure and split skin graft

HBOT helps block the action of harmful bacteria and strengthens the body's immune system. HBOT can disable the toxins of certain bacteria. It also increases oxygen concentration in the tissues. This helps them resist infection. In addition, the therapy improves the ability of white blood cells to find and destroy invaders.[3]

HBOT encourages the formation of new collagen and new skin cells. It does so by encouraging new blood vessel to grow. It also stimulates cells to produce certain substances, like vascular endothelial growth factor. These attract and stimulate endothelial cells needed for healing.[3]

ROLE OF HYPERBARIC OXYGEN IN PLASTIC SURGERY

Wound management and healing are one of the main armamentarium in the field of plastic surgery. Wound healing is a complex process which involves a multitude of factors, all set together to get an adequate wound healing. For wounds to heal the main factor is adequate blood flow and tissue oxygenation which is achieved by both macrocirculation and microcirculation.[4]

Hyperbaric oxygen plays a major role in wound healing by helping to improve circulation, especially in no healing wounds.[5]

CASE 1

Diabetic foot ulcer of both feet

A 55-year-old lady who has diabetes Type II for past 15 years was admitted in the hospital for plantar ulcers with pus discharge from the right foot second metatarsal and ulcer over the head of the fifth metatarsal of the left foot [Figure 1a]. After obtaining the X-ray both feet, ABPI, the Doppler arterial blood flow of the lower limbs, and the diabetic status of the patient, the diagnosis of osteomyelitis of the right second metatarsal head was made.

After diabetic control with human mixtard insulin, the patient was treated with wound debridement and excision of the right second osteomyelitic bone followed by gastrosoleus recession lengthening and floating osteotomy of the left fifth metatarsal [Figure 1b]. Patient was treated with 2.0 ATA pressure of HBOT for 15 days. The wound healed well and she was sent with protective foot wear on the 16th post-operative day [Figure 1c].

CASE 2

Snake bite with cellulitis and muscle necrosis

A 11-year-old boy was admitted with a history of poisonous snake bite, over the right fore-arm volar aspect [Figure 2a]. After diagnosing the bite as a hemolysin toxin, the patient was treated with anti-snake venom and plasma transfusion to control his prothrombin time and INR, he was taken up for surgery, fasciotomy was done and the flexor carpi ulnaris (FCU) muscle was found involved by the snake venom [Figure 2b]. After envenomation, the muscle was found to be partially viable. Wound closed partially and on the 2nd post-operative day taken up for HBOT [Figure 2c].

After four sessions of HBOT with 1.5 ATA for 60 min, the wound was explored again [Figure 2d]. The FCU muscle was found necrosed and non-viable. The limb edema has reduced. The necrosed FCU muscle was excised and wound closed partially and HBOT was continued from the next day for another six sessions. After ten sessions of HBOT, the remaining wound raw area was covered with split thickness skin graft and

Figure 7: (a-c) Non-healing multiple ulcers both legs

Figure 8: (a-c) After 14 session HBOT

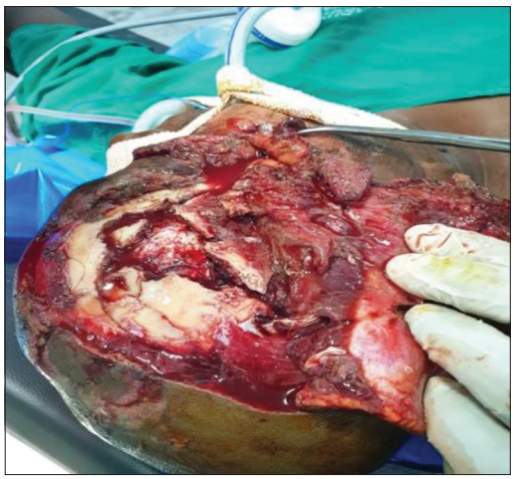

Figure 9: Head injury on admission and before haematoma evacuation

delayed primary suturing [Figure 2e]. The wounds healed well within 2 weeks and the patient was sent home [Figure 2f].

CASE 3

Thermal burns patient treated with HBOT

A 12-year-old patient was playing with old unburnt cracker remains, a day after the annual diwali festival [Figure 3a]. He has opened that the cracker remains and was lighting it, when the cracker burst on his face and he sustained burn wound injuries and referred to the hospital. On admission, his chest X-ray and CT scan were taken to identify any inhalation burns injuries [Figure 3b]. The patient was treated with wet collagen sheet dressing under general anesthesia and on the 1st post-operative day, he developed facial edema [Figure 3c]. He was treated with 1.5 ATA pressure for 60 min for 5 days.

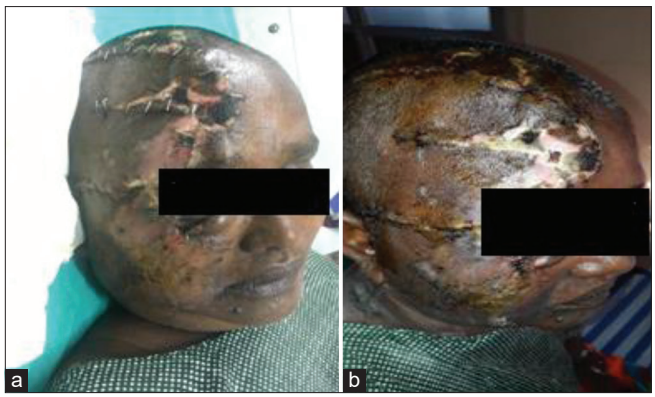

Figure 10: (a and b) After weaning out from ventilator support

Figure 11: (a and b) After 10 days of hyperbaric oxygen therapy

He was discharged from the hospital on 6th post-operative day. His wound healed well without any scars [Figure 3d].

CASE 4

Fournier's gangrene of scrotum and penis

A 65-year-old diabetic, who is on irregular treatment with oral anti-diabetic drugs for past 12 years, was admitted with sudden

Figure 12: (a and b) After 21 days of hyperbaric oxygen therapy

Figure 13: Post-traumatic raw area right foot before HBOT

Figure 14: (a and b) After ten sessions of HBOT

Figure 15: (a) Keloid chest wall (b) Keloid left shoulder (c) Keloid right arm and shoulder (d) Sessions of HBOT

cellulitis involving penis and scrotum following a paraphimosis infection. The penis and scrotum with the inguinal region was involved in the infection [Figure 4a]. Patient had wound debridement under regional anesthesia [Figure 4b]. After 2 days of dressing, he was treated with negative pressure wound therapy (VAC) and with HBOT at 1.5 ATA pressure for 60 min for 11 days [Figure 4c].

After that, the patient was taken up for delayed primary suturing of the scrotum and split thickness skin graft to the remaining raw area [Figure 5a and b]. Postoperatively, patient was treated with HBOT for 5 days. Wound healed well [Figure 6a-c].

CASE 5

Chronic superficial ulcers of leg

A 65-year-old female patient who developed multiple superficial ulcers over the dorsum, medial, and lateral aspect of both the legs and dorsum of foot associated with mild limb edema past 3 months. She was investigated for arterial and venous pathology by MRI angiogram, Doppler arterial, and venous flow studies [Figure 7a-c].

She was started on parenteral antibiotics and treated with HBOT at 1.5 ATA pressure for 60 min for 14 days [Figure 8a-c].

The wounds healed well without any scar contracture.

CASE 6

Post-traumatic head injury with compromised skin flap

A 40-year-old female was hit by a four-wheeler and sustained injuries on her head with compound communited fracture of the skull bones and subdural and intracranial hematoma [Figure 9].

She was taken up for emergency evacuation of the hematoma and skin cover to the facial and scalp cover [Figure 10a and b].

After wound debridement and evacuation of the hematoma, the scalp defect and infra orbital defect were covered with Mustarde's cheek advancement flap and wound closed primarily. Patient was on ventilator support for 7 days. After weaning out from the ventilator, the patient was examined and the skin flap was compromised and impending infection [Figure 11a and b].

The patient was put on HBOT after repeat CT scans of brain showed no progression on ICH and EDH. She was treated with 1.8–2.0 ATA pressure for a period of 21 days. The compromised flap survived and the wound and the hematomas resolved completely [Figure 12a and b].

CASE 7

A 70-year-male came with h/o non-healing ulcer right leg with h/o trauma 30 days back [Figure 13]. H/o burns 10 years before. Now patient having trauma over the burn healed site. Patient undergone ten sessions HBOT under 1.5 ATA [Figure 14].

CASE 8

A 60-year-old female came with multiple scars over chest, right arm, back, breast an left shoulder with complaints of irressitable itching, and pain [Figure 15a]. Patient underwent multiple intralesional steroids [Figure 15b]. Symptoms still persisted [Figure 15c]. Patient undergone 15 sessions of HBOT [Figure 15d]. following which patient developed significant reduction of itching and pain. As per persons verbal comment the skin over the scar got soft, less tense, and very minimal itching and pain. The quality of life is improved.

DISCUSSION

The wound management and wound healing is one of the main components in the field of plastic surgery.[5] Wound healing is a complex process which involves a multitude of factors, all set together to get an adequate wound healing. For wounds to heal the main factor is adequate blood flow and tissue oxygenation which is achieved by both macro circulation and microcirculation.[5] HBOT is a novel and advanced treatment and a major tool in the treatment all sorts of wounds. It reduces the time period for wound healing as well as the need for amputation in diabetic ulcer patients.[6]

Osteomyelitis is an infection of bone. Bacteria present in the bloodstream from infectious diseases spreads to the bone.[7] Osteomyelitis treatments mainly include extensive irrigation and debridement, intravenous antibiotics, and reconstruction. HBOT helps osteogenesis, neovascularization, and collagen production. In ischemic wounds, tissue oxygenation is obtained by hyperbaric oxygen through formation of new vessels by neovascularization and increase in vascular endothelial growth factor.[8-11] Therapeutic effects of HBOT on infections can be made by direct suppression the growth of anaerobic bacteria such as clostridia and hyperoxygenation in tissues causes increase the fibroblasts and collagen proliferation, neovascularization of ischemic tissues and stimulation of bacterial lysis by leukocytes.

In the process of wound healing, HBOT plays an important role. HBOT plays an essential role in the healing of wounds from burns, diabetic ulcers, venous ulcers, crush injuries, the flap survival, split skin graft take, and osteomyelitis. HBOT acts by increasing oxygenation in the blood vessels and tissues by improving fibroblast function, collagen synthesis, and neovascularization that helps in wound healing.[8-11]

CONCLUSION

HBOT is effective in treatment of many conditions either as a primary as well as an adjuvant effect. Infected non-healing wounds reduce the quality of life of the patients. HBOT along with the hyperoxygenation improves the immune system by the enhancement of antimicrobial effects and reduces inflammatory cytokines. Long-term studies to be conducted to see the outcome of HBOT treatment in different pathological conditions. HBOT also reduces the hospital stay of the patients as well as it improves the quality of life by the patients.

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Authors' Contributions:
TMD- Concept and design of the study, prepared first draft of manuscript; **SS**- Reviewed the literature and manuscript preparation; **SK**- Concept, coordination, statistical analysis and interpretation and preparation of manuscript; M**SS-** Interpreted the results and revised the manuscript.

Work attributed to:
Priyam Multispeciality Hospital, Kondalampatti, Salem - 636 010, Tamil Nadu, India**.**

Orcid ID:
Dr. Thenmozhi MD - https://orcid.org/0009-0002-8976-8851
Dr. Sivakumar S - https://orcid.org/0009-0003-8097-9553
Dr. Sethuraja K - https://orcid.org/0009-0004-7902-3164
Dr. Meera SS - https://orcid.org/0000-0003-4876-8206

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