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Altitude Chamber Training: Is It Worth the Risk?

Thousands of pilots continue to be exposed to altitude chamber training scenarios. However, there is evidence that such training is often not only unnecessary but potentially dangerous.

by
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During the past half century, altitude chamber training has gained considerable support as an appropriate learning experience.

A U.S. Air Force flight surgeon wrote recently: "Hypobaric chamber exposures have proved to be a very safe and cost effective way to introduce flyers to the physiologic limitations of unpressurized flight and for recurrent indoctrination in the use of life support equipment." (4)

But is such training really necessary? Are the potential health dangers worth the risk?

Their use is still widespread today. NATO military aviation services have standardized statutory requirements for both initial and refresher air crew physiology training inside an altitude chamber. Indeed, an individual's occupational "currency" depends, in part, on its timely completion.

Nonmilitary government agencies that routinely conduct air operations frequently follow the example of their uniformed colleagues. In the United States, U.S. Drug Enforcement Administration and Immigration and Naturalization Service pilots are expected to maintain a comparable physiology training currency. Training utilizes nearby military facilities.

There are no U.S. Federal Aviation Administration (FAA) requirements for such training. No civilian owned and operated altitude chambers exist for such work. There is a perception, nevertheless, among commercial and corporate pilots that altitude chamber training must be a worthwhile experience because the military continues to require it. Similarly, general aviation follows the lead of its professional pilots and adopts such training (29).

Many of these chambers are 30-50 years old. It is not known, however, how many "cycles" these aging devices can withstand before they become mechanical hazards. A 40,000-foot altitude pressure exposes a chamber to inside pressures only 2.15 psi away from a vacuum. This safety issue is being studied by an engineering contractor for the U.S. government.

In 1991, the U.S. Customs Service canceled its requirement for such training after reviewing statistical experiences of medical complications from altitude chamber exposures (amendment to U.S. Customs Service *Aviation Operations Handbook*, March 4, 1991). However, proponents of such training contend it is safe when conducted

under proper conditions. [The Civil Aviation Medical Association has encouraged aviation medical examiners to refer pilots for altitude training at military or FAA facilities. The association says such training is necessary for civilian pilots to understand the problems of hypoxia, rapid decompression and time of useful consciousness.]

Table 1 lists some other chamber uses that have developed through the years.

The original purpose in having an altitude chamber in an operational setting was to conduct hypoxia training. But altitude chamber testing can also cause clinical problems of variable significance. They include:

Table 1
Altitude Chamber Applications

- Teach correct use of an oxygen mask;
- Teach pressure breathing techniques;
- Teach communication while wearing a mask;
- Teach Valsalva techniques for clearing ears;
- Demonstrate individual hypoxia symptoms;
- Demonstrate rapid decompression phenomena;
- Identify claustrophobes;
- Identify Eustachian tube dysfunctionals;
- Identify paranasal sinus problems;
- Perform scientific research; and
- Perform special medical evaluations.

- Expanding gas syndromes;
- Hyperventilation;
- Cerebral hypoxia;
- Decompression sickness; and,
- Pneumothorax.

The morbidity and mortality rates associated with these clinical problems are more serious than is generally understood in the user community. They occur in several categories and involve a variety of symptoms and complications.

Chambers Not Necessary for Gas Expansion at Altitude Demonstrations

• Ear Blocks

The correct use of the Valsalva technique to equalize pressure in the middle ear during descent from altitude is a special skill not readily imparted by didactic lecturing alone. It is learned by trial and error, either in a trainer aircraft or in a chamber. Inflight incapacitation is the potential price to be paid by the uneducated. This skill is acquired by many pilots without altitude chamber exposure.

• Sinus Blocks

Altitude chambers offer a unique controlled environment to identify the one to two percent of students entering aviation (69) whose sinus disease is severe enough to preclude an aviation career without an attempt at medical or surgical intervention. It is the painful sinus block itself that signals the presence of such a defect. But unpressurized flight in a dual-piloted training airplane produces the same result. For both ears and sinuses, a 25,000-foot exposure is not required to identify who has the problem. The majority of such barotrauma incidents take place at altitudes where pressurization is not required.

• Abdominal Gas

The expandable surgical glove tied to the chamber's ceiling becomes mute testimony to the state of trapped abdominal gas. At 18,000 feet, it has doubled its size. A similar fate awaits the pilot who flies while suffering from an intestinal upset, but his chamber experience does not guarantee immunity from a firsthand experience during a flying career.

• Pulmonary Gas Expansion During a Rapid Decompression (RD) Demonstration

Chamber trainees are warned to avoid swallowing when the rapid decompression takes place, to prevent catastrophic over-pressurization of the lung that could cause a traumatic pulmonary tear and collapse of that organ. The resulting pneumothorax (literally, air leaked into the chest) may be immediate and dramatic, or delayed for a few hours depending on how big the tear is. What follows this warning, dramatic though it may be, is hardly a learning experience. The sudden noise, temperature drop and fogging of the chamber does not equip the student to better cope with such an event in an aircraft other than to help him identify the event. A movie will do the same thing without risk.

There are eight known cases (and probably twice that number) of pneumothorax (70) caused by Air Force chamber RD exposure and resultant lung collapse. This is a high price to pay for an experience. The same potential disaster awaits a very few unfortunates who happen to be swallowing during an actual aircraft decompression. The U.S. Navy discontinued RD demonstrations more than a

decade ago because it believed the risks outweighed the benefits. (68)

• Conclusion

For the specific issues related to the physiology of gas expansion, unpressurized flight in altitude chambers using current protocols should not be defended as a necessary training experience. The lessons that need to be learned are already available for study outside the chamber — in movies, training lectures and trainer aircraft.

Chamber Exposure Does Little to Help Pilots Cope with Hyperventilation

• Operational Experience

Anxiety is normal when one is faced with the unknown. This is especially true in the unique world of the student pilot. Unusual attitudes, perhaps a strange mask over the mouth and nose in combination with strange and conflicting sensory inputs, are part of the unknown new world of flight. No one is surprised at air sickness or nervousness during the initial stages of flight training. But after the first few flights, instructors should not have to contend with such factors unless the "fear of flying" syndrome (76) lurks in the student's psyche. The trappings of flight can become familiar and comfortable as long as the skill available is not exceeded by the skill required. The key to success is the student's deep commitment and involvement in the carefully measured challenges presented by the instructor. The student pilot is actively involved. The experience is not passive. Anxiety will be replaced with confidence born of experience.

• Training Experience

Altitude chamber training is a passive experience. Even seasoned pilots often dislike the chamber experience. Student pilots who have little difficulty in the airplane can find themselves on the receiving end of an anxiety attack in the chamber — one that may lead the observer to consider them unlikely candidates for flight. After all, aviation lore has it that only passengers hyperventilate, real pilots do not. But there are only passengers aboard a chamber. Anxiety here does not necessarily predict suitability (or unsuitability) for flight training.

• Conclusion

Use of an altitude chamber to identify student pilots who have an undiagnosed fear of flying syndrome can lead to erroneous conclusions, and may be therefore inappropriate.

Any pilot can find himself in a severe anxiety-provoking situation. Hyperventilation is a fact of life. Chamber exposure cannot make a pilot more adept at coping with emergencies or at subverting the normal physiology of stress.

Mishaps Are Part of Hypoxia Training

• Operational Experience

An 11-year Navy experience with hypoxia in aircraft (between January 1977 and December 1988) reported by the Naval Safety Center provides a baseline from which to measure the seriousness of the hypoxia problem. Three Class A (severe) accidents occurred. Two deaths resulted from one of these mishaps. Twelve additional mishaps listed hypoxia as a "possible" contributor. A total of 69 hypoxic "physiologic incidents" were reported. (75)

Use of an altitude chamber to identify student pilots who have an undiagnosed "fear of flying" syndrome can lead to erroneous conclusions ...

• Training Relevance

Each year, the Navy has exposed between 17,000 and 20,000 flyers to hypoxia in an altitude chamber that simulates a 25,000-foot unpressurized flight. (68) At this altitude, trainees are asked to remove their masks until the supervisor instructs the trainees to replace them. All Navy flyers receive requalification training every fourth year. Thus, a 20-year veteran has had probably five such hypoxia exposures. Altitude chamber trainees are taught that their symptoms are both unique and repeatable. This assumption is scientifically flawed. (65, 71)

Trainees are warned that operational considerations may present such a distraction that they may not notice the symptom complex they learned. Indeed, the carefully orchestrated hypoxia exposure in the controlled environment of the chamber, with subjects attentively awaiting the appearance of symptoms, bears little resemblance to the sensory overload of the airborne crisis. Not only does hypoxia depend on the precise scenario in which symptoms occur, it also varies with age, with fatigue state, with physical conditioning and with other elements that comprise the setting. In some settings, the first symptom may be unconsciousness. A recent Israeli study (71) reported repeatability of hypoxia symptoms to be less than 50 percent. Ample anecdotal information that points to this training shortcoming exists in the user community, but it has not received widespread recognition or attention.

Air Force trainees undergoing refresher training are told to stop the process of hypoxia as soon as they detect their first symptom, frequently less than three minutes into the event.

They are introduced to hypoxia symptoms by a demonstration of the loss of color vision on a printed plate held before them while the chamber altitude is held at 18,000 feet. Were the full-blown hypoxia demonstration to take place at this altitude, students would wait in excess of two hours for their symptom complexes to develop; at 25,000 feet, it can take four minutes. (77)

Navy trainees, both initial and refresher, are expected to proceed to the point where the chamber attendants believe incapacitation is near, usually in excess of four minutes into the event. Commonly, one Navy trainee will be allowed to proceed through hypoxic euphoria into incapacitation for the others to see; his or her reoxygenation then becomes the responsibility of an attendant. These differing examples of hypoxia training cannot be of equal merit.

Following a hypoxia-caused crash, first-tour Navy pilots responded to a questionnaire about recollections of their initial hypoxia training experience. (75) They complained of the "… foolishness of adults playing patty cake," while pointing out that being embarrassed in front of peers by such "juvenile activities" ranked low as a memorable training event. Some failed to recall any hypoxia training experience at all.

In the name of hypoxia training, altitude chambers instill aviators with a specious confidence.

In the past four years, nearly 70,000 Navy personnel were made hypoxic in an altitude chamber. Their trainers point to the statistical averages that show only one hypoxia-caused mishap during this period as proof of the safety of their training.

In general aviation, it is common to see active pilots much older than those found in the military. The fact that each has had a recent physical examination and electrocardiogram that met ground level standards offers no insight into what risks are underwritten or what damage is caused by a deliberate hypoxic exposure at an altitude of 25,000 feet. It is possible that an electrocardiogram taken at altitude on one of these older pilots during a hypoxia demonstration would show transitory changes consistent with "cardiac ischemia." In such a case, the pilot's career would be halted until comprehensive cardiac tests (echocardiography, treadmill stress test, thallium study and coronary artery angiography) produced the clinical answer. (74) There is wisdom in the refusal of aviation communities to require periodic altitude training.

• Conclusion

In the name of hypoxia training, altitude chambers instill aviators with a specious confidence. Memorizing personal and special set hypoxia symptoms will not keep them safe. A chamber ride is not an airplane flight, although they are equated together in this setting. The user community is better served by an appreciation of the variability and possible unpredictability of hypoxia presentations rather than their constancy. This is best done in a classroom setting at ground level. A reasonable and defensible solution to this issue would be to give youthful pilots a onetime-only hypoxic episode in the chamber, and not use the chamber for refresher training.

Decompression Sickness (DCS) Increases Risk

• Operational Experience

The Naval Safety Center (73) reports that in a 20-year period, 15 people were stricken with DCS in 12 Navy and Marine Corps aircraft. No crashes resulted from these events, but two subjects required recompression therapy after landing. Air Force experience is similar (5), with 34 people during 26 years recorded as having been afflicted in flight. The size of the DCS problem in operational aircraft is thus quantified as small, although the true prevalence is believed to be underreported. Pilots whose flight profiles require unpressurized flight at altitudes above 18,000 feet are those most clearly at risk(2, 62), although *any* aircraft can be the subject of an unannounced pressurization failure. The aeromedical issue results from circulation loss in joints, lungs, spinal cord, cerebrum, cerebellum or the brain stem, probably from intravascular nitrogen bubbles.

• Training Experience

DCS in the altitude chamber training environment is not a small problem. *Aviation, Space and Environmental Medicine* published 22 articles on the subject between July 1988 and July 1992. (1-31) In addition, a total of 35 papers (32-66) were presented on DCS at the Aerospace Medical Association's 1989, 1990, 1991 and 1992 conventions.

The statistics reporting the incidence of DCS from all the military services during the past 30 years are consistent (4, 13, 39, 68, 72). There has been about one DCS case for every 1,000 chamber exposures. One Air Force study reported their incidence as 105/100,000. (4) A Navy study

reported 140/136,696 during an eight-year period. (68) There is also an identifiable subgroup, discussed below, where the DCS risk is three times greater.

Although 75 percent to 85 percent of DCS cases are not life threatening, and one quarter of these will not need treatment (the primary problem being joint pain), 15 percent to 25 percent of DCS cases risk a residual defect or a fatality. All "joint pain only" cases that persist after return to ground level, and those that begin after the altitude run is completed, will require hyperbaric therapy in a chamber. Only those whose pain completely subsided during descent will escape recompression treatment.

One Air Force study reported on 133 complicated and potentially fatal cases occurring during a 26-year period. (5) There have been 20 known fatalities (all but one of which preceded the routine application of oxygen prebreathing and hyperbaric therapy begun in the early 1960s), (22) and eight cases with permanent residual defects (13) despite such treatment.

Because only 33 percent of DCS cases manifest themselves while the patient is still at altitude, (4) most are confronted with delayed symptoms, and an unlucky few are left with symptoms that may not appear until they have completed training and returned to a remote home base. Diagnosis of DCS the day after completing a chamber flight is uncommonly challenging for the average doctor, who would not be familiar with the various DCS clinical syndromes. The issue of permitting flight in an airplane to return home after the chamber experience is also contentious because airborne flight following chamber "flight" risks precipitating DCS. (41)

Overall, the baseline DCS risk is about 1/1,000 for altitude exposures in excess of 18,000 feet. Below 18,000 feet, DCS is a clinical oddity. The list of potentially predisposing factors that can change the risk to 1/300 or less continues to grow, and is listed in Table 2. Twelve percent of those afflicted by DCS have one or more of these factors. (5) Prudence would require that subjects considering chamber flight be screened for these risk factors before being allowed aboard.

• Research Directions

The development of experimental Doppler technology that could identify the presence of intravascular bubbles appeared to open the door to studies that might identify those at risk for DCS. (3) The accepted underlying physiologic premise was that nitrogen outgassing from tissue into the blood stream would affect circulation in a detectable way.

Although it is helpful to conceive of the DCS process as being the end result of a physiologic vapor lock, Doppler studies only clouded the issue. For example:

- Most DCS patients bubbled;
- Some subjects bubbled without any symptoms;
- Some subjects had DCS without bubbles;
- Some subjects' bubbles persisted for 48 hours;
- Females had fewer bubbles but more DCS; and,
- Males had more bubbles but less DCS.

Ultrasonic monitoring (1) as a predictive tool was also disappointing.

- Almost one quarter of DCS patients did not bubble; and
- Almost half who did not get DC bubbled anyway.

The use of 100 percent oxygen by mask prior to chamber flight is a valid attempt to set up a steep enough differential or gradient between the pulmonary tissue and the inspired nitrogen-free gas so that the loss of tissue nitrogen is expedited; a 30-minute pre-breathe is usually performed. Although this is better than nothing, the U.S. National Aeronautics and Space Administration (NASA) has shown that denitrogenation to guarantee no risk of DCS is a 24-hour process, not a 30-minute one. (33, 36, 38, 44, 67)

Table 2
Factors That Can Contribute to DCS

Pre-flight exercise	Post-flight exercise
In-flight exertion	Over age 40
Recent injury	More than 14 lbs. over ideal weight
Dehydration	Alcohol
Hypoxia	Cold temperature
Menstrual flow	Being female
Morning flight	Recent immunizations
Higher altitude	Longer altitude stay
Faster ascent rate	Repeated exposures
Aircraft flight following	No denitrogenation
Scuba diving in prior 24 hours	

• Chamber Costs

Altitude chamber training costs about $100 per person. In the event that recompression therapy is deemed necessary for DCS treatment and provided that the treatment is uncomplicated (pain only), the cost increases to nearly $5,000. Forms of DCS that involve the lungs, the spinal cord, the brain or the brain stem can be lengthy and complex, and with correspondingly high costs.

• Conclusion

The aviation physiology community that offers altitude chamber training is very aware of the DCS risk. Examination of the issue of acceptable risk is a cyclically recurrent topic that, at the October 1990 Hypobaric Decompression Sickness Workshop in San Antonio, Texas, U.S., was shelved awaiting a better "… definition of this term (which) varies with the mission and is dependent upon accurate incidence data." (22) Not all aeromedical communities agree. (68, 72)

At the 1991 Aerospace Medical Association Annual Scientific Assembly, U.S. Navy physiologist Robert Bason, Ph.D., ended a presentation on the Navy's DCS experience for the seven-year period ending Sept. 30, 1988, with the following statement:

"The incidence of decompression sickness reported here suggests that present Navy altitude chamber profiles are once again in need of re-examination. Unless DCS is to be dismissed as a necessary risk, hypobaric exposure should be restudied. Altitude chamber flights beyond minimum levels acceptable for demonstrating the effects of hypoxia cannot be defended when less dangerous avenues are available. Alternate means of inducing hypoxia, such as using gas mixtures at ground level, should be fully explored." (68)

Altitude chambers can continue to have utility as research tools, but they should be removed from the business of hypoxia training. (64) Just as it takes an ear block to make a believer out of some people, decompression sickness painfully forces education on its victims. ♦

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