Federal Aviation Administration

ALTITUDE-INDUCED DECOMPRESSION SICKNESS

Tiny Bubbles, BIG Troubles

Decompression sickness (DCS) describes a condition characterized by a variety of symptoms resulting from exposure to low barometric pressures that cause inert gases (mainly nitrogen), normally dissolved in body fluids and tissues, to come out of physical solution and form bubbles. DCS can occur during exposure to altitude (altitude DCS) or during ascent from depth (mining or diving). The first documented cases of DCS (Caisson Disease) were reported in 1841 by a mining engineer who observed the occurrence of pain and muscle cramps among coal miners exposed to air-pressurized mine shafts designed to keep water out. The first description of a case resulting from diving activities while wearing a pressurized hard hat was reported in 1869.

ALTITUDE-INDUCED DECOMPRESSION SICKNESS

Altitude DCS became a commonly observed problem associated with high-altitude balloon and aircraft flights in the 1930s. In present-day aviation, technology allows civilian aircraft (commercial and private) to fly higher and faster than ever before. Though modern aircraft are safer and more reliable, occupants are still subject to the stresses of high altitude flight—and the unique problems that go with these lofty heights. A century and one-half after the first DCS case was described, our understanding of DCS has improved, and a body of knowledge has accumulated; however, this problem is far from being solved. Altitude DCS still represents a risk to the occupants of modern aircraft.

Tiny Bubbles

According to Henry's Law, when the pressure of a gas over a liquid is decreased, the amount of

gas dissolved in that liquid will also decrease. One of the best practical demonstrations of this law is offered by opening a soft drink. When the cap is removed from the bottle, gas is heard escaping, and bubbles can be seen forming in the soda. This is carbon dioxide gas coming out of solution as a result of sudden exposure to lower barometric pressure. Similarly, nitrogen is an inert gas normally stored throughout the human body (tissues and fluids) in physical solution. When the body is exposed to decreased barometric pressures (as in flying an unpressurized aircraft to altitude, or during a rapid decompression), the nitrogen dissolved in the body comes out of solution. If the nitrogen is forced to leave the solution too rapidly, bubbles form in different areas of the body, causing a variety of signs and symptoms. The most common symptom is joint pain, which is known as "the bends."

Trouble Sites

Although bubbles can form anywhere in the body, the most frequently targeted anatomic locations are the shoulders, elbows, knees, and ankles.

Table 1 lists the different DCS types with their corresponding bubble formation sites and their most common symptoms. "The bends" (joint pain) account for about 60 to 70% of all altitude DCS cases, with the shoulder being the most common site. Neurologic manifestations are present in about 10 to 15% of all DCS cases, with headache and visual disturbances being the most common symptoms. "The chokes" are very infrequent and occur in less than 2% of all DCS cases. Skin manifestations are present in about 10 to 15% of all DCS cases.

Medical Treatment

Mild cases of "the bends" and skin bends (excluding mottled or marbled skin appearance) may disappear

during descent from high altitude, but still require medical evaluation. If the signs and symptoms persist during descent or reappear at ground level, it is necessary to provide hyperbaric oxygen treatment immediately (100% oxygen delivered in a high-pressure chamber). Neurological DCS, "the chokes," and skin bends with mottled or marbled skin lesions (see Table 1) should always be treated with hyperbaric oxygenation. These conditions are very serious and potentially fatal if untreated.

Facts About Breathing 100% Oxygen

One of the most significant breakthroughs in altitude DCS research was the discovery that breathing 100% oxygen before exposure to a low barometric pressure (oxygen prebreathing), decreases the risk of developing altitude DCS. Oxygen prebreathing promotes the elimination (washout) of nitrogen from body tissues. Prebreathing 100% oxygen for 30 minutes prior to initiating ascent to altitude reduces the risk of altitude DCS for short exposures (10-30 min. only) to altitudes between 18,000 and 43,000 ft. However, oxygen prebreathing has to be continued, without interruption, with inflight 100% oxygen breathing to provide effective protection against altitude DCS. Furthermore, it is very important to understand that breathing 100% oxygen only during flight (ascent, enroute, descent) does not decrease the risk of altitude DCS and should not be used in lieu of oxygen prebreathing.

Although 100% oxygen prebreathing is an effective method to provide individual protection against altitude DCS, it is not a logistically simple or an inexpensive approach for the protection of civil aviation flyers (commercial or private). Therefore, at the present time, it is only used by military flight crews and astronauts for their protection during high altitude and space operations.

Table 1. Signs and symptoms of Altitude Decompression Sickness.

DCS Type	Bubble Location	Signs & Symptoms (Clinical Manifestations)
BENDS	Mostly large joints of the body (elbows, shoulders, hip, wrists, knees, ankles)	• Localized deep pain, ranging from mild (a "niggle") to excruciating. Sometimes a dull ache, but rarely a sharp pain. • Active and passive motion of the joint aggravates the pain. • Pain can occur at altitude, during the descent, or many hours later.
NEUROLOGIC Manifestations	Brain	• Confusion or memory loss • Headache • Spots in visual field (scotoma), tunnel vision, double vision (diplopia), or blurry vision • Unexplained extreme fatigue or behavior changes • Seizures, dizziness, vertigo, nausea, vomiting and unconsciousness may occur
	Spinal Cord	• Abnormal sensations such as burning, stinging, and tingling around the lower chest and back • Symptoms may spread from the feet up and may be accompanied by ascending weakness or paralysis • Girdling abdominal or chest pain
	Peripheral Nerves	• Urinary and rectal incontinence • Abnormal sensations, such as numbness, burning, stinging and tingling (paresthesia) • Muscle weakness or twitching
CHOKES	Lungs	• Burning deep chest pain (under the sternum) • Pain is aggravated by breathing • Shortness of breath (dyspnea) • Dry constant cough
SKIN BENDS	Skin	• Itching usually around the ears, face, neck arms, and upper torso • Sensation of tiny insects crawling over the skin • Mottled or marbled skin usually around the shoulders, upper chest and abdomen, accompanied by itching • Swelling of the skin, accompanied by tiny scar-like skin depressions (pitting edema)

PREDISPOSING FACTORS

Altitude

There is no specific altitude that can be considered an absolute altitude exposure threshold, below which it can be assured that no one will develop altitude DCS. However, there is very little evidence of altitude DCS occurring among healthy individuals at altitudes below 18,000 ft. who have not been SCUBA (Self Contained Underwater Breathing Apparatus) diving. Individual exposures to altitudes between 18,000 ft. and 25,000 ft. have shown a low occurrence of altitude DCS. Most cases of altitude DCS occur among individuals exposed to altitudes of 25,000 ft. or higher. A US Air Force study of altitude DCS cases reported that only 13% occurred below 25,000 ft. The higher the altitude of exposure, the greater the risk of developing altitude DCS. It is important to clarify that although exposures to incremental altitudes above 18,000 ft. show an incremental risk of altitude DCS, they do not show a direct relationship with the severity of the various types of DCS (see Table 1).

Repetitive Exposures

Repetitive exposures to altitudes above 18,000 ft. within a short period of time (a few hrs.) also increase the risk of developing altitude DCS.

Rate of Ascent

The faster the rate of ascent to altitude, the greater the risk of developing altitude DCS. An individual exposed to a rapid decompression (high rate of ascent) above 18,000 ft. has a greater risk of altitude DCS than being exposed to the same altitude but at a lower rate of ascent.

Time at Altitude

The longer the duration of the exposure to altitudes of 18,000 ft. and above, the greater the risk of altitude DCS.

Age

There are some reports indicating a higher risk of altitude DCS with increasing age.

Previous Injury

There is some indication that recent joint or limb injuries may predispose individuals to developing “the bends.”

Ambient Temperature

There is some evidence suggesting that individual exposure to very cold ambient temperatures may increase the risk of altitude DCS.

Body Type

Typically, a person who has a high body fat content is at greater risk of altitude DCS. Due to poor blood supply, nitrogen is stored in greater amounts in fat tissues. Although fat represents only 15% of an adult normal body, it stores over half of the total amount of nitrogen (about 1 liter) normally dissolved in the body.

Exercise

When a person is physically active while flying at altitudes above 18,000 ft., there is greater risk of altitude DCS.

Alcohol Consumption

The after-effects of alcohol consumption increase the susceptibility to DCS.

Scuba Diving Before Flying

SCUBA diving requires breathing air under high pressure. Under these conditions, there is a significant increase in the amount of nitrogen dissolved in the body (body nitrogen saturation). The deeper the SCUBA dive, the greater the rate of body nitrogen saturation. Furthermore, SCUBA diving in high elevations (mountain lakes), at any given depth, results in greater body nitrogen saturation when compared to SCUBA diving at sea level at the same depth. Following SCUBA diving, if not enough time is allowed to eliminate the excess nitrogen stored in the body, altitude DCS can occur during exposure to altitudes as low as 5,000 ft. or less.

WHAT TO DO WHEN ALTITUDE DCS OCCURS

- Put on your oxygen mask immediately and switch the regulator to 100% oxygen.
- Begin an emergency descent and land as soon as possible. Even if the symptoms disappear during

descent, you should still land and seek medical evaluation while continuing to breathe oxygen.

- If one of your symptoms is joint pain, keep the affected area still; do not try to work pain out by moving the joint around.
- Upon landing seek medical assistance from an FAA medical officer, aviation medical examiner (AME) military flight surgeon, or a hyperbaric medicine specialist. Be aware that a physician not specialized in aviation or hypobaric medicine may not be familiar with this type of medical problem. Therefore, be your own advocate.
- Definitive medical treatment may involve the use of a hyperbaric chamber operated by specially trained personnel.
- Delayed signs and symptoms of altitude DCS can occur after return to ground level whether or not they were present during flight.

THINGS TO REMEMBER

- Altitude DCS is a risk every time you fly in an unpressurized aircraft above 18,000 feet (or at lower altitude if you SCUBA dive prior to the flight).
- Be familiar with the signs and symptoms of altitude DCS (see Table 1) and monitor all aircraft occupants, including yourself, any time you fly an unpressurized aircraft above 18,000 ft.
- Avoid unnecessary strenuous physical activity prior to flying an unpressurized aircraft above 18,000 ft. and for 24 hrs. after the flight.
- Even if you are flying a pressurized aircraft, altitude DCS can occur as a result of sudden loss of cabin pressure (inflight rapid decompression).
- Following exposure to an inflight rapid decompressions do not fly for at least 24 hrs. In the meantime, remain vigilant for the possible onset of delayed symptoms or signs of altitude DCS. If you present delayed symptoms or signs of altitude DCS, seek medical attention immediately.
- Keep in mind that breathing 100% oxygen during flight (ascent, enroute, descent) without oxygen prebreathing prior to take off does not prevent the occurrence of altitude DCS.
- Do not ignore any symptoms or signs that go away during the descent. In fact, this could confirm that you are actually suffering altitude DCS. You should be medically evaluated as soon as possible.
- If there is any indication that you may have experienced altitude DCS, do not fly again until you are cleared to do so by an FAA medical officer, an aviation medical examiner, a military flight surgeon, or a hyperbaric medicine specialist.
- Allow at least 24 hrs. to elapse between SCUBA diving and flying.
- Be prepared for a future emergency by familiarizing yourself with the availability of hyperbaric chambers in your area of operations. However, keep in mind that not all of the available hyperbaric treatment facilities have personnel qualified to handle altitude DCS emergencies. To obtain information on the locations of hyperbaric treatment facilities capable of handling altitude DCS emergencies, call the Diver's Alert Network at (919) 684-8111.

For More Information

If you are interested in learning more about altitude DCS, as well as the other stressors that may affect your performance and/or your health during flight, we encourage you to enroll in the Physiological Training Course offered by the Aeromedical Education Division (Airman Education Programs) at the FAA Civil Aerospace Medical Institute in Oklahoma City. A similar course is also available at US military physiological training facilities around the country through an FAA/DOD Training Agreement. For more information about any of these courses, call us at (405) 954-4837.

Medical Facts for Pilots

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To order copies of this brochure and others listed below, contact

FAA Civil Aerospace Medical Institute
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Other Pilot Safety Brochures Available

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AM-400-01/1	*Physiological Training Courses for Civil Aviation Pilots*
AM-400-05/1	*Sunglasses for Pilots: Beyond the Image*

To view these pilot and passenger safety brochures, visit the Federal Aviation Administration's Web Site

www.faa.gov/pilots/safety

Physiological Training Classes for Pilots

If you are interested in taking a one-day aviation physiological training course with altitude chamber and vertigo demonstrations or a one-day survival course, learn about these courses by visiting this FAA Web site:

www.faa.gov/pilots/training/airmen_education