8 Indications, Contraindications, and Complications of HBO Therapy

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In this chapter we summarize the literature and present a synthesis regarding:

Table 8.1
Uses of HBO Approved by the Undersea and Hyperbaric Medical Society

- Air or gas embolism
- Carbon monoxide poisoning and carbon monoxide poisoning complicated by cyanide poisoning
- Clostridial myonecrosis (gas gangrene)
- Crush injury, the compartment syndrome, and other acute traumatic ischemias
- Decompression sickness
- Enhancement of healing in selected problem wounds
- Exceptional anemia resulting from blood loss
- Necrotizing soft tissue infections (of subcutaneous tissue, muscle, or fascia)
- Refractory osteomyelitis
- Intracranial abscess
- Radiation tissue damage (osteoradionecrosis)
- Compromised skin grafts and flaps
- Thermal burns

Indications

Indications for hyperbaric oxygen (HBO) therapy vary in different countries and are described in Chapter 43. The indications approved by the Undersea and Hyperbaric Medical Society (Table 8.1) are very limited and rely on the proof of efficacy of HBO by controlled studies. A summary of indications is shown in Table 8.2. The table lists all the conditions where HBO has been shown to be useful, although, to date, few of these have been proven by controlled studies.

Contraindications

Contra-indications for HBO therapy are shown in Table 8.3.

Pneumothorax. The only absolute contraindication for HBO is untreated pneumothorax. Surgical relief of the pneumothorax before the HBO session, if possible, removes the obstacle to treatment.

The contraindications listed below are not absolute but relative. The potential benefits should be weighed against the condition of the patient and any ill-effects that may occur.

Upper Respiratory Infections. These predispose to otobarotrauma and sinus squeeze.

Emphysema with CO_2 Retention. Patients with this problem may develop pneumothorax due to rupture of an em-

Table 8.2
Summary of International Indications for HBO

1. Decompression sickness
2. Air embolism
3. Poisoning: carbon monoxide, cyanide, hydrogen sulfide, carbon tetrachloride
4. Treatment of certain infections: gas gangrene, acute necrotizing fascitis, refractory mycoses, leprosy, osteomyelitis
5. Plastic and reconstructive surgery:
   - for nonhealing wounds
   - as an aid to the survival of skin flaps with marginal circulation
   - as an aid to reimplantation surgery
   - as an adjunct to the treatment of burns
6. Traumatology: crush injuries, compartment syndrome, soft tissue sports injuries
7. Orthopedics: nonunion of fractures, bone grafts, osteoradionecrosis
8. Peripheral vascular diseases: shock, myocardial ischemia, aid to cardiac surgery
9. Peripheral vascular disease: ischemic gangrene, ischemic leg pain
10. Neurological: stroke, multiple sclerosis, migraine, cerebral edema, multi-infarct dementia, spinal cord injury and vascular diseases of the spinal cord, brain abscess, peripheral neuropathy, radiation myelitis, vegetative coma
11. Hematology: sickle cell crises, severe blood loss anemia
12. Ophthalmology: occlusion of central artery of retina
13. Gastro-intestinal: gastric ulcer, necrotizing enterocolitis, paralytic ileus, pneumotoides cystoides intestinalis, hepatitis
14. For enhancement of radiosensitivity of malignant tumors
15. Otorhinolaryngology: sudden deafness, acute acoustic trauma, labyrinthitis, Meniere's disease, malignant otitis externa (chronic infection)
16. Lung diseases: lung abscess, pulmonary embolism (adjunct to surgery)
17. Endocrines: diabetes
18. Obstetrics: Complicated pregnancy – diabetes, eclampsia, heart disease, placental hypoxia, fetal hypoxia. Congenital heart disease of the neonate
19. Asphyxiation: drowning, near hanging, smoke inhalation
20. Aid to rehabilitation: spastic hemiplegia of stroke, paraplegia, chronic myocardial insufficiency, peripheral vascular disease.

Table 8.3
Contraindications for HBO Therapy

Absolute
- Untreated tension pneumothorax

Relative
- Upper respiratory infections
- Emphysema with CO_2 retention
- Asymptomatic air cysts or blebs in the lungs seen on chest X-ray
- History of thoracic or ear surgery
- Uncontrolled high fever
- Pregnancy
- Claustrophobia (see complications of HBO)

physematous bulla during HBO. Pretreatment x-rays of the chest should be taken to rule this out.

Air Cysts or Blebs in the Lungs Seen on Chest X-Ray. These may predispose to pulmonary barotrauma by causing air trapping during HBO treatment. A survey was conducted to determine how patients were evaluated for pulmonary blebs or bullae in different hyperbaric centers (Toklu *et al* 2008). Of the 98 centers that responded to a questionnaires, sixty-five (66.3%) reported that they applied HBO to the patients with air cysts in their lungs. X-ray was the most widely used screening method for patients with a history of a lung disease. The prevalence of pulmonary barotrauma in theses centers was quite low at 0.00045%.

History of Thoracic Surgery or Ear Surgery. The patient should be thoroughly evaluated before HBO therapy is considered.

Uncontrolled High Fever. Fever predisposes to seizures. If HBO therapy is indicated for an infection with fever, the temperature should be lowered before therapy is commenced.

Pregnancy. There is animal experimental evidence that exposure to HBO during early pregnancy increases the incidence of congenital malformations. However, if a pregnant woman is poisoned with CO_2 the primary consideration is to save the mother's life. Exposure to HBO later in pregnancy appears to have no adverse effects. If the mother's life is threatened, for example in CO poisoning, she should receive HBO therapy as this has priority over consideration for the fetus. Many successful HBO treatments have been carried out during pregnancy without any danger to the fetus (see Chapter 33).

The following conditions have been considered to be contra-indications previously but are not supported by evidence. Several patients have been treated by use of HBO with aggravation of these conditions.

Seizure Disorders. Patients CNS disorders such as stroke may suffer seizures as a manifestation their primary disorder. However, seizures are rare during HBO sessions for neurological indications where the pressures do not exceed 2.5 ATA. If the disorder is due to a focal cerebral circulatory disorder or hypoxia, HBO should help to reduce the tendency toward seizures. Wong and Zhao (1994) treated 100 epileptic children with HBO and reported improvement in control of seizures in 68% and cognitive function in 38%. They were able to reduce the amount off antiepileptic drugs and there was no aggravation of seizures.

Malignant Disease. There is some concern regarding the effect of HBO on tumor growth because HBO is used as an adjunct to radiotherapy and also for the treatment of radiation necrosis in patients who may have residual cancer. This topic is discussed in Chapter 16 where it is concluded that malignant disease is generally not considered to be a contra-indication for HBO therapy.

Complications of Hyperbaric Oxygenation

Some of the complications of HBO therapy are listed in Table 8.4.

Table 8.4
Complications of Hyperbaric Oxygen Therapy

- Middle ear barotrauma
- Sinus pain
- Myopia and cataract
- Pulmonary barotrauma
- Oxygen seizures
- Decompression sickness
- Genetic effects
- Claustrophobia

Middle Ear Barotrauma. This is the commonest reported complication of HBO but the incidence varies in different series. A review of 1505 patients who underwent 52,758 2-h HBO treatment sessions showed that patients had to be removed from the hyperbaric chamber during treatment on 198 occasions (0.37%) because of an inability to equalize middle ear pressure; the sessions were resumed after treatment and training (Davis 1989). In 11,376 HBO therapy sessions within a multiplace chamber in an orthopedic clinic, more than 17% of all patients experienced ear pain or discomfort as an expression of problems in equalizing the middle ear pressure (Plafki *et al* 2000). Most episodes were not related to a persistent eustachian tube dysfunction since they only occurred once. Barotraumatic lesions on visual otological examinations (ear microscopy) were verified in 3.8% of all patients. Patients with sensory deficits involving the ear region need special attention, because they seem to be at risk for rupture of the tympanic membrane (three cases documented).

The Eustachian tube openings in the nasopharynx are slit-like, and the patient may have difficulty in equalizing the middle ear pressure with that of outside air during compression. Most patients can learn to remedy this by Frenzel's maneuver which consists of pinching the nose, closing the mouth, and pushing the tongue against the soft palate to force air through the Eustachian tubes into the middle ears. This complication can lead to permanent hearing loss and vertigo. Unconscious patients and infants present a special diagnostic challenge because of difficulties in communicating pain and

equalizing pressure across the ears. The slow compression method of HBO has proved to be safer as well as better than the standard compression technique and reducres the incidence of middle ear barotrauma (Vahidova *et al* 2006).

The use of nasal decongestants is considered to be helpful. However, in a prospective, parallel, double-blind, randomized trial, there was no significant difference in the occurrence of ear discomfort in those receiving the decongestant oxymetazoline from those receiving spray of distilled water (Carlson *et al* 1992). This study suggests that topical decongestants may not be effective in preventing middle ear barotrauma. Capes and Tomaszewski (1996) carried out a phone survey to all hospital-based HBO centers in the United States concerning routine practice for middle ear barotrauma prophylaxis. Results indicate that more than a fifth of centers always do routine prophylactic myringotomies on intubated patients (30 of 126) and infants (19 of 86). Less than half of centers never performed the procedure as routine prophylaxis. A third of centers (49 of 145) routinely administered prophylactic drugs before HBO treatment. Topical nasal decongestants, particularly oxymetazoline, were preferred to systemic oral medications. These results show that there is great variance in clinical practice with regard to middle ear barotrauma prophylaxis among US HBO centers.

Clements *et al* (1998) reviewed 45 patients referred to a department of otolaryngology for inability to tolerate hyperbaric oxygen therapy. All patients underwent bilateral myringotomy and tube placement. Seventeen (38%) of these patients experienced complications, with most having more than one. Most complications occurred after conclusion of hyperbaric oxygen therapy. Otorrhea was most common, occurring in 13 patients (29%) and persistent tympanic membrane perforations occurred in 7 patients (16%). This rate of complications is higher than reported for placement of tympanostomy tubes in other patient populations. Coexisting illness, such as diabetes mellitus, may contribute to the development of complications in patients undergoing hyperbaric oxygen therapy. Alternative methods of tympanostomy, with emphasis on shorter duration of intubation, should be considered in this patient population.

In a prospective study, Fernau *et al* (1992) measured the changes in Eustachian tube function before and after HBO treatment in 33 adult patients by 9-step inflation-deflation test of Bluestone. Fifteen of these (45%) had evidence of Eustachian tube dysfunction after the treatment was initiated and all of them complained of a sensation of fullness in the ears. Thirteen of these patients (87%) developed serous otitis media and 7 (47%) required tympanostomy tubes. Patients with history of Eustachian tube dysfunction after first HBO treatment were found to be at greater risk of developing serous otitis media with subsequent treatments.

Unconscious patients are more likely to show barotrauma in the middle ear due to obvious inability to equalize pressure changes.

Sinus Pain. Sinus block during pressurization may produce severe pain, particularly in the frontal sinuses. If a patient has upper respiratory infection, the HBO treatment should be postponed, or, if it is urgently required, the patient should be given decongestant medication and the compression performed slowly.

Myopia and Cataract. Myopia is a reversible complication of acute exposure to HBO and cataract is a complication of chronic long-term exposure. These are discussed further in Chapter 32.

Pulmonary Barotrauma. Incidence of pulmonary barotrauma is quite low and most series with treatments under 2ATA do not report any cases. However, overinflation with pressure may lead to lung rupture, which may present as an air embolus, mediastinal emphysema, or tension pneumothorax. Pneumothorax in a patient under HBO treatment is a serious complication. In a multiplace chamber the physician should auscultate the patient, although the lung sounds are difficult to hear. Lung rupture may be suspected from the symptoms – sudden stabbing chest pain and respiratory distress. Tracheal shift and asymmetrical movements of the chest may be the only signs on physical examination. Decompression should be halted and thoracentesis performed. Plainly, this complication is more difficult to detect and to treat if it happens in a monoplace chamber.

Murphy *et al* (1991) reported three comatose patients who developed tension pneumothorax while receiving HBO therapy for CO poisoning. Each patient was intubated and received closed chest compressions for cardiac massage prior to HBO session. There was no evidence of pneumothorax prior to HBO therapy and tension pneumothorax was detected after decompression. These authors recommended serial physical examinations, arterial blood gas determinations, and chest radiographs in patients with a high index of suspicion of this complication in the setting of emergency HBO therapy.

Oxygen Seizures. Seizures as a manifestation of oxygen are described in Chapter 6. In a series of 80,000 patient treatments with HBO, only two seizures were documented, yielding an incidence of 2.4 per 100,000 patient-treatments and both cases occurred in a multiplace chamber pressurized to 2.4 ATA with O2 delivered by mask for three × 30 min with 5-min air breaks (Yildiz et al 2004). Use of pressure at 1.5 ATA does not lead to any oxygen-induced seizures when the duration of treatment was kept below one hour. If a seizure occurs in a multiplace chamber, the oxygen mask should be removed; this will invariably stop the seizure. If not, 60–120 mg of phenobarbital should be given. The chamber pressure should not be changed: sudden decompression of the chamber during a seizure can

cause lung rupture: Decompression can be carried out after the seizure stops.

Decompression Sickness. This occurs only when high pressures are used and decompression is sudden. It is more likely to occur in the attendants in the hyperbaric chamber who breathe air. Decompression sickness (DCS) occurs rarely during therapeutic compression to 6 ATA in air embolism cases. Richter *et al* (1978) reported an incident that occurred in Hanover, FRG. Twenty elderly patients were receiving HBO in a multiplace chamber at 4 ATA. One patient developed air embolism after 1 h when decompression was started during the first dive. During the second dive, at about 5 h, the chamber door was opened with a sudden explosive reduction of pressure. Five patients died of DCS. This was the first report of fatal accident involving DCS in a hyperbaric chamber. There are no reports of such a complication in recent years.

Genetic Effects. Treatment of cells with HBO can result in generation of reactive oxygen species and induction of DNA damage. Cytogenetic data obtained from peripheral blood of patients who were treated with HBO at 1.5–2 ATA for 40 min daily for 10 days showed significant increase of chromosome aberrations. These were considered to be mainly caused by chromatid and chromosome breaks and showed individual variations. These results indicate that HBO may have an indirect effect on the genetic apparatus of the human somatic cells. High quantity of chromosome breaks in cells of somatic tissues is an adaptive reaction of the organism to HBO.

Exposure to 100% oxygen at a pressure of 1.5 ATA for a total of 1 h has been shown to induce DNA damage in the alkaline comet assay with leukocytes from test subjects. Under these conditions, HBO does not lead to an induction of gene and chromosome mutations. Because of known genetic effects, exposure of humans to HBO is limited, and possible genetic consequences of HBO cannot be completely evaluated *in vivo*. HBO treatment of cell cultures is a suitable model for investigating the relationship between oxygen-induced DNA lesions and the formation of genetic chromosome mutations. The results of one study indicate that HBO induces sister chrmatid exchange and that lymphocytes retain increased sensitivity to the genotoxicity of mitomycin C one day after completing the HBO (Duydu *et al* 2006).

Claustrophobia. This is often referred to as a complication and or contraindication for hyperbaric therapy, and some patients decline or discontinue treatment for this reason. Claustrophobia is relatively common in the general population and some of the claustrophobic individuals may require HBO treatments. Claustrophobia can be a manifestation of anxiety due to confinement in a closed space and unfamiliar surroundings. It is more likely to be experienced in a small monoplace or portable chamber and less likely in a large multiplace chamber with easy communication to the outside. Hillard (1990) reported the case of a patient who refused HBO treatment because of her claustrophobia. After an intensive two-week treatment of her phobia, she underwent HBO treatments successfully.

Anxiety reactions. There are several reports in the literature of anxiety reactions in patients undergoing HBO treatment. Anxiety levels of patients undergoing HBO treatments can be assessed by Spielberger State-Trait inventory Questionnaire. There is an increase in magnitude of anxiety with a new treatment but this decreases after the treatment. It is important to communicate with the patient and explain the procedure with reassurance. Larger studies on this topic would be useful.

Complications in critically ill patients. Patients are more likely to have a complication during HBO treatment if they are critically ill, unconscious or intubated. Keenan *et al* (1998) reviewed thirty-two children were treated with HBO while mechanically ventilated: 21 had necrotizing infections, 9 had CO poisoning, and 2 had iatrogenic arterial air embolism. Complications or events occurring during HBO therapy included hypotension (63%), bronchospasm (34%), hemotympanum (13%), and progressive hypoxemia (6%).

Coincidental Medical Events in the Hyperbaric Chamber

A medical event may take place in the hyperbaric chamber and may not have any relation to the HBO therapy. Often such events are mistakenly attributed to HBO therapy. Reported coincidental events include the following:

1. Stroke
2. Myocardial infarction patients with known atherosclerotic disease and other risk factors for heart disease.
3. Focal seizures in patients with a history of epilepsy or intracranial lesions.

Precautions in Selection of Patients for HBO Treatment

In emergency situations, it is not possible to select patients and sometimes a risk has to be taken. For elective treatments, the patients should be screened carefully. History-taking should include information of any chest or ear operations.

Examination of the patient should include the following:

- *Chest x-ray*
- Pulmonary function testing
- Examination of the ear drums

In many other conditions, the decision should be made on an individual basis. Particular attention should be paid to the following two situations:

1. Large skull defects. In a patient with a large skull defect following surgery, HBO treatments should be avoided if the scalp flap is caved in.
2. Implanted devices.
   - Cardiac pacemakers. If the patient is wearing a cardiac pacemaker, it should be ascertained that it is one of the newer models that are pressure proof. Failure of temporary cardiac pacemakers has been reported under HBO. They recommended the use of permanent hermetically sealed pacemakers, which function quite well under hyperbaric conditions. In a recent review all pacemakers were reported to be adequate to treatment depths below 3 ATA (Simmons 1998).
   - Intrathecal pumps are used for administration of drugs directly into the intrathecal space of the spinal canal for relief of spasticity or pain. Baclofen infusion pump is used in paraplegic patients with spinal cord spasticity. These patients may be treated by HBO for decubitus ulcer. Akman *et al* (1994) reported a patient who developed retrograde leakage of CSF into the pump reservoir while undergoing HBO treatment at 2 ATA. There is no adverse effect of this except for the dilution of the medication in the pump. Tests by the manufacturers of these pumps have not shown any collapse of the pump although the pumps do not function during the exposure to high atmospheric pressure. This information may be important if spasticity is to be treated with HBO.

Increase of pain during HBO treatment was reported in another patient receiving morphine via an intrathecal pump (Baker 1992). Presumably the device did not function during the hyperbaric exposure.

Conclusions

Generally speaking, no serious complications are associated with moderate pressure HBO treatment, but some complications may be related to the primary disease treated. Contraindications should be noted and precautions taken during treatment of those with risk factors for complications. Some implanted devices used in treatment of patients may not function properly in hyperbaric chambers.