

# Late Treatment of Severe Brain Injury with Hyperbaric Oxygenation

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## ABSTRACT

Controlled studies have demonstrated safety and efficacy of hyperbaric oxygenation therapy (HBOT) in the treatment of anoxic, traumatic, ischemic, or thrombotic brain injury. Over the past 15 years, our clinic has treated 350 seriously brain-injured patients, from six months to 14 years after the event, many of whom suffered from various degrees of the apallic syndrome ranging from 1 to 8. Despite the hopeless prognosis that most patients were given by their physicians, varying degrees of clinical improvement occurred, along with substantial reductions in the cost of ongoing care. Clinical improvements were correlated with increased perfusion and metabolism, with reactivation of idling neurons demonstrated by sequential single photon emission computerized tomographic (SPECT) scanning.

## Background

With major traumatic or ischemic brain insults, there is an epicenter of irreversible damage surrounded by a plume of viable but "idling" neurons. It is hypothesized that improved tissue oxygenation, made possible through the much higher plasma concentrations of oxygen that occur when patients breathe 100 percent oxygen under hyperbaric conditions, can revitalize these dormant neurons. Oxygen tension in tissues and cerebrospinal fluid follows Henry's gas law.

In the 1970s, clinical and electroencephalographic (EEG) improvements were shown in both early and chronic post-stroke patients by Holbach and coworkers.<sup>1</sup> As previously noted,<sup>2</sup> randomized, controlled studies showed that HBOT improved survival and recovery rates in patients with traumatic brain injury,<sup>3</sup> as well as having a favorable effect on cerebral metabolism and intracranial pressure.<sup>4</sup>

Our clinic was the first to demonstrate the existence of the ischemic penumbra and its reperfusion after HBOT with sequential single photon emission computerized tomographic (SPECT) scanning.<sup>5,6</sup>

As we believed that this experimental work and the encouraging clinical results offered a promising new modality to treat otherwise hopeless cases, we made it available to patients seeking our care.

## Methods

As our facility is a clinic devoted to patient care rather than a research institution, we optimized each patient's treatment regimen according to our own judgment and the patient's circumstances. This is thus an observational study of approximately 350 patients referred to our clinic over 15 years as a "last resort."

Ages ranged from 3 to 93 years. The duration of infirmity was from 6 months to 14 years. Diagnoses included thrombotic stroke, hemorrhagic stroke, traumatic brain injury, and anoxic encephalopathy. The patients' initial status ranged from apallic

syndrome (also known as the "persistent vegetative state") to semi-ambulatory. About 30 patients were considered to have apallic syndrome, levels 1 to 8,<sup>7</sup> with scores on the Glasgow Coma Scale (GCS) ranging from 3 to 5.

Patients were treated in a Vickers monoplace chamber pressurized with 100 percent oxygen to pressures of 1.25 to 1.75 atmospheres absolute (ATA). Each treatment session lasted one hour at pressure. The number of treatments ranged from 40 to 600.

Patients were videotaped before, during, and after completion of therapy. Nearly all patients had an initial and follow-up SPECT scans performed with an Elscint high-resolution single-head gamma camera, using technetium-99 either as Ceretec or Neurolite. In long-term cases, scanning was repeated after each 80 to 100 sessions.

Physical therapy, occupational therapy, and speech therapy were all utilized. Some patients also received acupuncture treatments, and many took nutritional supplements such as ginkgo biloba, ginseng, CoQ-10, pycnogenol, and vitamins.

## Results

### Case Reports

CASE 1. A 54-year-old white man had experienced a middle cerebral thrombotic stroke about 15 months before referral. All rehabilitative therapy had been abandoned, and the patient sent home to be "kept comfortable." He had a right-sided spastic hemiplegia and was wearing a brace on his right leg and a sling on his right arm. He also had a severe expressive aphasia and emotional lability. He received 51 exposures to HBOT at 1.5 ATA. The sling and brace were removed, and the patient was able to walk with a cane. He regained his speech and emotional stability. The SPECT scan showed significantly improved function in the left cerebral cortex. With approximately 80 percent restoration of function, he was judged to be leading a basically normal life, with normal cognitive function.

CASE 2. A white male tennis professional sustained a severe traumatic brain injury at age 23. After 4 months in an apallic state, he underwent rehabilitation for 6 months. He remained semi-comatose with a GCS score of 6. Between April 1997 and May 1999, he received 208 sessions of HBOT at pressures of 1.5 to 1.75 ATA. Intensive physical therapy, occupational therapy, and speech therapy were instituted; a gymnasium was built for him in his home. By April 2002, he had received 600 treatments and was largely self-sufficient though having some residual motor disability and a mild speech impediment. His GCS score returned to normal, his gastrostomy tube was removed, all medications were discontinued, and aggressiveness resolved. He was able to hold a tennis racket and hit a tennis ball, participate to a limited extent in outdoor activities, and make his own decisions.

CASE 3. A 31-year-old white man had sustained a severe anoxic insult due to a suicide attempt with carbon monoxide 12 years before he presented to our clinic. He had been unresponsive since, receiving meticulous care at home. He was treated only because his mother had driven 3,000 miles to the clinic and begged us to "do

something." Had she telephoned in advance, she would have been advised that there was no hope. After 60 sessions of HBOT, there was marked improvement in the frontal lobes by SPECT scan, and the patient began to awaken. Physical, occupational, and speech therapy were begun. A chamber was installed in his home. After 350 treatments, the patient was functioning in society with minimal cognitive defects.

CASE 4. An 89-year-old woman had fallen and sustained a head injury 18 months previously. After a month in an apallic state, she spent 9 months in a nursing home. She had a gastrostomy tube, spastic paralysis of her left side and right arm, and an expressive aphasia. After 38 sessions of HBOT at 1.1 ATA, the patient was alert and smiling, able to lift her left leg and walk with assistance, and much less spastic. Her speech improved considerably. After her return home, all therapy was disallowed because of her age. Nonetheless, improvements have been sustained for 6 months, and her gastrostomy tube can probably be removed.

CASE 5. A 21-year-old man was seen two years after a severe motor vehicle crash in which he sustained a torn aorta and multiple fractures. He was comatose for 2 weeks and in an apallic state for 3 to 4 months. He recovered to some extent and was semi-ambulatory, but his status had reached a plateau except for some gradual improvement in eye-hand coordination. Motor skills, balance, reading ability, and short-term memory were markedly impaired. After 64 sessions of HBOT at 1.5 to 1.75 ATA, his SPECT scan showed significantly better perfusion, and there were significant improvements in ambulation, balance, speech, and cognition.

CASE 6. A 23-year-old woman was in an apallic state after a cardiac arrest resulting from septic shock. She had severe spasticity and no purposeful movement. She was dependent on a gastrostomy tube. About 9 months after her injury, she was sent from the Netherlands to our clinic on a stretcher. After 400 sessions of HBOT over the course of a year, her GCS score improved from 7 to 14, and she demonstrated awareness of her surroundings and very cheerful spirits. As she was able to eat, her gastrostomy tube was removed. Improvements continued after her return home. Her spasticity has decreased markedly, and she can formulate words. She has recently received and accepted a proposal of marriage. (*Incidental Note:* there were many similarities between this case and that of Terri Schindler Schiavo. Although our patient's cardiac arrest was much more recent, her neurologic state was apparently worse, as far as we could determine from the videotape of Schiavo and written reports of an examination by Dr. William Hammesfahr. Our offer of pro-bono treatment was rejected by Michael Schiavo three years ago.)

### Overall Results

Very few of our patients experienced results as remarkable as those described above. Nonetheless, the majority of patients demonstrated some degree of improvement, which even if small can be of great significance to caregivers. Most patients with a GCS of 1 to 3 improved to a score of 8 to 10. Many patients regained the ability to communicate, either verbally or with a word board or computer. About 80 percent of gastrostomy tubes and 70 percent of tracheostomy tubes were successfully removed. Hospitalizations were less frequent, and many drugs such as anticonvulsants were discontinued without adverse consequences, resulting in cost savings of up to 90 percent.<sup>8</sup>

It is our impression that hemorrhagic strokes respond better to treatment than thrombotic ones. Results are extremely variable in traumatic brain injury. Severe anoxic encephalopathy is the most challenging, but sometimes improvements are seen even after 400 to 500 treatments.

### Conclusions

Our clinic generally receives patients with severe brain injuries long after the time when spontaneous improvement can be expected. Thus, our observations of a large percentage of patients with slight or moderate improvements, and a small number of patients with significant improvements, are unlikely to be coincidental.

The impressions of family members are difficult to evaluate because they are so desperate to see improvements that they tend to overinterpret any sign of possible responsiveness. Consistency and reproducibility of responses must be sought. More confidence can be placed in indicators such as degree of spasticity or functional abilities. The SPECT scan can give some indication of the presence of recoverable brain tissue and help guide decisions about the value of continued treatments.

Interest in and funding for controlled studies have been lacking. Moreover, there are ethical problems in subjecting patients to a very large number of sham treatments, especially when the chance of benefit diminishes as the time since injury increases. A crossover design with frequent functional imaging would be most appropriate.

In our study, each patient served as his own control in that there was a period of stability before treatment compared with favorable changes after HBOT. Potentially confounding variables include the passage of time, more aggressive rehabilitation efforts, better nutrition, or greater patient and caregiver efforts resulting from renewed hope.

It is reasonable to expect that HBOT could lead to much better results if used as quickly as possible after the event, rather than waiting until the prognosis is apparently hopeless. The occurrence of *any* late recoveries—given the enormous difference between an "observed" return to near normalcy and the "expected" hopeless prognosis—is a strong argument for immediate expansion in the availability of this treatment, with careful documentation of outcomes and comparison with results from rehabilitation facilities that do not employ HBOT.

Offsetting the cost of HBOT is the potential for reducing the cost of care of neurologically disabled patients, even if they cannot be returned to a fully functional status. A course of HBOT might, at a minimum, render far more patients able to speak for themselves about continued treatment, rather than relying on substituted judgment or advance directives executed long before an injury.

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