# Hyperbaric OXYGEN Bounces Back

## After years in the shadows, high-dose, high-pressure oxygen administration is making a comeback as a legitimate treatment for certain conditions

By JOANNE SILBERNER

Hyperbaric oxygen therapy — the administration of 100 percent oxygen at greater than sea level pressure — has had its ups and downs. For most of its history, its application has been based on concepts that may have sounded good but lacked scientific backing, and the process went in and out of vogue.

Only now, hyperbaric researchers say, is the field getting the scientific study it deserves, and the work is revealing hyperbaric oxygen therapy to be a useful adjunct in treating a variety of conditions. The upswing has not gone unnoticed by the medical community: Between 1977 and 1984, the number of hyperbaric chambers in the United States increased sixfold.

Because of its ability to force gas bubbles in the blood into solution, stimulate wound healing and deliver oxygen to oxygen-starved tissues, the therapy is now used for such conditions as gas emboli, crush injuries and carbon monoxide poisoning.

As long ago as 1662 a scientist built a chamber that controlled air pressure with valved bellows. He treated acute diseases with high pressure and chronic conditions with low pressure. In the 1800s hyperbaric chambers became popular across Europe, and were referred to as "compressed air baths."

In the 1930s the use of oxygen at high pressure was established for treating the bends — the decompression sickness suffered by deep-sea divers who ascend too rapidly. And for the next 30 years, that accounted for most of the technique's application.

But in the 1960s, after European researchers established the value of hyperbaric oxygen for treating gas gangrene and carbon monoxide poisoning, medically unsubstantiated use set in. "Clinical people with little research background picked up the concept and applied it," says Christian Lambertsen of the University of Pennsylvania in Philadelphia, who with colleagues at the Institute of Environmental Medicine there has studied the effects of oxygen on humans and animals. "Some of the applications were rational, some were not." The therapy was touted as a treatment for everything from baldness to senility. High levels of oxygen would rejuvenate old or diseased tissue, it was thought, and many medical and research institutions invested in hyperbaric chambers.

Extensive studies were done to determine whether cancer could be treated with high-pressure oxygen along with radiation treatments, since the low oxygen levels of tumors as they outgrow their blood supply are known to make them more resistant to radiation. "The theory was good," says Jefferson C. Davis, a clinical researcher in San Antonio, Tex. "But follow-up studies showed very little improvement in long-term survival rates."

Heart surgery was sometimes conducted in the chambers, in the hope that the high-pressure oxygen would remain in cardiac muscle longer, permitting a longer "downtime" for the heart. But while it improved results, says Davis, the procedure was difficult and was superseded by other surgical advances.

When the overtouted therapy didn't deliver on its promise in the late 1960s and early 1970s, it was pushed into the shadows, its use acknowledged only for treating decompression sickness. Around the world, chambers that had cost $500,000 or more fell into relative disuse.


Photos: University of Pennsylvania

*Patients whose bone infections failed to respond to surgery and antibiotics inhale 100 percent oxygen at two atmospheres pressure.*

But a small coterie of researchers remained believers. Rather than base the use of hyperbaric oxygen on an abstract notion — that oxygen, as an element vital to life, could stimulate tissue into doing what it should — they laid a detailed groundwork of basic and clinical research, and showed that forcing oxygen into tissues is helpful in treating some conditions but not others. To them, the future for hyperbaric oxygen looks bright — so long as the therapy is not overpromoted.

What turned things around, says Lambertsen, is research on tissue healing. After work on animals established that high-pressure oxygen stimulates healing, hyperbaric oxygen was tried on bones beset by osteoradionecrosis — bone tissue death induced by radiation treatment for cancer. The technique gained high marks.

In osteoradionecrosis, Lambertsen explains, the bone loses some of its small arterioles and capillaries. With no oxygen, subsequent bone repair and bone growth



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don't occur, and chronic wounds result. With hyperbaric treatment, he says, "the higher pressure in the blood allows the budding of new capillaries into the poorly vascularized tissue — more blood, more oxygen, more tissue growth."

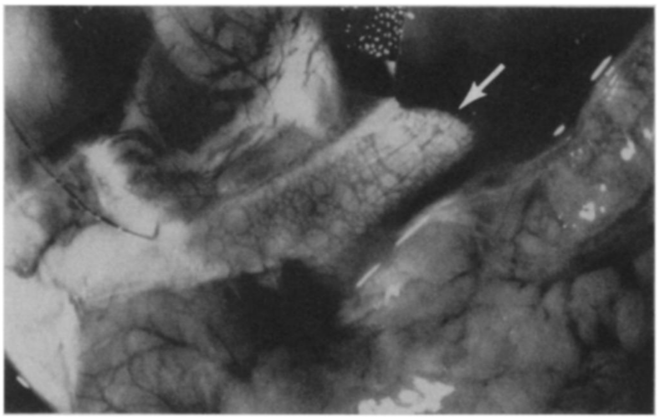
Since its formation in 1967, the Undersea Medical Society of Bethesda, Md., has been carefully shepherding the resurgent therapy. The founders, interested in the medical aspects of diving, have been working to legitimize hyperbaric oxygen by differentiating between proven and unproven treatments. In addition to treatment for the bends, the society includes the following uses as "proven," with the therapy used as an adjunct in most cases: osteoradionecrosis, carbon monoxide poisoning, gas gangrene, gas embolisms, crush injuries, problem wounds, cyanide poisoning, cerebral edema and several hard-to-treat bone, fungal and soft-tissue infections. As a measure of its acceptance, hyperbaric treatment for nearly a dozen conditions is paid for by Medicare, and Blue Cross/Blue Shield recommends that its state organizations cover the therapy for specific situations.

Areas legitimately under investigation but by no means proven, according to the society, include use in burns, head and spinal cord injury, bone grafts and multiple sclerosis (SN: 5/25/85, p. 328). The American College of Physicians, headquartered in Philadelphia, has looked at some of the more controversial uses. In 1982 it deemed hyperbaric oxygen therapy unacceptable for arthritis, investigational for chronic osteomyelitis and as-yet-unproven for actinomycosis, a fungal infection. In 1983, the College declared its use in senility, certain blood flow problems, skin ulcers and multiple sclerosis not established.

Hyperbaric oxygen can be administered in a monoplace chamber, which holds a single person, or in larger multiplace chambers, sort of walk-in iron lungs, capable of treating six or eight people. In the multiplace chambers, the air is maintained at high pressure and the persons receiving treatment inhale 100 percent oxygen through tubes.

The process isn't painful. People in the chambers experience the same ear-popping as people in airplanes; the sensation can be alleviated by blowing out gently with mouth shut and nostrils pinched closed. The high pressure within chambers or that experienced underwater by divers isn't crushing because it is uniformly transmitted throughout the body. Under extreme hyperbaric conditions used on healthy people to establish limits, voice quality temporarily changes, representing what one researcher says is "nothing more than an interesting and often amusing effect."

The supporting gas canisters, gauges, dials and airlocks make the chambers look as though they are supporting an extraterrestrial system; indeed, much of the research in the 1960s was aimed at determining ways to limit damage to divers coming up from deep water and spacewalkers leaving their pressurized capsules. If a diver or astronaut moves to a lower pressure too quickly, dissolved gases can literally — and fatally — effervesce out of the blood. "Hyperbaric medicine is really an outgrowth of man exploring unusual environments," says Lambertsen.



*Isobaric inert gas counterdiffusion poisoning, seen (arrow) in pig tissue, occurs when pressurized gas seeps into the skin. Human studies at the University of Pennsylvania have resulted in guidelines that prevent the condition from occurring in high-pressure, long-duration dives.*

Clinical use of the therapy has lately been booming. In 1977, says Roy A.M. Myers, who keeps a registry for the Undersea Medical Society and is director of hyperbaric medicine at the University of Maryland in Baltimore, there were 37 functional chambers. In 1984 there were 215. Even so, notes Thomas K. Hunt of the University of California at San Francisco, "If you talk with 100 physicians and surgeons, you'll probably find 10 who know about it." The chambers run the gamut from sophisticated research installations to single units that are advertised in newspapers and treat patients for ailments that have not been proven responsive.

During the 1970s, Hunt did much of the basic research on how hyperbaric oxygen works in wound healing. With a normal wound, which heals at its own rate, hyperbaric oxygen is of no value. But radiation damage, a crushing injury or diabetes can destroy the small capillary beds, limiting oxygen flow and subsequent healing.

Hunt and his colleagues found the low-oxygen state impaired the reproduction of the cells that produce collagen, the body's matrix. They demonstrated that increasing the oxygen increased the production of collagen.

Hunt found a second positive effect that seems to explain hyperbaric oxygen's benefit in recalcitrant infections—such as cases of osteomyelitis, a bone infection, that have not responded to antibiotic therapy. Hyperbaric oxygen boosts the activity of white blood cells that kill bacteria. It does so by stimulating the cells and inducing them to form free radicals — oxygen with an unpaired electron. The white blood cells manufacture these free radicals to kill bacteria.

"We noted that test wounds in animals rid themselves of bacteria better if the animals are breathing [hyperbaric] oxygen," says Hunt.

That oxygen aids in wound repair can be seen in the differential rate of healing in different parts of the body. "If you cut yourself on your feet or hands, you're rather likely to get infected," says Hunt, "but if you cut your face it almost never gets infected." Surgical wounds in the area of the anus also rarely get infected, he notes, despite the high number of bacteria present. The reason? The blood supply and thus the oxygen tension is greater in the face and the anus than in the hands and feet, Hunt says.

But too much oxygen can be poisonous. "This is a drug," says Lambertsen. "It can be toxic."

A person breathing uninterrupted 100 percent oxygen "would progressively begin to be poisoned by the effect on enzymes and cell membranes," he says. In the lungs there would be progressive soreness, coughing and ultimately cell destruction, presumably caused by the exhaustion of the enzymes that destroy the oxygen radicals. Oxygen can also poison the neurons through the same process. Eventually all the body's cells would be affected.

About one full day of 100 percent oxygen at 1 atmosphere of pressure or 12 hours at 2 atmospheres causes some damage to the lungs. After three days at 1 atmosphere or an estimated one day at 2 atmospheres, a person would be near death. Lambertsen and his colleagues have worked out a way to lessen the toxicity — they give oxygen intermittently rather than constantly. Twenty minutes on and five off doubles the tolerance to oxygen; the intermittency pattern should vary depending on the condition being treated, says Lambertsen.

The rationale for intermittency is partly knowledge, partly conjecture, says Lambertsen. "The enzymes [levels] are approaching detectable toxicity; some are recovering, others are produced more rapidly," he says. Giving oxygen intermittently gives the system enough time to catch up. And the intermittent schedule may stimulate the production of enzymes.

Free radicals, which are credited with enhancing wound repair, have also been associated with cancer, but hyperbaric oxygen researchers note that they are treating life-threatening conditions and that they do not suspect use of hyperbaric oxygen will cause a problem. "Breathing oxygen at high pressure is not a new thing," says Lambertsen, noting that divers have been doing it for years. "The process turns off as soon as oxygen administration is stopped."

Al Tappel of the University of California at Davis, an expert in free radicals, says that while he is unaware of studies of hyperbaric oxygen and cancer, he suspects the link, if any, would be small because people naturally have protective enzymes against free radicals.

"From the clinical standpoint," says Davis, a former head of the Undersea Medical Society, "we have never seen any evidence [of carcinogenicity] to concern us."

What researchers fear today is "another simultaneous wave of not very scrupulous characters who set up chambers in offices to make a lot of money," says Davis. "It's an expensive modality. We're very concerned about overzealous uses."

*A researcher monitors the effect oxygen poisoning has on vision. The subject here is breathing 100 percent oxygen at three atmospheres of pressure.*

The therapy has proven its value as an adjunct for certain conditions, and controlled clinical trials are under way for other ailments. What would be most damaging now, say these researchers, is another unfounded rise in expectations. □

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urements at a site provide the best indications of a potential hazard. Data collected in the past or in other countries are sometimes difficult to use because the measurement techniques were different or standards varied.

Earthquake engineers are also far from being able to make accurate predictions about how much the ground will shift if an underlying sand layer liquefies, says Youd, because so many factors influence the process. Many more case histories are needed to shed light on exactly what happens, he says.

The problem is that there are very few places where both the characteristics of a shaking during an earthquake and the soil properties before an earthquake are known. Nevertheless, some researchers are digging into historical records and geological data for clues about past episodes. Photographs and written accounts of the 1906 San Francisco earthquake, for example, clearly show that soil liquefaction played an important role in destroying buildings resting on landfill and in breaking gas and water mains. Although the focus on soil liquefaction research is relatively recent, the problem has existed for as long as earthquakes have affected civilization.

Despite the uncertainties, soil liquefaction is a hazard that's now relatively recognizable, says William F. Marcuson III of the U.S. Army Corps of Engineers in Vicksburg, Miss., but selecting a solution can get very complicated. "There will never be a cookbook approach for seismic stabilization," he says. "It has to be done on a case-by-case basis."

Experience shows that soil liquefaction can damage all types of structures, from dams and towers to roads, pipelines and underground storage tanks. If a soil at a particular site turns out to be susceptible, then the structure must be abandoned, relocated or improved. Improvements, which include replacing or packing down loose sand, providing better drainage or rebuilding a structure on deeper pilings, may be very costly. On top of that, adds Marcuson, "We have little field experience for guidance."

To earthquake engineers, large earthquakes like the one that rocked Mexico, although a human tragedy, provide valuable information about what works and what doesn't work. How large a role liquefaction played in destroying buildings in Mexico City won't be known until a direct inspection takes place. Earthquake specialists are heading for the city to see at first hand what happened and to garner clues that could lead to better construction practices and remedial measures.

"Any progress that we make in understanding [soil liquefaction] is important," says Frank Press, NAS president and a geophysicist by training. "We respond to crises as they happen," he says. "That's wrong. We need to plan ahead to take this and other potential hazards into account." □

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