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Breaking Comas

Peter Catalano

Some patients in a long-term comatose state can be revived to nearly normal functioning through multiple treatments of hyperbaric oxygen.

In December 1989, Charlie Smith suffered life-threatening injuries in a single-car accident along a busy Ohio interstate. Rescue workers found the 40-year-old man unconscious. In trying to save his life they botched an attempt to insert a breathing tube, exacerbating Smith's injuries. Later, at the hospital, a CT scan showed he had a broken cheekbone and, more seriously, that air had penetrated his skull. Smith stayed in the intensive care unit for two weeks before being placed in a coma-management program.

He remained there in critical condition for a month, unresponsive to commands and unable to respond to arousal or open his eyes. His limbs thrashed spastically. Despite slight improvement, it became increasingly clear to Smith's doctors that his recovery had plateaued, leaving

• Aided by treatments of pressurized, pure oxygen, high school student Aaron Baqui of Chicago, who suffered severe brain injury in an auto accident in April 1994, is slowly regaining movement, speech, reading, and coherent thought.

him indefinitely locked in a semi-vegetative state. He was discharged from the hospital in June 1990-after exhausting $400,000 in medical insurance-seven months after his accident.

Smith's case was deemed hopeless. His wife was advised by doctors in Ohio that he would remain seriously disabled and totally dependent on caregivers throughout the remainder of his life.

Today, Charlie Smith is contemplating a return to work. He lives independently and takes care of all his own needs. Although his rehabilitative therapy continues, his only real disability is a slight limp requiring occasional use of a cane.

His recovery is nothing short of a medical miracle, only this miracle has a name: the Neubauer-Gottlieb technique for brain tissue recovery. The technique was developed by Dr. Richard Neubauer, an internist who is medical director of the Ocean Hyperbaric Center of Lauderdale-by-the-Sea in Florida, and Sheldon Gottlieb, professor of physiology at the University of South Alabama in Mobile.

This technique offers the only current hope to patients in long-term care whose disease and injury leave them in persistent vegetative states or comas.

Though truly brain-dead patients usually die within a few days of their injury, brain tissue recovery may offer some hope for those written off as severely vegetative. Such patients might otherwise be candidates for euthanasia by withdrawal of food and water, as occurred in the much-publicized case of Nancy Cruzan.

Fortunately for Smith, his desperate wife brought him to Dr. Neubauer's clinic after several months of fruitless therapy following his hospital discharge. Neubauer used an advanced medical imaging technique called SPECT (single-photon emission-computed tomography) to scan Smith's brain and evaluate the long-term damage.

The diagnostic procedure

developed by Neubauer and Gottlieb is a two-step process that starts with a baseline SPECT scan. According to Neubauer, Smith's scan showed that the frontal and parietal lobes of his brain, which control vital cognitive and motor coordination, had severe neuronal-activity deficits.

Dark blues and reds in the SPECT scan depicted depressed metabolism in key parts of Smith's brain, accounting for his disabilities. The scan showed Neubauer that these deficit regions were either dead, and thus unrecoverable, or "idling" in a state of dormancy. In the latter case, restoration of neuronal activity might be possible.

After evaluating the baseline scan, Neubauer proceeded with step two, which was needed to evaluate Smith's prospects for recovery if he were treated with hyperbaric oxygen (HBO).

Smith was placed in a hyperbaric chamber with its pure oxygen at a pressure of about one and a half times that of air at the earth's surface. After this HBO session, a second SPECT scan of his brain showed light-colored patches of tissue where the baseline image had been darker. These patches had absorbed the radioactive tracer injected into the bloodstream that is detectable with the SPECT camera. Their lighter color indicated that the idling neurons had been provoked into metabolic activity because more oxygen was reaching them.

Neubauer now had scientific reason to believe that further HBO treatment would permanently reactivate the electrical functioning of these cells, which in turn would restore his patient's mental and physical powers. Showing great potential for substantial recovery, Smith began the next phase of therapeutic

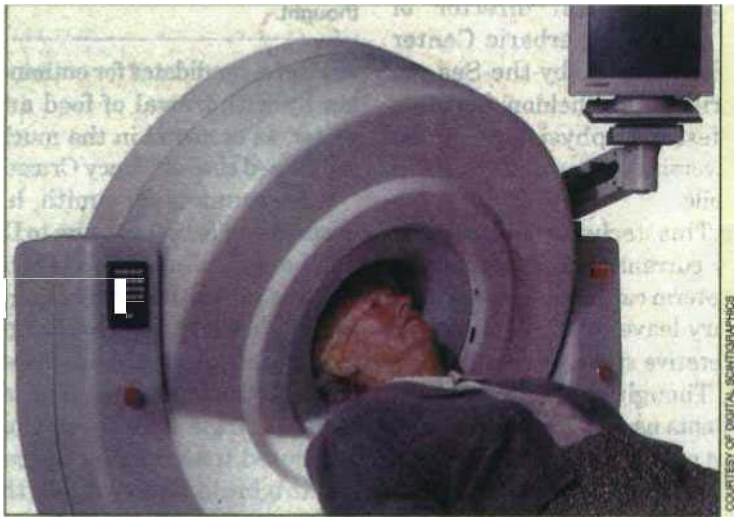
SPECT Imaging of the Brain

Single-photon emission-computed tomography (SPECT) provides planar images of the body's organs, similar to those generated by computerized tomography (CT). In fact, SPECT images showing blood flow and metabolism can be superimposed on CT scans showing anatomical structure, a procedure that is particularly useful in brain studies. SPECT most commonly uses the radioactive isotope technetium-99, which emits a photon with each nuclear decay. When injected into the bloodstream, technetium-99 crosses the blood-brain barrier and circulates into deep regions of the brain.

Normal, healthy brain cells absorb the tracer, which decays harmlessly within 4-6 hours. A special camera detects the position and energy of photons emitted from the decaying technetium. The image is reconstructed in planar slices, with a color scale assigned in proportion to the strength of the signal.

Because dead brain cells do not absorb the tracer, SPECT can distinguish between living and necrotic tissue. Neubauer and Gottlieb say they can identify living tissue in an idling or electrically inactive state by using SPECT in conjunction with hyperbaric oxygen.

-P. C.



- A SPECT scan machine is basically an array of sensors that detects photons released from a short-lived radioactive tracer that has been injected into the bloodstream.

HBO treatments.

He also received intensive occupational and physical rehabilitation. "The recovering brain tissue needs to be retrained," says Gottlieb. "Physical and mental therapy stimulate the plasticity of the brain's nerve cells."

After 160 HBO treatments, a SPECT scan revealed a stark increase in neuronal activity in areas of Smith's brain that had been metabolically marginal or inert in the baseline SPECT. Regions that had been dark on the first SPECT were now much brighter, even white, indicating high levels of metabolic activity.

Later SPECTs showed sustained recovery, though minor deficit regions still remained. Bet ter oxygenation provided by the HBO had assisted the brain's own healing, in the process dramatically improving Smith's mental and motor skills. Yet there was room for further recovery.

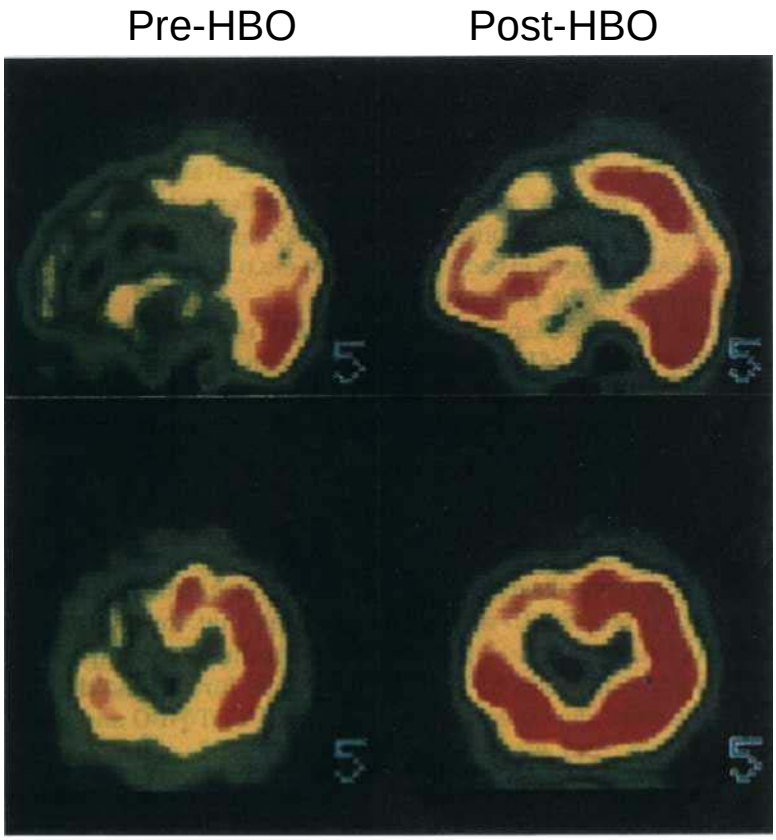
In this case, there were to be 27 more treatments, for a total of 188. By then, Smith's brain deficits had all but disappeared. His clinical psychologist, George Dunlevy, would write in a final report, .

[Smith] has had markedly dramatic improvement in many of his cognitive functions. He has become ambulatory, acquired good communication skills with others again; he has become independent once more in his self-help skills and regained much of his short-term and long-term memory. He seems to have responded to the hyperbaric treatment programs.

The lucky few

Unlike Smith, most head-injury patients do not have the benefit of SPECT/HBO in the emergency room or during convalescence. Nationwide, 500,000 people are hospitalized every year for head injuries. Most are the result of auto accidents and gunshot wounds, the rest being nontraumatic injuries resulting from carbon monoxide asphyxiation, drug overdose, near drowning, and strangulation. About 90,000 are left with permanent injuries.

Like stroke, most of these life-threatening injuries are characterized by impaired blood flow that reduces oxygenation of brain tissue. Without early intervention, these cases often end tragi-



0 SPECT scans provide a functional map of the brain, with green representing a major deficit of blood flow and oxygen; yellow, less deficit; and red, near normal. These pre- and post- (after three treatments) HBO scans of a stroke patient's brain show considerable increase in the amount of yellow and red, indicating that the patient should respond well to HBO treatments.

Hyperbaric Oxygen Therapy

• Hyperbaric oxygen chambers for one-person occupancy are made in several designs, as shown here. Multiperson chambers for use as operating rooms are also manufactured.

Hyperbaric oxygen (HBO) therapy has been used for decades, most notably for divers suffering from decompression illness (the bends) that occurs when they surface too rapidly.

Hyperbarics works by dissolving much higher levels of oxygen than normal breathing does into body fluids, especially blood plasma. Usually, 95 percent of the body's oxygen needs are transported by red blood cells, but the percentage delivered can be greatly reduced by injury or disease. When patients are placed in a container in which pure oxygen is pressurized at 1.5-1.75 times ambient air pressure (one atmosphere), the amount of oxygen dissolved in other body fluids that reaches the brain is about six times that of normal respiration. That's because oxygen in body fluids is related to the pressure of oxygen in the lungs (Henry's law).

Other benefits of HBO treatments are wide ranging. A study reported in 1992 by Dr. Gaylan Rockswold and associates at the Hennepin County Medical Center in Minnesota showed that HBO treatment soon after acute head injury reduces mortality by more than 40 percent. HBO has proved effective for treating patients who have been bitten by the brown recluse spider [see "Battling the Brown Recluse with Innovation," THE WORLD & I, March 1994, p. I871.

HBO is routinely used to speed wound healing in burn victi ms. It is also believed to improve the body's removal of dead tissue (phagocytosis), scavenge for toxins called free radicals, stimulate collagen production, and lay down new blood vessels to sustain recovery. "There is no drug that can facilitate wound healing the way oxygen can," says Gottlieb. "Through hyperbarics, oxygen can be delivered faster, safer, and in higher concentrations at the site of injury than any other drug. A brain injury is like any other wound and can be healed like any other wound with oxygen."

-P. C.

tally. Those who survive the initial injury often remain in a vegetative or severely disabled state for years, a fate Smith seemed destined for.

It's especially hard on loved ones. "Doctors save them," say the families, "but what for, if there's no rehabilitative treatment out there?"

At this point, SPECT/HBO offers the only possible treatment option for such patients. Gottlieb estimates that for as little as $1-1.5 million, an important study could further test the viability of SPECT/HBO and refine its use in specific patient populations according to age, prior health, and collateral injuries.

Waiting for what?

Families of patients with debilitating head traumas are not waiting for further studies, however, particularly those families whose loved ones have survived initial injuries and now languish in hospitals and nursing homes. Communications being what they

Through hyperbarics, oxygen can be delivered faster, safer, and in higher concentrations at the site of injury than any other drug.

are today and with medically literate, savvy consumers using these networks, promising, dramatic breakthroughs cannot be kept secret. Neubauer's daughter Virginia, who assists in running the Ocean Hyperbaric Center, says that an underground, word-of-mouth network is flocking to her father's facility.

"We get very few referrals from physicians," she notes. "But many of these head-injury patients belong to recovery support groups. When they return home, we get inquiries from other families. Some of these patients also get publicity from local newspapers and local television." (Charlie Smith, for example, appeared with Dr. Neubauer on national TV.)

"Some of the families raise money for the treatment; before they even come here, they are promoting this treatment. Frankly, word spreads worldwide," she observes.

Persuaded by Dr. Neubauer that HBO/SPECT treatment offers a viable hope for obviating the huge costs of long-term nursing care for comatose, disabled patients, some insurance companies will reimburse for HBO treatments of patients who meet Neubauer's criteria.

"It's not routine," says Virginia Neubauer. "But if insurance companies look at the data, what they are facing in the neurologically injured patient is very, very expensive, full custodial care for 30-40 years. HBO is a cost-effective modality. If we can return these patients to self-sufficiency, the insurance companies can save a great deal of money."

She reminds insurers that a $1,200 SPECT scan followed by 150 outpatient hyperbaric treatments at $200 a session is an insurance bargain compared to round-the-clock nursing care that costs upward of $50,00 a year.

Results with vegetative patients

Significant data support the efficacy of SPECT/HBO therapy for long-term head-injury cases. Most of the data come from trials conducted by Dr. Neubauer.

These studies are a bit different from control trials where one set of patients gets the therapy and another does not. As there is no alternative therapy for "hopeless" long-term cases, Dr. Neubauer's SPECT/HBO treatment constitutes a medical trial in which the patients serve as their own control against known outcomes. Any improvement can be measured against both these standard expectations and the objective evidence of SPECT scans.

Fortunately, baseline recovery outcomes have been calculated, most recently in a study published last year by a team of biostatisticians and a neurologist at the University of Virginia. This study indicated that after six months, 94 percent of comatose patients show no significant further recovery. None of the vegetative patients in the Virginia study, for example, had a good recovery or even emerged mildly disabled; about 25 percent died. Severely brain-injured patients such as Smith have only a 5 percent chance of good recovery with only slight disability.

In this light, a report Neubauer published in 1985 on the treatment of 17 long-term coma patients is especially significant. Fourteen of his patients had severe comas, defined as a score of 9 or less on the Glasgow coma scale, whose index runs from 3 (vegetative) to 14 (mild impairment). For these 14 patients, the average length of coma prior to Neubauer's study was 7 months, with some as high as 22 months. After Neubauer's HBO treatment, 12 of the 14 had moderate or good recovery, far exceeding expectations published by the Virginia team's outcomes study.

In a later control study of 30 vegetative patients who had been

in comas for 2.5 to 22 months, Neubauer reports 50 percent recovered to useful and self-sufficient life-styles, a dazzling success rate compared to standard outcomes.

Working with Gottlieb, Dr. Paul Harch at the Jo Ellen Smith Hyperbaric Center near New Orleans reported in the literature on SPECT/HBO therapy among 18 patients with long-term metabolic brain deficits causing impaired performance. All 18 showed motor, behavioral, personality, and cognitive gains.

For brain damage due to causes ranging from near drowning to auto accidents and strokes, the Glasgow coma scale gives doctors a means of roughly quantifying the degree of coma exhibited by the patient.

Idling neurons

The scientific basis for the apparent efficacy of SPECT/HBO in treating long-term comatose and semicomatose patients lies in the ability of brain tissue to survive a 20-30 percent reduction of minimal blood supply. The buffer zone in which the brain tolerates reduced blood flow (ischemia) without immediate death was dubbed the "ischemic penumbra" by several neurosurgeons (Astrup, Siesjo, and Symon) in a famous 1981 editorial in the journal *Stroke.* The poetic imagery of the "ischemic penumbra" arises because the authors associated the 20-30 percent buffer zone with the half-shaded zone around the center of a complete solar eclipse, that is, the penumbra.

When functioning normally, nerve cells in the brain-neurons--conduct tiny electrical currents that can be picked up by detectors placed on the skull and graphed as electroencephalograms (EEG). These electric currents allow individual neurons to communicate and work collectively in regulating and controlling the body's mental and physical activity.

Electrical signals between neurons noticeably flatten when cerebral blood flow is constricted by hemorrhage, a blood clot (thrombosis), or an abnormal particle in the blood, such as plaque from heart disease or an air bubble (embolism). Starved for oxygen and nutrients, nerve cells in the brain follow a program that selectively shuts down electrical functions to conserve energy. This response preserves other, more critical, cellular operations, such as pumping out toxins and keeping an electrolytic balance along the cell membrane,

Outside the penumbral buffer zone, cell death is almost immediate. Within the penumbral buffer zone, however, the impaired blood flow and reduced oxygen cause the neurons to become electrically silent as measured on an EEG. Nonetheless, as Astrup and colleagues pointed out, these cells are still alive and

The Glasgow Coma Scale

Used to determine the types of long-term coma.

Eyes Open:	
Never	1
To pain	2
To verbal stimuli	3
Spontaneously	4

Best Verbal Response:	
No response	1
Incomprehensible sounds	2
Inappropriate words	3
Disoriented and conv erses	4r
Oriented and converses	

Best Motor Response:	
No response	1
Extension (decerebrate rigidity)	2
Flexion abnormal (decorticate rigidity)	3
Flexion withdrawal	4
Localizes pain	5
Obeys	6

To determine the type of coma, study the responses of the subject in each of the 3 areas (A,B,C), and circle the appropriate number. Add the three numbers and refer to the table below.

Types of Long-term Coma:

Persistent Vegetative State: 3-6
Severe Coma: 3-8
Semi-coma: 9-14
Normal: 15

With restored oxygen levels, the idle, lethargic cells return to normalcy and once again become electrically active.

capable of being resuscitated.

But for how long?

In April 1995 a team of neurologists and neurosurgeons published a study in the Annals of Internal Medicine. Called "Emergency Brain Resuscitation," it put the viability of neurons in the ischemic penumbra at 4-6 hours. Many physicians-Dr. Michael Sukoff, director of neurosurgery at the Western Medical Center of Santa Ana, California, for one-consider this far too short. Neubauer and Gottlieb believe they have evidence that neurons may dwell in an idling state for years. Their SPECT/HBO studies have been published in refereed medical journals in the United States and Europe.

Neubauer and Gottlieb believe that the effects of diminished blood flow within the ischemic penumbra-whether the penumbra is the result of stroke, accident, or poisoning-can be reversed by hyperbaric therapy, which dissolves higher levels of oxygen in the blood plasma. With restored oxygen levels, the idle, lethargic cells return to normalcy and once again become electrically active. Bodily functions are correspondingly restored.

This restoration of neuronal functioning can be visualized on SPECT scans. There is, however, some controversy in interpreting the neurophysiological information they contain. SPECT scans measure the uptake of minute amounts of radioactive technetium into the cell during the course of its normal functioning. It is inferred-reliably so in most opinions-that the cells must also be ingesting oxygen and glucose along with the hitchhiking technetium tracer, which serves no metabolic purpose.

Radiology professors and neurosurgeons are nevertheless convinced that SPECT is a cost effective, reliable tool for researching and diagnosing Alzheimer's and other brain diseases. Sukoff is even blunter. He says the results Neubauer and Gottlieb have attained with SPECT scans in conjunction with HBO are irrefutable.

He is quick to add, however, that much more research has to be done to meet the scientific standards of biology and medicine. By these standards, Sukoff says, SPECT/HBO therapy of long-term comatose patients is "still anecdotal unless you get a lot of them and have two or three independent investigators doing these studies.

"Still, I find them very impressive," he continues. "There's no question there is that penumbra." Of patients such as Charlie Smith, disabled for years by head injuries, Sukoff says, "Except for the hyperbarics, there's no reason for them to have gotten better."

What is needed now, he adds, is "some reputable people who are associated with an honest university" to do intense research trials to advance the use of the Neubauer-Gottlieb technique.

'Me universities have got to get involved with it," says Sukoff. "If it comes out of a clinic like Neubauer's, everyone is going to say he's just interested in making money." As yet, there have not been enough bona fide studies to substantiate the efficacy and scientific validity of SPECT/HBO to the levels acceptable to the rest of the profession.

Nonetheless, says Sukoff, Neubauer and Gottlieb "deserve a giant pat on the back. They're sincere. They have established the need for continued investigation of hyperbarics for chronic vegetative state. No question, it's impressive."

Peter Catalano is a free-lance writer living in the Boston area.