Recognizing And Preventing Slow-Onset Hypoxia

Killing you softly

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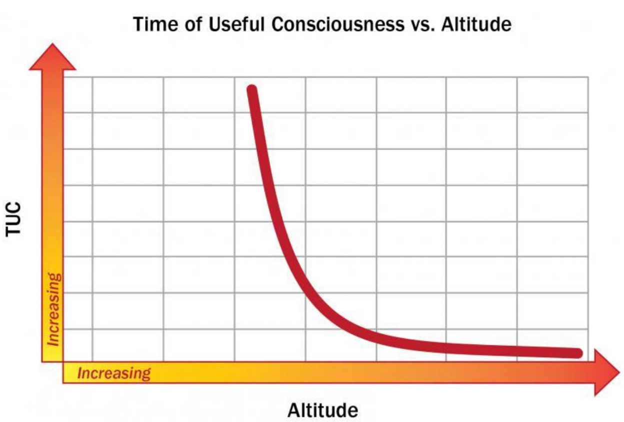
Slow-Onset Hypoxia

We of the high-altitude jet set train extensively for the remote possibility that some day our aircraft will suddenly depressurize and exchange our nice, breathable air for the cold and sterile vacuum of what might as well be extraterrestrial space.

So, we practice donning our oxygen masks and throwing the airplane into a stomach-churning plummet back to life-sustaining altitudes. We do this for our initial qualification and our recurrent check rides. Some of our aircraft are even programmed to do the "high dive" automatically. We are told from day one that unless we do all of this correctly, we have mere seconds to live.

But for all of this worry and practice, there has never been a recorded case of an aircraft lost due to a rapid depressurization. Of course you don't want the one you're flying to be the first, so all that practice is time well spent.



But there is another looming threat out there, one that has killed many times. It is much more deadly than a rapid decompression because it sneaks up on you and you may never know it is there, even after it is too late. It is slow-onset hypoxia and results from a gradual loss of cabin pressure or a failure of the cabin to pressurize. Fortunately there are preventative measures and in an airplane with more than one pilot, the cure is quick and easy.

Altitude	**TUC/EPT**	**Following Rapid Decompression**
18,000	20-30 min.	10-15 min.
22,000	10 min.	5-6 min.
25,000	3-5 min.	1.5-2.5 min.
28,000	2.5-3 min.	1-1.5 min.
30,000	1-2 min.	30 sec. - 1 min.
35,000	30 sec. - 1 min.	15-30 sec.
40,000	15-20 sec.	nominal
43,000	9-12 sec.	nominal
50,000	9-12 sec.	nominal

Hypoxia's Track Record in Aviation

The clinical definition of hypoxia is "a state of oxygen deficiency in the blood, tissues and cells sufficient to cause an impairment of body functions." A pilot's most-important body function is the ability to think and reason.

When looking at a Time of Useful Consciousness (TUC) chart, like the one presented in Advisory Circular 61-107B "Aircraft Operations at Altitudes Above 25,000 Feet," we often see two columns. The first usually shows we have 20-30 min. of TUC at 18,000 ft. and the numbers don't seem that bad all the way to 30,000 ft. where you still have 1 to 2 min. One minute is lots of time in the world of a jet pilot. But the second column, the one that says "following rapid decompression," that one presents dire news indeed. That column tells us we have mere seconds at flight levels. That is naturally where we pay attention. But the TUC acronym is misleading.

I believe a better one is EPT, for Effective Performance Time. After all, TUC or EPT don't represent the amount of time you have left conscious but rather the amount of time you have before impaired judgment gets the better of you. Once you've exhausted your TUC or EPT you might still be awake and vaguely aware of your deteriorating environment, but you may not have the mental or physical ability to do anything about the deteriorating situation.

Since 1999, there have been at least five cases in which an airplane may have been lost because of slow-onset hypoxia. Because the aircraft was either lost or completely destroyed, the reason for the loss of pressurization or failure to pressurize is rarely determined. In a few instances the oxygen system was turned off at the source. In others, the pressurization system was ineffective before the flight even began.

Oct. 25, 1999 — Learjet 35A (N47BA). The aircraft's oxygen system may have been empty and there may have been a bleed-air valve problem. Like most of these cases, the exact cause will never be known. Regardless of the cause, the airplane out-climbed the cabin and by the time the 10,000-ft. cabin altitude aural warning horn sounded the pilots were no longer usefully conscious, about 14 min. after takeoff. All eight passengers and crew on board were killed.

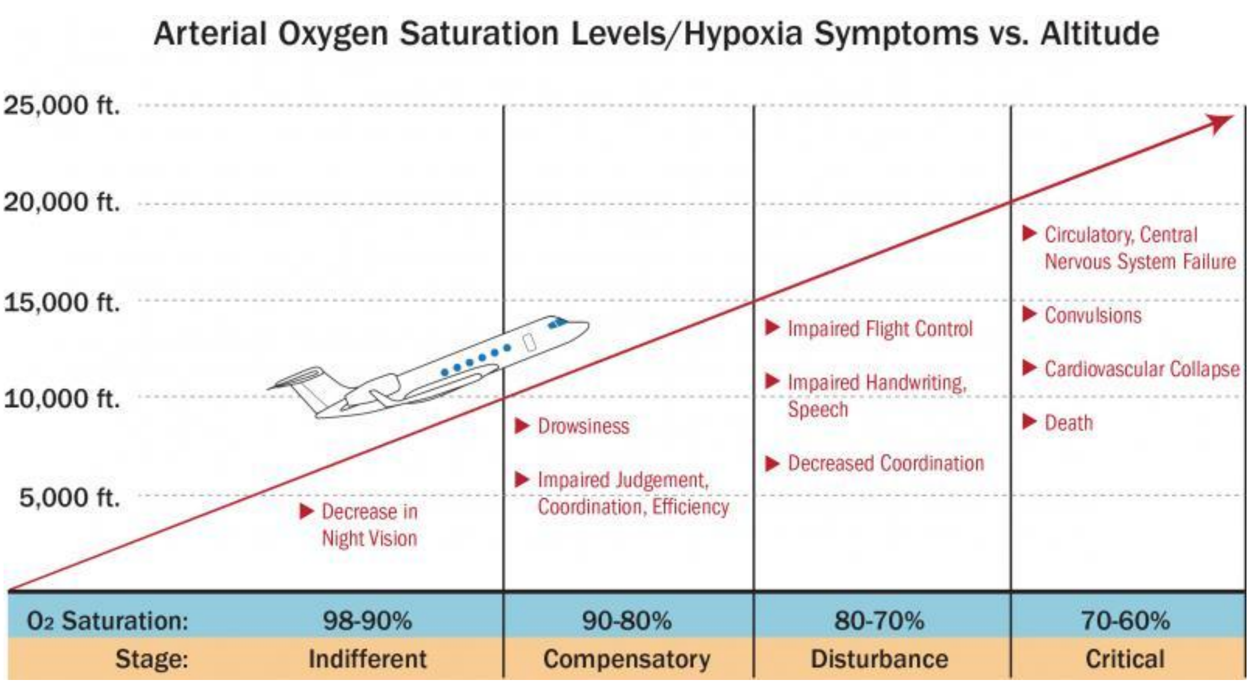
Sept. 4, 2000 — Beechcraft 200 Super King Air (VH-SKC). The airplane's pressurization system may have been improperly set and the cabin altitude warning system wasn't enough to alert the pilot he had climbed to 25,000 ft. without adequate pressurization. All eight people on board were killed. The pilot appeared to have lost useful consciousness 20 min. after takeoff.

Aug. 14, 2005 — Boeing 737-315 operating as Helios Airways Flight 522. The airplane's pressurization system had a history of problems and was improperly signed off after abbreviated maintenance work. The pilots missed a critical switch position and took off without the pressurization system working. They mistook the cabin altitude alert warning to be a ground-only takeoff configuration warning. While troubleshooting, the pilots lost consciousness. The crash that followed killed all 121 passengers, pilots and cabin crew. The pilots appeared to have lost useful consciousness 13 min. after takeoff.

April 19, 2012 — Cessna 421C (N48DL). The owner and operator of the cabin twin flew it to 27,000 ft., apparently unpressurized and without wearing the installed oxygen mask. The aircraft was intercepted and observed to circle for 3 hr. with the pilot slumped over, unconscious. The aircraft eventually crashed into the Gulf of Mexico and was not recovered. The pilot was killed and sank to the bottom with his airplane. He appeared to have lost useful consciousness about 30 min. after takeoff.

Oct. 8, 2012 — Socata TBM 700N (C-FBKK). It appears the pilot took off with the oxygen switched off at the bottle and may have either failed to open or later mistakenly closed the bleed air source from the engine. He may have initiated an emergency descent, but soon lost useful consciousness. This occurred about 16 min. after takeoff. He was killed.

Each of these cases remains shrouded in mystery because the aircraft were destroyed to the point where reconstruction was virtually impossible. There is a common thread, however. Each aircraft appeared to take off with the ingredients for the disaster already baked into the scenario. Between 13 and 30 min. after takeoff, every pilot was beyond the point of recognizing that he or she was in terrible danger.



The Recognition Problem

Knowing how oxygen gets from either the air in your surroundings or in the oxygen mask clamped to your face and to your brain is crucial to understanding just how dangerous slow-onset hypoxia can be. When you breathe, your lungs exchange oxygen and carbon dioxide through thousands of air sacs, called bronchioles, where capillaries allow the gases to move into and out of the bloodstream. From there it is distributed throughout the body. The blood is the key component in the transportation of oxygen to where it needs to go.

Blood is made up of cells and a liquid called serum, which is mostly water. The red blood cells physically carry oxygen molecules attached to a cell called hemoglobin. When these red blood cells become saturated with oxygen, they turn the bright-red color we associate with arterial blood. This hemoglobin saturation level determines the efficiency of the transportation of oxygen. This level is normally between 95 and 98% for a human being at sea level.

Human physiology automatically prioritizes the brain's need for oxygen over all other parts of the body. Your muscle coordination, vision and many other functions will start to show signs of impairment before your brain ceases to function. But your brain may suffer impairment before it recognizes the warning signs displayed by the rest of the body. Therein lies the crux of the problem with slow-onset hypoxia.

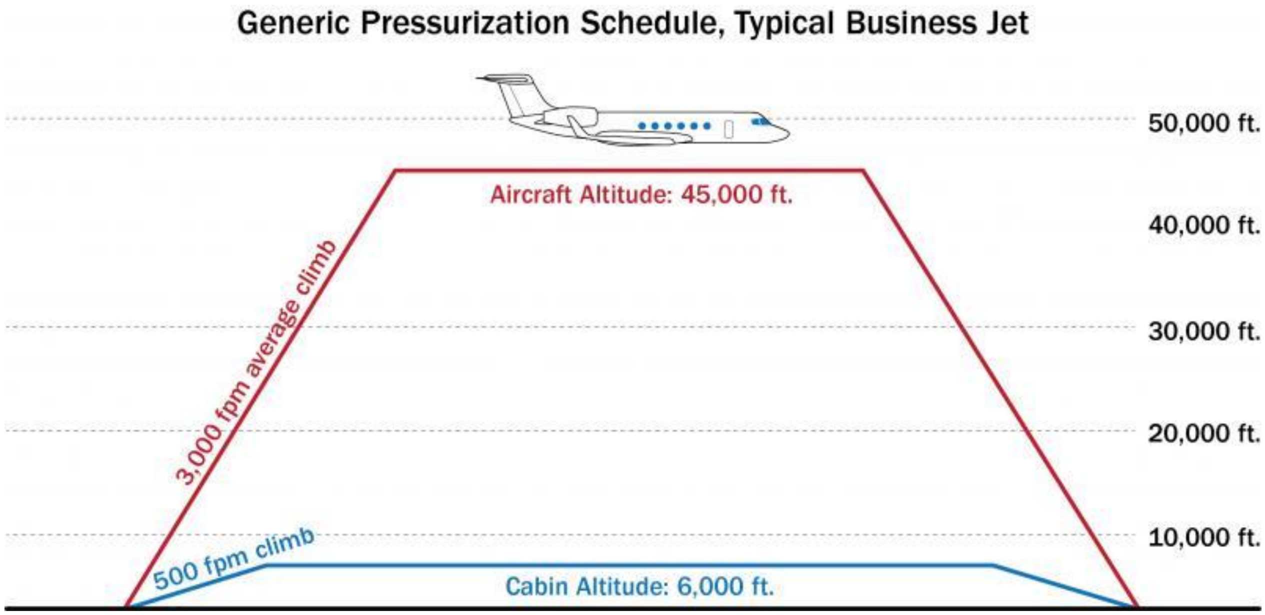
Physiologists, particularly those interested in aviation and other high-altitude pursuits, long ago realized the link between altitude and the oxygen saturation in blood. Years of altitude chamber work show a general pattern as to what functions are lost as altitude goes up and oxygen saturation goes down. Individual cases vary, but in general:

We all seem to do pretty well through 10,000 ft. of altitude, what some flight surgeons call the indifferent stage. The only adverse effect is dark adaptation, the ability to see well at night.

Between 10,000 and 15,000 ft. our bodies make respiratory and circulatory adjustments in the compensatory stage. In general we can see an increase in pulse and respiratory rates, as well as an increase in fatigue and irritability, and a decrease in judgment.

Between 15,000 and 20,000 ft. our physiological responses become inadequate to fight off the low oxygen saturation levels in our blood. This is the disturbance stage. We start to lose our vision, our sense of touch decreases and muscular coordination is reduced. Intellectual impairment becomes pronounced; we think more slowly, our memory is faulty and our judgment is poor.

Above 20,000 ft. there is almost complete mental and physical incapacitation. In this, the critical stage, we will see unconsciousness, convulsions and finally a failure of respiration and death.



Looking at the progression through each stage, it becomes obvious why recognition of slow-onset hypoxia is so difficult. Many of the symptoms in the compensatory stage can be mistaken for just another day in the cockpit. By the time your brain recognizes that hypoxia is the threat, your memory about what to do about it and the muscle coordination required to act may both be gone.

Prevention Is Easy

Looking at the five examples where the evidence strongly suggests slow-onset hypoxia resulted in loss of life and aircraft, you can devise an easily implemented strategy to prevent this from happening to you.

(1) Address pressurization system problems immediately, thoroughly and by the book. Small leaks in your fuselage only become larger with the passage of time and the repair procedure may not always be obvious. The mechanics for Helios Airways Flight 522 thought pumping the fuselage to maximum differential pressure was the best way to prove the fuselage did not leak. But the Boeing manual called for much less pressure with a timed measurement of pressure loss. They failed to detect a leak the book answer would have caught.

(2) Preflight oxygen supply and delivery equipment prior to every flight. Oxygen systems tend to be sturdy until they aren't. A $2.00 Schrader valve, for example, can last for years until it simply quits. A full oxygen system can empty itself overnight. The only sure way to know the system's status is to check it. There is evidence suggesting a proper oxygen preflight could have saved the day for Learjet N47BA and Socata TBM 700N C-FBKK.

(3) Check cabin pressure when passing 10,000 ft., at level-off and every hour of the flight. The cabin altitude warning system can fail, can be overlooked or can be misinterpreted. In each of the accidents cited, the airplane appeared to take off with the pressurization and oxygen systems set to fail. You should know what a normal cabin pressure reading is for all phases of

flight. If your airplane typically climbs out at around 3,000 ft. per minute, for example, you will cross 10,000 ft. of aircraft altitude in less than 4 min.

Altitude chamber, Offutt Air Force Base, April 4, 2013. Credit: U.S. Air Force/Wikimedia

If your automatic pressurization control system climbs the cabin at 500 ft. per minute, which is a common rate for jet aircraft, your cabin altitude should be no higher than 2,000 ft. You should make another check at level-off since your engine power will soon be reduced, and if you have a small cabin leak this is when that can become evident. Repeat this check every hour. You should know what your by-the-book maximum cabin altitude is. If you are flying a Gulfstream 450, for example, you should never see a cabin altitude above 6,000 ft. unless you are departing from or heading to an airport at that altitude or higher.

(4) Keep an eye on the other pilot. We pilots are the worst detectors of hypoxia in ourselves. We tend to excuse momentary lapses in our own behavior or can be blind to them. You may be a better judge of the other pilot's symptoms. Or, you may actually have a greater altitude tolerance.

(5) When troubleshooting a pressurization problem, don oxygen first. Donning oxygen will not only improve your mental capabilities, it also can keep you in the game if things go south quickly or insidiously. The pilots of Helios Airways Flight 522 appeared to have gotten so wrapped up in their troubleshooting efforts they completely ignored their hypoxia symptoms until it was too late.

When in doubt, don oxygen and descend. If you are not hypoxic consider this an insurance policy. If you are hypoxic, it will cure what ails you.

The Cure Is Easy (But Elusive)

Altitude chamber tests reveal that you can go from very poor oxygen saturation (63%) to very good (99%) in less than a minute after donning an oxygen mask and breathing 100% oxygen. But you have to be very familiar and practiced with your oxygen equipment to do this even if you are just slightly hypoxic.

Credit: Christopher L. Parker

Simulator practice is not good enough; it isn't just like your airplane and doesn't keep you proficient. A brand-new mask may not pull out of its container easily the first time or even the 10th time. The only way to find out is to try it.

You should develop the muscle memory of pulling the mask out and placing it onto your face in 5 sec. or less until it becomes second nature. There may come a time when all the other precautions have failed and the oxygen saturation level in your blood is just enough to trigger your brain into action. It would be a pity if the saturation level in your arms, hands and fingers struggled for lack of muscle memory. This kind of practice is the price of admission to the high-altitude pilot class. It is a small price and well worth it.