

Hyperbaric oxygen and cerebral palsy: no proven benefit and potentially harmful

Charles Essex FRCPCH DO, Consultant Neurodevelopmental Paediatrician, Child Development Unit, Gulson Hospital, Coventry CV1 2HR, UK.

Correspondence to author at above address.
E-mail: room101@ntlworld.com

Any good paediatrician will point out to the parents of a child with cerebral palsy (CP) that their child's brain damage is fixed and cannot be altered. This is not being over pessimistic but simply honest. The paediatrician then suggests a variety of treatments/therapies aimed at maximizing the child's potential. However, it is understandable if parents still go on to seek treatments which they hope can alter their child's condition. Such treatments include conductive education, cranial osteopathy, and hyperbaric oxygen (HBO) – to name a few. This article seeks to review available information on the use of HBO in the treatment of children with CP.

A review of 64 conditions treated with HBO concluded that evidence supported use of HBO in only 12 of them (Table 1). These are: very specific 'blood-gas' conditions (such as decompression sickness), healing, and certain infections.¹ They did not include neurological conditions such as multiple sclerosis (MS), stroke (either acute or chronic), nor CP.

HBO treatment is available in settings of variable quality. The best, safest, and highest quality HBO centres are usually associated with universities, hospitals, or naval bases. The treatment is administered in multiplace or monoplace chambers. Multiplace chambers have airlocks (which allow staff to enter in an emergency without decompressing the chamber) and cost around £300000. The chamber is pressurized with air and the patients breathe HBO through properly fitting face masks. This reduces the amount of oxygen in the chamber and lessens the risk of explosion or fire. Monoplace chambers allow treatment of one patient at a time; the patient is monitored and observed from outside. At the other end of the spectrum are monoplace chambers or head boxes that are run by local MS support groups, or even bought privately and installed in individuals' homes.²

Oxygen and the brain

Inspired air at sea level contains 21% oxygen and 79% nitrogen and has a pressure of 1 atmosphere absolute (ATA), or 760mmHg. The partial pressure of oxygen (pO_2) at 1ATA is approximately 160mmHg (21% of the total volume of gas). As oxygen passes from inspired air to the tissues, along each stage of the pathway its partial pressure drops. By the time it reaches the cells the pO_2 is only a few mmHg. Provided pO_2 is

more than 1 to 3mmHg in the capillaries adjacent to the cells, oxygen diffusion can take place and oxygen availability is not a limiting factor in the rate of chemical reaction in the intracellular organelles.³ Intracellular pO_2 cannot yet be measured in humans. However, microelectrodes implanted in the giant neurons of aplysia have shown an autoregulatory mechanism which keeps the intracellular pO_2 fairly constant at quite a wide range of extracellular pO_2 .⁴ It is uncertain whether increasing the tissue oxygen levels will cause the intracellular organelles to work more efficiently.

Under normal circumstances haemoglobin is 97% saturated with oxygen. Under hyperbaric conditions oxygen is dissolved in the plasma and the cells use this more readily than oxygen bound to haemoglobin. Oxygen delivery to the cells is, therefore, limited by blood flow rather than by haemoglobin. Oxygen is a vasoconstrictor and, paradoxically, hypercapnia rather than hyperoxia increases cerebral blood flow.

Why HBO treatment in CP?

A recent meta-analysis has shown that HBO treatment is ineffective in MS.⁵ Although it continues to be used by some individuals with MS and MS support groups, it has fallen in popularity and there are, therefore, a number of low-quality HBO facilities owned by MS groups which are underused. This fall in demand for HBO treatment for MS coincided with reports suggesting that there is a penumbra of inactivated or 'idling' neurons surrounding dead neurons which are viable but non-functioning and which can be re-activated with exposure to HBO.^{6,7} How long these neurons remain viable is uncertain. Research into neuronal function following acute stroke has focused on the period immediately after the brain insult (E Hillhouse, personal communication 1997) but anecdotal reports have noted improvement in function using HBO years after the initial insult. This led to the suggestion that HBO might be used to treat CP.

Does HBO treatment improve function in CP?

The largest randomized, placebo-controlled, double-blind trial consisted of 111 children with diplegia and quadriplegia who were treated with HBO or pressurized air as a placebo.⁸ Improvement in the HBO group was not greater

than that in the placebo group. Ear pain was experienced by 47% of the children in the HBO group and 28% of those in the placebo group. Criticisms of the study include the observation that the children in the HBO group may have been more severely affected than those in the placebo group.⁹ There is also the question as to whether the pressurized air was truly a placebo. A smaller unblinded study of 25 children with diplegia showed improvement in some children in their gross and fine motor skills, decrease in their spasticity, and improvement in their parents' perception of their skills.¹⁰ Thirteen of these children had grommets inserted because of ear pain.

The majority of evidence for the effectiveness of HBO treatment in children with CP is anecdotal or based on poor quality trials. Reports of the success of the treatment may be based on three possibilities: (1) although the lesion which has caused the CP is static, the clinical manifestations change. Motor skills of children with CP increase, albeit at a slower rate than in unaffected children, and these developments may be ascribed to the HBO treatment rather than to 'natural progress'; (2) there may be a subgroup of children with CP, perhaps a specific type of CP, who do improve more than would be expected over the period that a course of HBO treatment is given; (3) cognitive dissonance may play a part, i.e. it would be a very honest and brave person who would admit, after spending possibly thousands of pounds on HBO treatment, that it had not worked. This tendency is compounded if funds for the treatment have been raised by voluntary donations and there has been media interest in the case.

Can HBO treatment do any harm?

Hazards of HBO treatment are summarized in Table II. Even when used according to recognized guidelines, HBO can cause reversible barotrauma in 15 to 20% of patients; pulmonary symptoms in 15 to 20%; reversible ocular symptoms in up to 20%; and severe CNS symptoms in 1 to 2% of patients.¹¹ HBO treatment can cause barotrauma to the ear: unequal pressure between the external ear canal and the middle ear can cause otalgia and perforation of the tympanic membrane, or of the round or oval window, or bleeding into the middle ear, all of which are contraindications to diving; divers perform a Valsalva manoeuvre (forced exhalation effort against occluded nostrils and a closed mouth) as they descend,

to lessen the risk of barotrauma to the ear. It would be very difficult to teach a young child to perform the Valsalva manoeuvre: a child with spastic quadriplegia affecting the bulbar muscles may be unable to perform it. Children with significant communication difficulties would not be able to indicate that they had gone deaf or were experiencing dizziness. Consequently, the child may have to undergo repeated HBO treatments when unfit to do so.

If a plug of mucus blocks a bronchus or bronchiole when the pressure is increasing or decreasing, this can lead to a pneumothorax. As the pressure of a gas increases, its density also increases, and although this would not be noticed by healthy adults, a child who has a decreased respiratory reserve or impaired respiratory function may develop respiratory difficulties, particularly as treatment sessions last up to 1 hour. One of the effects of HBO is to wash out nitrogen which increases susceptibility to lung collapse.¹²

Myopia from -1.5 to -9 dioptres has been reported in adults following HBO treatment.^{13,14} Most resolved within 3 months of stopping the treatment. Myopia is generally pressure dependent and as CP is treated at pressures of 1.5 to 1.75ATA, there is less chance of myopia developing. Cataracts have also been reported as a result of HBO treatment.¹⁵

Contrary to popular opinion, an oxygen-rich atmosphere does not produce an increased fire risk as oxygen is not flammable. However, when oxygen is present, material that can burn will ignite more quickly and burn more readily. Burning rates increase exponentially as the percentage of oxygen in the atmosphere increases.¹⁶ In pure oxygen environments the burning rate is so rapid that a 'fireball' occurs. There have been 77 known deaths over a 73-year period from fires in HBO chambers¹⁷ and a further 11 people were incinerated in a fire in a multiplace HBO chamber in Italy in 1997.

Oxygen-induced convulsions have been reported at HBO pressures as low as 2.2ATA (P Bryson, personal communication 1988). Although HBO treatment is not intentionally used above 2ATA for children with CP, the calibration of the equipment of some chambers may be inaccurate. Also, children with CP are at increased risk of epilepsy compared with the general child population. It may be that the threshold for oxygen induced convulsions in this population is reduced. Conversely, those seizures which have been reported as occurring at relatively low pressures in hyperbaric chambers may have coincided with being in the hyperbaric chamber rather than

Table I: Therapeutic uses of hyperbaric oxygen treatment¹

Blood-gas conditions	Decompression sickness Arterial gas embolism Severe carbon monoxide poisoning and smoke inhalation Severe anaemia from blood loss
Healing conditions	Improved skin graft and flap healing Radiation induced injury Acute traumatic ischaemic injury Prolonged failure of wound healing Prevention and treatment of osteoradionecrosis
Infectious conditions	Clostridial myonecrosis Refractory osteomyelitis

Table II: Hazards of hyperbaric oxygen treatment¹¹

Ear pain
Perforated ear drum
Perforated round or oval window
Bleeding into the middle ear
Pneumothorax
Increased respiratory effort
Myopia
Fire/explosions
Oxygen induced convulsions
No examination of the child's/carer's fitness to have HBO treatment
Presence of assistants and their training
Not linked to hospital
Satisfactory insurance?

caused by the HBO treatment. Very few children or their carers are examined to assess their 'fitness' to undergo HBO treatment.

The Faculty of Occupational Medicine has written guidelines for the safe operation of hyperbaric chambers, including safety and maintenance standards, which the UK National Health Service hyperbaric facilities follow. The guidelines require that: (1) patients and carers are not allowed to take anything into the chamber which could cause a spark; (2) doctors trained in hyperbaric medicine are on site; (3) resuscitation and emergency equipment are available; (4) the chambers are flushed out with air between treatments; and (5) the chambers are linked to NHS hospitals.¹⁸

Many chambers do not have suitably qualified staff nor medical backup and cannot offer a rapid response in case of an emergency as they may be on industrial estates or in private homes. Most chambers do not have airlocks so that to get medical aid to the child would necessitate rapid decompression of the chamber which would put the patient at risk of decompression sickness. At some centres parents are taught how to use the chamber and are then allowed to operate the controls themselves. The standard of maintenance and safety regulations of these chambers is uncertain and probably very variable. Also, some of the organizations running the chambers may not have satisfactory insurance.

In summary, non-consenting children are being made to undergo treatment which has not been shown to be effective and which is potentially very dangerous. The optimum pressure in the chamber, length of each treatment, and the number of treatments to give maximum benefit (if any) and least risk have not been established. Further randomized placebo-controlled, double-blind trials are needed. Trials should be conducted at hyperbaric centres which adopt satisfactory working practices to ensure the safety of the children. All hyperbaric chambers should be registered, including ones in private homes, and minimum legal safety standards should be drawn up and rigorously enforced. Until then, parents should be advised of the lack of evidence of the effectiveness of HBO treatment and the risks involved. Enthusiastic use of oxygen for respiratory distress without proper trials in preterm babies led to numerous cases of blindness from retinopathy of prematurity in the 1940s and 50s.

To use a pertinent proverb, 'It is better to curse the darkness than to light the wrong candle'.

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