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Mayo Alumni

Then and now: Mayo Clinic's hyperbaric medicine moves boldly into the future

The 3,800-square-foot hyperbaric chamber — the hallmark of Mayo Clinic's new Hyperbaric Medicine Program — was installed in the Charlton Building. The 24-patient chamber will provide limb-saving, tissue-saving and lifesaving treatment with hyperbaric oxygen therapy. The chamber also will be used for altitude research and development.

Everything old is new again

Hyperbaric Medicine Program

They have unearthed a powerful resource that could lead to improved patient outcomes, and discoveries and advances in medicine.

In an age where medical advances almost always involve new technologies and a mandate to look forward, hyperbaric medicine — a form of treatment involving pressurized chambers that has been used for more than half a century — might seem antiquated.

In recent years, scientists, physiologists and others in medicine have revisited hyperbaric medicine, studying and refining the technology and discovering potential clinical and environmental applications. They have unearthed a powerful resource that could lead to improved patient outcomes, and discoveries and advances in medicine.

The culmination of two separate missions

Today, Mayo Clinic is at the forefront of hyperbaric medicine as it prepares to open a 24-patient hyperbaric treatment facility by late fall 2007. The 3,800-square-foot facility will be one of the largest hyperbaric chambers in North America.

According to Paul Claus, M.D., an Internal Medicine specialist in Mayo Clinic's Division of Preventive, Occupational and Aerospace Medicine and director of the new Hyperbaric Medicine Program, the program culminates the convergence of two separate missions at Mayo Clinic — Aerospace and Vascular Medicine.

Dr. Paul Claus

"Hyperbaric study has traditionally been done by the military, but downsizing of many programs on military installations has led to the need for outside resources to complete research. We've been planning to get re-involved in human altitude research in healthy and compromised people for safer travel, occupational exposure and patient air transport at increasing altitudes. We also have been preparing to conduct applied altitude research for civilian air transport systems, such as new-generation emergency oxygen delivery system testing, and NASA denitrogenation protocols for future space endeavors."

— Paul Claus, M.D.

In recent years, the aerospace group has been planning to return Mayo Clinic to a leading role in applied environmental physiology by studying technology to address human responses to extreme environments, such as altitude. The size of Mayo's staff specializing in Aerospace Medicine has increased in the past seven years due new opportunities in aerospace-related research and clinical demand for highly complex forensic evaluations required for pilot certification. These pilots have potentially disqualifying medical conditions, such as heart attacks, cancers or neurological abnormalities. Since 2002, Mayo has consulted with representatives from the National Aeronautics and Space Administration (NASA) and the U.S. military to help guide its program and equipment capabilities, with the intent of competing for anticipated research contracts in this field of study.

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Concurrently, the Mayo Clinic Gonda Vascular Center was involved in researching therapies for treating wounds. In 2000, a major benefactor approached Thom Rooke, M.D., associate director, Vascular Medicine, with news clippings and information about the benefits of hyperbaric chambers. The benefactor asked why this treatment was not available at Mayo Clinic.

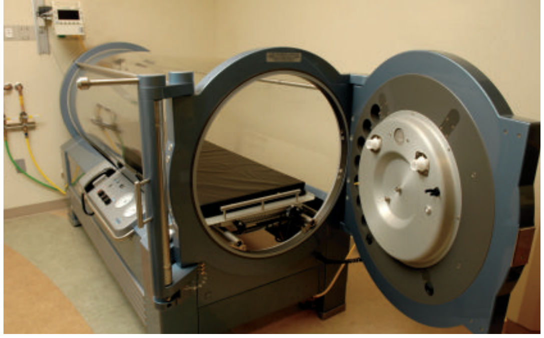
That query began a quest to seek out the known science about hyperbaric oxygen therapy and determine how it might fit with Mayo Clinic's goals and mission.

Dr. Claus learned that of the 14 institutions considered to be the nation's leading hospitals, Mayo Clinic was the only one that did not have a hyperbaric medicine program or a local referral facility for hyperbaric treatment.

In 2002, Mayo convened a panel of NASA scientists, hyperbaric medical experts, operational specialists and physicians specializing in altitude medicine to examine these dual missions — hyperbaric medicine and altitude medicine. This effort was led by J. Richard Hickman Jr., M.D., then chair of the Division of Preventive, Occupational and Aerospace Medicine; and Clayton Cowl, M.D., chief of the Section of Aerospace Medicine.

"The panel unanimously concluded that Mayo Clinic should have a facility to perform hyperbaric treatment and practice altitude medicine, and should move the research forward and become a leader in advancing these disciplines," says Dr. Claus.

After approval from Mayo Clinic leadership, 6,000 square feet in the Charlton Building were designated for major remodeling to house the Hyperbaric Medicine Program.



Far left, a smaller version of hyperbaric chamber designed for individual treatments will also be available for patients. Left, finishing touches are being made to the interior of the large chamber.

Funds were allocated to hire and train staff devoted to creating what Dr. Claus describes as an atmosphere of healing. The space houses the hyperbaric chamber, patient dressing rooms, and four wound care exam and treatment rooms.

Mayo Clinic's hyperbaric chamber system was developed by Fink Engineering, an Australian company that is solely devoted to building rectangular hyperbaric chambers.

"Rectangular chambers are considered superior because they provide maximum internal usable floor space with minimal external volume. They are more space-efficient than a cylindrical chamber," says Dr. Claus.

The chamber almost looks like any other medical treatment room, with standard-sized doors and space to accommodate the equipment required for hyperbaric treatment.

"Hyperbaric chambers have evolved from something that brings to mind a World War II submarine to something that looks more like a waiting room," says Dr. Claus.

Large windowlike ports in the chamber allow for natural lighting. A full audio-video entertainment system allows for patient education from the clinic's on-demand video services. Or patients can bring reading materials or socialize with each other.

Treatments boost oxygen to 15 times normal levels

Historically, hyperbaric oxygen therapy has been used to recompress deep-sea divers experiencing "the bends" that occur when dissolved nitrogen gas bubbles form in the body's tissues when a diver returns to the water surface too quickly. Dr. Claus foresees Mayo's new program serving patients from Rochester and the surrounding area and patients hospitalized at Mayo Clinic for three primary types of treatment with hyperbaric oxygen therapy:

1. **Limb saving** — Diabetes-related non-healing wounds, generally in the lower extremities. Fifteen percent to 20 percent of these patients are at risk of amputation. Limited outcome data show a greater than 50 percent reduction in amputation rates in patients treated with hyperbaric oxygen therapy.

2. **Tissue saving** — Chronic infection on bone (osteomyelitis); gas gangrene; crush injuries; longer term effects of radiation therapy to the bladder, colon, soft tissues and skin; or complications after skin or muscle flap grafting.

"Successful tissue grafting is dependent on new tissue receiving adequate oxygen and nutrients through a local blood supply," says Dr. Claus. "Skin grafts will receive hyperbaric oxygen therapy to promote the formation of these vessels and deliver exceptionally high levels of oxygen during the critical time these new connections are being formed. Other forms of grafts are pieces of tissue that are moved from other parts of the body along with their existing blood supply connections. Or, tissue can be reimplanted using microscopic procedures to reconnect the blood supply. Either method can result in a temporary compromise of these tenuous connections. Hyperbaric oxygen therapy can support the tissue until new microscopic blood vessels are formed and adequate circulation can be restored surgically."

3. **Lifesaving** — The only primary treatment for potentially fatal air-gas embolisms, which occur when air enters a person's vascular system accidentally from an instrument scope passing into an organ or vessel; the only treatment for decompression sickness, experienced by scuba divers who surface too quickly; severe carbon monoxide poisoning.

During treatment in the hyperbaric chamber, the oxygen level is boosted to 15 times the normal level to ensure patients are breathing high levels of oxygen. The air pressure is increased to allow more oxygen molecules into the same space, or more oxygen into each breath. Pressure during treatment is equivalent to that at 33 to 66 feet below the surface of sea water.

"That's approximately the same pressure at which I dive with my son to look at coral reefs," says Dr. Claus.

Patients wear transparent oxygen delivery hoods to allow comfortable breathing and conversation. Patients may notice a temporary change in air pressure, similar to what they experience when flying on a commercial airplane. Otherwise, the environment in the hyperbaric chamber is similar to that of any medical center waiting room. Patients also wear special cotton-blend clothing during treatment sessions to eliminate the risk of fire from ignition of high concentrations of oxygen at elevated pressures.

Although the primary role of the hyperbaric chamber is to improve patient outcomes, Mayo Clinic will use it for altitude research and development.

A treatment session lasts 60 to 90 minutes. Some conditions, such as carbon monoxide poisoning, can be treated in as few as three visits. Others, such as non-healing wounds, may require 25 to 30 treatments. Medical staff work inside and outside the chamber, monitoring patients and chamber performance.

One-of-a-kind fellowship brings unique educational opportunities

To prepare for his role as director of the Hyperbaric Medicine Program, Dr. Claus undertook a unique two-year fellowship in Advanced Clinical Training in Hyperbaric Medicine through the Mayo School of Graduate Medical Education. During the fellowship, he traveled worldwide to gain perspectives on hyperbaric medicine and its possibilities.

"I had received training in Louisville, Ky., and received training at private and academic institutions," he says. "I studied in Australia and traveled to Split, Croatia, to visit a former Yugoslavian naval base where they conduct hyperbaric treatment and research."

Aerospace research

Although the primary role of the hyperbaric chamber is to improve patient outcomes, Mayo Clinic will use it for altitude research and development. Testing can be done in the chamber with a large system of vacuums that can simulate an altitude up to 100,000 feet.

A 1940s-era hyperbaric chamber.

"Lack of oxygen at high altitudes results in confusion and deterioration of mental function. This is much more common among the general public than most would think," says Dr. Claus. "Commercial aircraft routinely subject the traveling public and crew to mild hypoxia for significant periods of time. Our knowledge of the human tolerance to this exposure for individuals compromised by age and heart and lung problems remains poorly understood. Traveling in this environment places all at risk in the event of sudden cabin pressure loss or emergency oxygen system failures. Current plans for suborbital air transport will present additional challenges as manufacturers balance the cost to maintain appropriate cabin oxygen for healthy travelers and those compromised by heart or lung conditions. Our aerospace group is working with contractors to develop emergency oxygen systems for commercial aircraft. Mayo Clinic can play an important role in setting scientifically sound standards to protect the traveling public.

"We also hope to participate in human subject testing with NASA, related to returning to the moon and planning for travel to Mars," he says.

Valuable research already under way

Although the program will not begin treating patients until November 2007, it is already scheduled to engage in cancer research.

Mayo Clinic's Department of Radiation Oncology and Hyperbaric Medicine Program will begin enrolling participants in a multicenter study, together with three other major medical centers, in a protocol for head and neck cancer patients receiving hyperbaric oxygen prior to standard radiation and chemotherapy. The study is funded through the Baromedical Research Foundation, which has supplied Mayo Clinic with temporary use of a single-person (monoplace) hyperbaric chamber for this research.

"Previous studies have confirmed that radiation is more effective in tissue that has a normal oxygen level," says Dr. Claus. "Research also has shown that large tumors contain areas that are relatively low in oxygen. Most likely, this makes the tumors resistant to radiation therapy.

"Many of the body's healing responses to hyperbaric oxygen are poorly understood," he says. "It is Mayo's intent to study the biochemical and cellular mechanisms to better administer hyperbaric oxygen therapy to patients and, hopefully, to discover new clinical applications for oxygen."

Mayo's history with aerospace research

Mayo Clinic has a history of internationally recognized scientific contributions to altitude and gravitational physiology, including pioneering human centrifuge work, which led to the development of today's G-suits.

G-suits are specialized garments worn by aviators and astronauts. The suits consist of tight-fitting pants with inflatable bladders that press firmly against the lower extremities and abdomen to prevent blood from blowing away from the brain during periods of very high gravitational acceleration, or "G." This prevents loss of consciousness (G-lock or blackout). The G-suit, combined with a specific abdominal straining maneuver (the M-1 or Mayo-1) developed at Mayo in the early 1940s, enable pilots to withstand combat or acrobatic maneuvers that are physically punishing and potentially lethal if their alertness were to be jeopardized for even a moment.

From the late 1930s through the World War II era, a group of talented and energetic physicians, physiologists and technicians collaborated as the Mayo Aeromedical Unit to focus on solving problems that faced aviators. The group included Walter Boothby, M.D., who directed the high-altitude laboratory; and E.J. Baldes, M.D., and Charlie Code, M.D., who worked on issues related to acceleration and decompression illness. Other major participants in the Aeromedical Unit included A.H. Bulbulian, D.D.S, H.F. Helhmolz Jr., M.D., Edward Lambert, M.D., W.R. Lovelace II, M.D., R.E. Sturm, M.D., and Earl Wood, M.D., Ph.D.

Other technicians and assistants provided invaluable service to the research that ultimately helped the Allies succeed. The Air Transport Command of the Army Air Forces assigned a fighter pilot, Ken Bailey, and a Navy fighter plane to Rochester to facilitate several Mayo Clinic acceleration studies with the Aeromedical Unit.

The Aeromedical Unit developed and optimized technologies such as the BLB mask (an acronym for Walter Boothby, Randy Loveless and Arthur Bulbulian), a face mask that had a combined inspiratory and expiratory valve and a bag for rebreathing, used mainly with oxygen delivery systems at high altitudes and, occasionally, for clinical administration of oxygen. Further pioneering work was continued by Dr. Wood and his colleagues after World War II. They took concepts initiated during wartime and developed clinical applications for use in patient care for procedures such as cardiac catheterization.

The Mayo Aeromedical Unit's chamber facility and acceleration centrifuge were dismantled in the 1970s when they were no longer needed.

Now, the Mayo Clinic Section of Aerospace Medicine has revitalized Mayo's involvement in clinical aeromedical research, including consulting for Federal Aviation Administration (FAA) pilot certification examinations, complex aviation forensic cases, aviation disability evaluations and special screening assessments for major airlines.

Recently, Mayo's aerospace group completed a research contract for the first phase of certification approvals for a new emergency oxygen delivery system to be used in a next-generation airliner. The group plans to seek contracts to perform similar altitude testing in the new chamber, and to perform human subject and instrument testing for NASA and the Department of Defense.

— Maren Dale