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## HYPERBARIC OXYGEN THERAPY

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### WHAT IS HYPERBARIC OXYGEN THERAPY?

Hyperbaric Oxygen Therapy (or HBO) is not a new or exotic medical therapy. Increased atmospheric pressure was already used for medical purposes by Henshaw, a British physician, in the 1600's - albeit with uncertain success. The first important clinical application of HBO was in 1957 when Boerema, a Dutch cardiac surgeon, discovered that exsanguinated piglets could survive without red blood corpuscles when pressurised to three times atmospheric pressure (2280 millimetres mercury) while breathing oxygen. His studies were directed at discovering a way of extending the available operating time in patients requiring open heart surgery. HB provided him with the extra minutes he needed. *HBO therapy has since developed into a well respected medical speciality.*

### HOW IS HBO TREATMENT GIVEN?

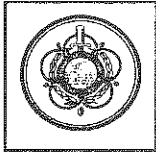
Patients receiving HBO are treated in a specialised pressure vessel known as a *hyperbaric chamber*. In these chambers the pressure can be raised above 760 millimetres mercury (i.e. the normal atmospheric pressure at sea level or 1 atmosphere absolute) while the patient breathes *one hundred percent oxygen*. The increased pressure causes a 10- to 15-fold increase in dissolved oxygen with a dramatic increase in tissue oxygen delivery. It was found that subcutaneous tissues had PO<sub>2</sub> values of 1400 millimetres mercury in patients breathing oxygen at two atmospheres absolute and that these remained elevated for up to four hours after returning to normobaric conditions. This effect could only be achieved by breathing 100 percent oxygen in hyperbaric (pressurised) chamber, and high pressure topical oxygen was ineffective. *HBO must be delivered to tissues by the circulation.*

There are two types of hyperbaric chambers, *monoplace* and *multiplace*:

*Monoplace chambers* can only accommodate one patient at a time and are pressurised with pure oxygen. *Multiplace chambers* allow more than one patient to be treated and are pressurised with compressed air while the patient breathes oxygen via a special mask or head tent.

The pressures that can be attained in these chambers may exceed six atmospheres (motor car tyres are inflated to three atmospheres absolute/two bars) although one hundred percent oxygen should only be delivered at pressures below three atmospheres absolute. Above three atmospheres oxygen becomes too toxic for general use. Multiplace chambers require attendants both in-and outside the chamber with an intercom link between them. The larger infrastructure and need for more personnel, make multiplace chambers more costly to run than monoplace chambers, but multiplace chambers do have an important advantage: medical attendants can enter the chamber with the patient to provide essential medical treatment (ventilation, CPR, defibrillation, drug administrations, suctioning, nursing, etc) that may be needed during HBO.

The Hyperbaric Therapy Unit at the Institute for Aviation Medicine (IAM) has a multiplace facility and is staffed by physicians trained in hyperbaric medicine. Patients are treated on almost a daily basis. Pressurisation of the chamber to 2,4 atmospheres generally takes between five and ten minutes followed by three thirty minutes sessions on oxygen. The sessions are interrupted by two intervals of five minutes breathing air (air breaks). At the end of the third session, the chamber is again



depressurised. Usually patients listen to music, read, or simply relax during the ninety minutes treatment that may be required once to three times a day. A minimum wait of four to eight hours is allowed between HBO treatments. The duration, pressure, frequency and number of treatment required depends on the condition being treated. The Hyperbaric Therapy Unit at IAM follows established international treatment protocols for HBO.

HBO has expanded so rapidly that the present IAM chamber is being replaced by a larger chamber in August. The new chamber, unlike the present one, was specifically designed for hyperbaric oxygen therapy by a South African company - Southern Oceanics. It is 4,5 metres long with a diameter of 1,8 metres. As chambers go this is very spacious. It has facilities for ventilating patients, it can accommodate intensive care monitoring (e.g., ECG, arterial lines, pulmonary arterial catheters, intracranial pressures and electro-encephalograms) and also boasts an ingenious patient loading system for non-walking patients.

### HOW DOES HBO WORKS?

During HBO, significant physiological mechanism are activated and oxygen attains certain pharmaceutical properties :

\* *Mechanical effect of increased pressure:*

Any free gas trapped in the body will decrease in volume as pressure increases (Boyle's Law). With a threefold increase in pressure, the size of the bubble, trapped in the body, is reduced by two-third. This ability to reduce gas volume has been successfully applied in the treatment of air embolism and decompression sickness.

\* *Hyperoxygenation:*

HBO physically dissolves extra oxygen into the plasma and tissues. Breathing pure oxygen at twice atmospheric pressure increases the tissue oxygen pressure in compromised tissues to normal or greater-than-normal values. It then induces the formation of new capillaries in ischemic or poorly perfused wounds due to the extreme oxygen gradient between the well oxygenated and hypoxic areas.

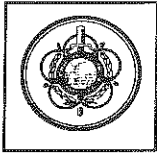
\* *Effects on the microcirculation:*

High-pressure oxygen causes vasoconstriction in normal tissues while maintaining oxygenation. This narrowing does not occur in injured, ischaemic tissues. HBO is therefore extremely useful in crush injuries and other traumatic ischemias. HBO also markedly reduces adherence of white cells to capillary walls thus preventing ischaemia-reperfusion injuries or the "no-reflow" phenomenon. Edema is reduced up to fifty percent through preservation of high-energy phosphate bonds (ATP) in the cells. HBO diffuses two to three times as far from capillaries into tissues. This keeps injured tissues with sparsely functioning bloodvessels alive. Preservation of ATP is also important in preventing progression of deep second-degree burns to full-thickness injury requiring grafting.

\* *Antibacterial activity:*

HBO inhibits the growth of a number of anaerobic organisms and enhances white cell killing of aerobic organisms. HBO can double or triple the bacteria-killing ability of white cells. It is particularly useful in patients where resistance factors are compromised. HBO acts synergistically to most antibiotics and even potentiates the bactericidal effect of aminoglycosides.

Other mechanism of HBO include angiogenesis, osteogenesis and increased blood/brain barrier



permeation.

## WHAT IS HBO USED FOR?

The indication for HBO vary considerably from country to country. The Hyperbaric Oxygen Committee of the Undersea and Hyperbaric Medical Society - a well respected international organisation, makes recommendations for the use of the HBO. The present recommendations are as follows:

### \* *Air or Gas Embolism*

HBO is the undisputed primary treatment for air embolism. It decreases bubble size and hastens the resolution of the embolized gas. It reduces mortality and minimises permanent neurological damage. There is no effective alternative therapy. Causes of air embolism include lung overpressure injuries during scuba diving, open heart surgery, neurosurgery, certain radiological procedures, arthroscopy, etc..

### \* *Carbon monoxide-, cyanide poisoning and smoke inhalation*

HBO is considered mandatory for severe carbon monoxide (CO) poisoning (i.e. where loss of consciousness or pregnancy are present). HBO breaks up carboxyhemoglobin at a much faster rate than oxygen at one atmosphere. Only HBO can mitigate a number of the complications of CO poisoning - including permanent neurological sequelae.

Death by smoke inhalation is the leading cause of death in fires. Due to the increase in synthetic building materials, cyanide gas - liberated by burning polymers and silk has been identified as a key contributor to some of these deaths. Carbon monoxide (CO) poisoning is an important co-contributor.

When CO is complicated by cyanide poisoning, HBO may have a direct effect in reducing the toxicity of cyanide.

### \* *Clostridial Myonecrosis (Gas Gangrene)*

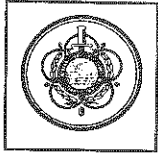
The recommended treatment for gas gangrene is a combination of HBO, surgery and antibiotics. When used early (i.e. within 24 hours of making the diagnosis) and *before* surgery, HBO can save many lives. The mortality rate is less than 11% using HBO compared to more than 30% without it. This is because HBO terminates the production of alpha-toxin - the lethal complication of gas gangrene. HBO also radically diminishes tissue destruction, and the need for extensive debridements and amputations. Following several sessions of HBO, patients are also in a far better condition to receive- and more likely to survive surgery.

### \* *Crush Injury and Other Acute Traumatic Ischemias*

HBO increases tissue oxygen tensions to levels which restore host responses to infections and acute ischemia and prevents ischaemia-reperfusion injuries. HBO may also negate the need for fasciotomy in compartment syndromes (if initiated early) by reducing edema. This means that less surgery, skin grafting and debridements are needed.

### \* *Decompression Sickness (DCS)*

HBO is the primary treatment for DCS. The increased pressure reduces bubble size while the oxygen establishes a favourable diffusion gradient to rapidly wash out the inert gas from the bubbles and provide oxygenation to ischemic and hypoxic tissues. There is no alternative therapy.



\* *Problem Wounds*

In an hypoxic environment, wound healing is halted by decreased fibroblast proliferation, -collagen production and -capillary angiogenesis. HBO restores a favourable cellular milieu in which healing and antibacterial mechanisms are restored and enhanced.

\* *Exceptional Blood Loss Anaemia*

In exceptional cases (Jehovah's Witnesses and certain haemolytic anemias) when cross-matched whole blood transfusion is not possible, the intermittent use of HBO dissolves enough oxygen in the severely anaemic patient to support metabolic needs until sufficient red blood cells are replaced by the body.

\* *Necrotizing Soft Tissue Infections*

As an adjunct to debridement and systemic antibiotics, HBO inhibits anaerobic bacterial growth by direct toxic mechanisms and potentiates white cell bacterial killing ability. This is clinically equally effective to administering an organism specific antibiotic and is additive thereto. Published studies indicate the routine use of HBO can decrease mortality in necrotizing soft tissue infections by two-thirds.

\* *Refractory Osteomyelitis*

HBO is an essential adjunct to antibiotics, debridement, nutritional support and reconstructive surgery in superficial, localized and diffuse refractory osteomyelitis, particularly when the patient is immunocompromised (as is usually the case). HBO also considerably improves the prognosis of sternal wound infections following cardiac surgery.

\* *Radiation Tissue Damage*

In proper coordination with surgical treatment, HBO has totally revolutionised the treatment of radiation necrosis. It has been shown to stimulate growth of functioning capillaries, fibroblast proliferation and collagen synthesis in radiated bone and soft tissue. HBO restores radiated tissues to within eighty percent of non-irradiated tissue. Healing can then occur normally and grafting of soft tissue and even bone is possible.

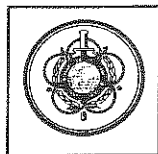
\* *Compromised Skin Grafts, Flaps and Replants*

Following ischemia or vascular repair (where there has been decreased microcirculation or hypoxia), HBO maximizes the viability and functional outcome of compromised nerve-, muscle-, bone- and skin grafts.

\* *Thermal Burns*

Although conventional treatment in burn centre is of primary importance in serious burns (e.g. more than 20% body surface area) adjunctive HBO helps to maintain microvascular integrity, minimizes edema, prevents propagation of burns into the adjacent and subjacent tissues and provides the substrate necessary to maintain the viability of the surrounding tissue. Mortality, hospital stay and the need for skin grafting are markedly reduced with the addition of HBO.

HBO is essential adjunctive to total patient care that may include life support, resuscitation, surgery,



antibiotic therapy and nutrition. When applied to treat accepted diseases in selected patients, results are very gratifying and sometimes even spectacular. Favourable results are frequently associated with the addition of HBO in the early phases - the "golden period", of the disease process (i.e., within ten thirty minutes in decompression illness or air embolism, four hours in head or spinal cord injury, and twenty-four hours in thermal burns).

Statistics have shown good success rates:

- \* 90 to 100 percent neurological recovery in air embolism and decompression sickness
- \* 88 percent success rate in previously non-healing, complicated and compromised wounds
- \* 90 percent viability restored in compromised skin grafts
- \* 89 percent (survival) in gas gangrene.

#### **SIDE EFFECTS AND SPECIAL PRECAUTIONS. IS HBO SAFE?**

Serious side effects are extremely rare in HBO. Personnel working in the Hyperbaric Therapy Unit are trained to prevent, identify and manage any problems that may occur.

The most common minor problems of HBO are barotrauma of the ears and sinuses caused by pressure changes and transient changes in visual acuity. Patients are taught middle ear autoinflation techniques and sometimes require the help of decongestants. When inability to equalise interferes with treatment, HBO may be delayed or postponed until the problem has resolved or grommets can be inserted. In emergency treatments and in unconscious patients a simple myringotomy may be performed.

Prolonged high pressure oxygen can cause two potentially serious conditions: seizures and pulmonary oxygen toxicity.

Seizures are extremely rare during HBO (1:10 000 treatments). They are not inherently harmful and, if they do occur, are self-limiting. HBO need not even be discontinued after a seizure, although additional precautions are taken. The risk of seizures can be minimised by reducing the oxygen partial pressure, providing air breathing intervals during HBO and giving prophylactic vitamin E.

A history of seizures, fever, acidosis, and low blood sugar are known risk factors and are taken into account before treatment is begun. Conventional seizure prophylaxis is effective and may be considered in selected cases.

Pulmonary oxygen toxicity is not seen in standard HBO therapy. It is far common under normobaric conditions with patients on high oxygen percentages for extended periods (e.g., in an Intensive Care Unit). However, if a patient requires an  $FiO_2$  of more than 0,4 (i.e., 40 percent oxygen) to maintain oxygenation, HBO may be contraindicated.

A few patients suffer from confinement anxiety that may interfere with treatment. This is reduced by having an attendant inside the chamber with the patient, by reassuring the patient that treatment may be discontinued on request any time, by using relaxation techniques and even by administering a mild sedative if necessary. Once the patient is being treated however, distraction by music alleviates anxiety and helps to pass the time.

Because of the increased  $PO_2$  under pressure, there is a slightly increased risk of fire. This is controlled by eliminating factors such as volatile substances, petroleum-based cosmetics, toiletries, jewellery, paper and synthetic fabrics. Obviously, items necessary for continuation of care that do not pose an immediate risk, are left in place.



Patients are expected to stop smoking during the entire course of HBO therapy. The vasoconstricting effect of nicotine interferes with angiogenesis. Smokers also have high carbon monoxide levels and consequently fail to receive the full benefit of oxygenation, especially between treatments.

#### ARE THERE ANY CONTRAINDICATIONS TO HBO?

The only absolute contra-indications for HBO are an untreated pneumothorax and doxorubicin (Adriamycin) or cis-platinum therapy. There are some relative contraindications such as active viral infections, sinusitis, early pregnancy, etc. Patients with an accepted indication for HBO are evaluated individually by the baromedical physician and are selected for HBO on a risk versus benefit basis.

#### HOW ARE PATIENTS REFERRED FOR TREATMENT?

Each patient, whether inpatient, outpatient or emergency transfer, will be evaluated by a physician from the Hyperbaric Therapy Unit upon request of the attending physician. Emergency referrals from another hospital can be accepted by telephone consultation. Before treatment begins, the patient receives a complete orientation to the chamber (if possible) and signs the consent forms.

The Hyperbaric Unit is situated at the Institute for Aviation Medicine in Verwoerdburg and is open from 8 a.m. to 4 p.m. five days a week for routine cases. Emergency treatment is available after hours. We welcome any enquiries and requests for further information.

#### WHAT ARE THE FINANCIAL IMPLICATIONS OF HBO THERAPY?

HBO therapy is both clinically- and cost-effective. It resolves a high percentage of notoriously difficult and expensive disorders and minimises hospitalisation. In its oldest accepted indication - air or gas embolism, HBO results in a marked decrease in mortality and morbidity. In carbon monoxide poisoning (including those complicated by cyanide poisoning), HBO is the primary method of treatment and is easily justified.

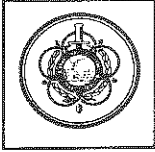
In crush injuries, where the percentage of complications is very high, costs may run between R50 000 and R100 000 for conventional treatments. The cost of total management *including* HBO may be less than one-sixth of that amount if applied correctly. The astronomical financial impact of non-traumatic amputations in diabetics is substantially lowered by HBO by preventing long term morbidity, the need for rehabilitation and general suffering. These are but a few examples of the financial advantages of using HBO. Many medical insurance carriers are prepared to reimburse HBO therapy if it is justified. For approved conditions, motivating letters or literature will gladly be provided by the Institute.

Charges for treatment (where applicable) vary depending on the severity of the patient's illness. Chronic conditions (which may be treated on an outpatient basis) generate a lesser charge than acute conditions or emergencies, where patients may require complex nursing and medical care during the HBO treatments.

#### SUMMARY

HBO is a safe and adjunctive treatment. It is used extensively throughout the world and is based on sound scientific principles. It only is available in South Africa at the Institute for Aviation Medicine in Pretoria and the Institute for Marine Medicine in Simon's Town. Several other hyperbaric chambers around the country may offer this service if requested. For more details on HBO please contact the author at the Institute for Aviation Medicine at (012)664-5954 extension 2054.

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