

Effects of Hyperbaric Oxygen in the Treatment of Traumatic Injury with Acute Vascular Insufficiency

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Abstract

FOURTEEN cases of traumatic injuries with acute vascular insufficiency and threatened gangrene have been treated with hyperbaric oxygen (HBO). Twelve showed marked improvement where the limbs could be saved. HBO helps in maintaining viability of ischaemic tissue and provides vital time for the reparative process to restore adequate circulation which may take a few days and thus save the limb. Additionally, HBO helps to control infection when used with antibiotics and also helps in early healing. It is a powerful therapeutic adjunct to surgical treatment in such cases and should be used for best advantage where the facilities exist.

Introduction

Acute traumatic injuries to the limbs resulting from industrial and vehicular accidents are on the increase in recent years. Injuries are often extensive involving damage to many vessels. These cases usually lead to increasing ischaemia of the limb due to vascular insufficiency and subsequent gangrene often necessitating amputation. Ischaemic necrosis due to acute vascular insufficiency has been treated with early administration of hyperbaric oxygen (HBO) in 14 cases of accidents. HBO therapy along with other surgical treatment resulted in saving of limbs in most of these cases.

HBO therapy in ischaemic conditions is based on the assumption that when the tissue survival is jeopardised by acute onset of tissue hypoxia, oxygen is made available in the form of physical solution bypassing the damaged vascular system. A linear relationship exists between the pressure under which oxygen

is breathed and the volume of oxygen available in solution. Thus, from a normal quantity of 0.3 ml of oxygen in solution per 100 ml of blood while breathing air at sea level, the volume increases to 6 ml while exposed to HBO at 3 atmospheric pressure (ATA). Moreover, HBO also leads to considerable increase in oxygen tension and thus results in a better transfer of oxygen to ischaemic tissues due to higher oxygen tension gradient.

In an injured limb with otherwise healthy blood vessels the ultimate value of HBO depends mainly on whether it can sustain hypoxic tissues while reparative processes restore an adequate circulation. Moreover, this also minimises permanent tissue destruction thereby allowing time to undertake elective surgery whenever there is any need.

Ketchum et al³, Illingworth² and Slack et al⁴ have reported encouraging results from HBO therapy in traumatic ischaemic lesions. This study presents a series of 14 cases treated with HBO, 8 of which were involved in road accidents affecting lower limbs and 6 cases of extensive injuries of upper limbs, resulting in fractures, ischaemic limb and threatened gangrene. 12 of these cases showed considerable improvement and limbs could be saved.

Treatment Schedule

The patient was placed in Hyperbaric Oxygen Chamber and oxygen was supplied through an oronasal mask. The chamber was pressurised to 28 psig (about 3 ATA) or to 22.9 psig (2.5 ATA), with compressed air. Breathing 100 percent oxygen

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through a well fitting mask provided with pressure-compensated expiratory valve ensured the supply of required oxygen under high pressure (OHP). During the first 24 hours, the patient usually received two such exposures, followed by one exposure daily on succeeding days. The duration used to be 2 hours on the first day and 1.5 hours on subsequent days. Initially, the patients were treated for as long as 10-15 days but later the number of exposures were reduced depending on individual's response to the therapy.

Group I: Compound fracture and soft tissue injury of lower limb with threatened gangrene:

Case 1

RW, 18 years, male. A case of scooter accident sustaining fracture of head of fibula and tibial tuberosity of right side. POP cast, which was applied initially, had to be removed after 36 hours due to onset of severe pain in leg and foot with blueish discoloration, marked swelling and cold feet below ankle. 6 days later, the skin over the wound was found discoloured and a large quantity of pus was drained which was found under tension. Pulsation below popliteal artery was absent. During the next three days large groups of muscles of all compartments of leg were found devitalised and patches of bluish and black discoloration over sole and dorsum were found extending to include all toes. Second toe had dry gangrene. In the presence of continuing deterioration with a picture of impending gangrene of foot and ischaemic necrotising myositis of leg, prognosis appeared to be grave and above-knee amputation was considered. However, it was decided to restrict the progress of necrosis by administration of OHP and the patient was sent for HBO therapy 10 days after the injury. He was found toxic and was managed by free incision drainage of the necrotic muscle groups, antibiotics and OHP. He had 2 exposures of 2 hours on the first day followed by one exposure daily for the next 8 days. Local discoloration started improving after the 4th exposure. Local temperature gradually improved and healthy granulation tissue was found after 6 days. The patient was then managed on daily dressings but as the improvement became static a second course of OHP was given after 10 days with daily exposures of 2 hours for 6 days. Remarkable improvement was noted both in local condition and toxæmia. Reconstructive surgery with skin grafting was undertaken later and thus a leg was saved which was almost being lost.

Case 2

HRB, 35 years, male. A victim of a motor cycle accident who sustained compound fracture of right tibia and fibula at the upper third. Gross vascular insufficiency was noted in the right leg and foot with bluish discoloration, cold extremity and absence of pulsation. He was treated with antibiotics and frequent drainage. There was no improvement in the patient's condition and he was referred on the third day after the accident for HBO therapy. OHP was administered twice during the first 24 hours and subsequently treated with one daily exposure for 10 days. He became fully ambulatory and returned to his full duties with a mild degree of foot drop, which has been corrected by a surgical boot.

Case 3

C, 30 years, male. A case of scooter accident sustaining fracture of left tibia and fibula with absence of pulsation below popliteal artery, cold feet and cyanotic discoloration. He was given OHP within 12 hours of the accident and 2 exposures during first 24 hours and one exposure daily on subsequent days. He did not show any improvement in temperature or discoloration and OHP was discontinued after 10 days. A below-knee amputation had to be carried out.

Case 4

PN, 22 years, male. A case of motor cycle accident who sustained fracture left femur, tibia and fibula. This was treated with nailing of femur and POP for tibia and fibula. This was followed by acute swelling of leg, pain and bluish discoloration from the ankle spreading upwards. He was treated with OHP, with one exposure daily. He reported relief from 4th day onwards and became symptom-free after 14 exposures.

Case 5

SN, 40 years, male. Met with a scooter accident sustaining multiple soft tissue injuries of right side of body, of right leg and thigh. X-ray showed gas shadows on lateral aspect of thigh and smear showing spore-bearing organisms. There was gross contamination of the wound with discoloration of leg and the foot was found cold. Along with other treatment he was given OHP with 2 exposures on the first day and one exposure daily on subsequent days. After the third exposure his local and general condition improved considerably with return of colour and

improvement in temperature. Pathological report did not confirm Cl. Welchii and OHP was discontinued after the progress was found to be satisfactory.

Case 6

ML, 24 years, male. A case of motor cycle accident sustaining fracture of right tibia and fibula. The patient was received after 24 hours for OHP treatment with cold feet and cyanotic discoloration upto ankle and absence of pulsation below popliteal artery. He was treated with 2 exposures during first 24 hours and one exposure daily on subsequent days for a total of 15 exposures. The improvement was noticed after the 4th day and he had an uneventful recovery.

Case 7

S, 22 years, male. A case of motor cycle accident with fracture of right tibia and fibula. His foot was cold with bluish discoloration upto ankle when the patient was received 24 hours after injury for OHP treatment. He was given 2 exposures during first 24 hours and one exposure daily on subsequent days. Local condition improved considerably on the third day and OHP treatment was discontinued 4 days later.

Case 8

GP, 48 years, male. A case of motor cycle accident with fracture right tibia at upper third and dislocation of head of fibula. The patient was received 3 days after the injury with foul smelling wound, oedema leg, cold feet with black discoloration below knee and absence of pulsation of popliteal artery. He was treated with 2 exposures of OHP on first day and 2 on second day. Gangrene had already set in and above-knee amputation was performed after the second OHP exposure. OHP was continued for 5 days, the wound healed and he responded well without further complications.

Group II: Extensive injuries of hand with threatened gangrene

Case 9

G, 20 years, male. Received extensive injuries of right hand, arm and palm from a rotating propeller of an aircraft. He had comminuted fracture around elbow joint including radius and ulna, injury of hand involving complete loss of 4th and 5th fingers from metacarpal, loss of thumb, middle and index finger from base of proximal phalanx, injuries of flexors of forearm, triceps and brachialis muscles

with damage to brachial artery. There was complete loss of skin on flexor side of forearm, hand and fingers. Due to the extensive nature of the injuries, OHP was started after the local dressing. 2 exposures were given during the first 24 hours followed by one exposure daily for next 7 days. The wound was covered with split skin graft from the thigh which took up well during OHP therapy. Reconstruction was done later with plastic surgery.

Case 10

GD, 35 years, male. Suffered an accidental blast injury of right hand from explosion of a grenade. Whole hand was macerated with multiple fractures. Fore finger and middle fingers were hanging loose with compound fracture through the base of metacarpal bones. Thumb and little fingers had compound dislocation and disruption of carpo-metacarpal joints. Ring finger had compound fracture through the base of metacarpal bone but had adequate tissue around it. Vitality of thumb was very doubtful. Index and middle fingers were shattered. Fracture dislocation of thumb, ring and little fingers were reduced and flaps were designed to give maximum skin coverage. OHP was started with 2 exposures during first 24 hours, 2 exposures on the second day and one exposure daily for the next four days. The skin graft was well taken and the thumb showed remarkable improvement in blood supply. Reparative surgery was carried out and the patient was discharged with working thumb, ring and little fingers with good range of movements.

Case 11

JW, 19 years, male. While working on a lathe the patient received crush injury of right hand resulting in degloving of skin from palm and dorsum upto the wrist. The patient was treated with antibiotics and local dressing for 15 days. Terminal phalanges of all fingers developed dry gangrene. Degeneration of skin was found extending proximally and secondary infection could not be brought under control. The patient was sent for OHP therapy after 15 days. He was given 2 exposures of OHP during first 24 hours followed by one exposure daily for next 3 days. Amputation of terminal phalanges was carried out. The wound was found to be clearing and skin grafting was carried out to cover the big area of raw wound over the palm followed by plastic surgery.

Case 12

HJ, 26 years, male. A case of blast injury of

right hand received while working on an aircraft engine. Whole hand was disorganised. There was deep lacerated wound running between the 4th and 5th fingers extending to the palm, and the index and middle fingers were hanging at the metacarpo-phalangeal joints and the thumb was hanging with a skin tag. Surgical toilet and repair were done. On the 5th day, gangrene of the index and middle fingers was noticed extending upto proximal phalanx of middle finger. He was treated with OHP for 7 days. Improvement was noticed from the 4th day in local and general condition. Discolouration was reduced and healthy granulation tissue was observed. Disarticulation was done at metacarpophalangeal joints of middle and index fingers. Wound healing was satisfactory and the thumb was taken up very well. He was discharged with a hand having a reasonably good grip.

Group III: Fracture of bones of forearm and arm resulting from accidental fall with acute vascular insufficiency and threatened gangrene

Case 13

GE, 5 years, male. Sustained right supracondylar fracture complicated with progressive ischaemia of hand and forearm on the 5th day after the injury. The boy was referred for OHP therapy and was found to have marked oedema with blister formation upto the lower third of forearm with black finger tips. The hand was completely cold. He was treated with OHP with 2 exposures on the first day followed by one exposure daily on subsequent days for 4 days. Local condition showed improvement on the 3rd day, temperature improved and the dark patches gradually cleared up. Impending gangrene was stopped and the fracture was managed followed by physiotherapy.

Case 14

B, 8 years, male. Sustained fracture of right humerus, radius and ulna from an accidental fall from a tree. His forearm was found cold with bluish discolouration which was noticed on the 3rd day. He was treated with OHP for 7 days. After 3 days of treatment gradual improvement was noticed and he made an uneventful recovery.

Results

Of the 14 cases treated with OHP, 8 cases had extensive injuries to the lower limb with threatened gangrene. Two of these cases reported a number of

days after the accident and took much longer time to heal. In 5 cases, treatment could be started early and showed good recovery. In one case, OHP had no beneficial effect after 10 days of treatment and amputation had to be carried out. Out of 4 cases of extensive injuries to the hand, one case reported 15 days after the injury. In this case HBO was helpful in controlling the infection and for a better uptake of skin graft during subsequent treatment. In other 3 cases, the injuries were extensive and with the impending gangrene, amputation at the level of wrist was considered unavoidable. However, OHP could save the damaged tissue and with reconstructive surgery all these patients were discharged with a working hand and a reasonable grip.

Discussion

In the treatment of limb injuries with acute vascular insufficiency OHP has an important role in removing ischaemia and delaying tissue necrosis. Oxygen is made available to the tissues for survival in an effort to buy time so that circulation can again be restored either by development of new collaterals or by opening up the existing ones. The main question is whether the tissue can be kept alive till such time reparative processes take place and this depends mostly on two factors: (a) the extent of damage to the blood vessels and tissues, and (b) the initial delay to start OHP treatment after the onset of vascular insufficiency. It has often been argued that the effect of OHP in augmenting the availability of oxygen in ischaemic tissue is doubtful, as increased oxygen content in blood is often nullified by associated vasoconstriction. In normal persons a reduction in limb blood flow by about 20 percent has been observed during exposure to OHP at 2 ATA. However, the associated vasoconstriction limiting the blood flow on exposure to OHP may be explained as a protective mechanism in normal healthy limb to limit oxygen and is not likely in ischaemic tissue where oxygen is primarily deficient. Stalker⁶ et al reported the effect of increased oxygen in experimentally produced acute prolonged ischaemia in the hind leg of dogs and observed that during hyperoxia availability of oxygen is increased in ischaemic limb with an increase in oxygen tension of the effluent venous blood. The argument based on the finding, of Bird and Telfar⁷ that OHP may lead to acute vasospasm has not been supported by other workers and with our experience with over 10,000 exposures in the hyperbaric chamber at our Institute a situation has not been met where acute spasm has occurred precipitating a crisis.

In extensive injuries where damaged tissues are badly contaminated and gross secondary infection has developed, blood vessels are likely to be affected due to infection and OHP helps in restricting its spread. It is more so in cases of road accidents where gas gangrene and tetanus are likely complications. Capillary proliferation, formation of healthy granulation tissue and epithelial regeneration are improved⁵ with OHP which accelerates healing. Excision of necrosed tissue can be delayed to an appropriate time and the extent of tissue loss can be reduced. Elective surgery can be undertaken when definite zone of demarcation is seen in cases of gangrene.

OHP in ischaemic limb injuries can be more effective if the therapy is instituted early, before the onset of gangrene. In extensive injuries with badly contaminated wounds it may even be used as prophylactic treatment wherever the facility exists. However, it should be kept in mind that OHP is not an alternative or replacement for surgery, but a powerful therapeutic adjunct to surgical treatment.

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