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Flying and Diving — A Unique Health Concern

Aviators must take special precautions to avoid the hazards of decompression sickness (DCS).

by
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Scuba (self-contained underwater breathing apparatus) diving is a recreation enjoyed throughout the world, especially at island resorts served by inter-island and international airlines. Aircraft crew members, as well as tourists, may be able to make several underwater dives in a single day. In some instances, enthusiasts may complete their final dives only a short time before an evening flight to home. These flights may be for several hours at cabin altitudes of between 6,000 and 8,000 feet. For the passenger or crew member who was scuba diving earlier that day, the flight could become a painful experience. Discomfort, pain or other symptoms might be caused by decompression sickness (DCS).

The incidence of DCS, also commonly called the "bends" which is one form of DCS, is low. The combination of certified scuba diving instructors teaching safe techniques and the use of well-designed and well-maintained equipment help prevent DCS problems. In aviation, cabin pressurization systems reduce the risk of DCS in flight. However, the combination of scuba diving and flying within a short time period can dramatically increase the risk of DCS. Although the incidence of in-flight DCS is not well documented, it is important for anyone who scuba dives to be aware of the DCS hazard if sufficient time is not allowed between diving and flying.

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The Divers Alert Network (DAN), a U.S. organization aimed at recreational scuba diving, is based at Duke University in North Carolina, U.S. In a recent four-year period, DAN received reports of 63 U.S. cases of DCS in divers who flew within 24 hours of diving. In another analysis, the divers in 16 DCS cases who flew shortly after diving, had followed the appropriate decompression procedures. Two of these cases did not develop symptoms until three days after their last dives. Some of the cases may have occurred with two to seven hour intervals between flying and diving.

Estimates are that 300,000 to 400,000 U.S. sport divers travel by air to and from diving locations during the year. DAN data suggests that current diving and flying procedures are relatively safe because the incidence of DCS is low.

DCS was first described about 125 years ago by a French physiologist during an investigation to determine why tunnel workers, who were breathing compressed air for long periods, returned to the surface bent in pain (hence, the term “bends”).

Tunnel workers and underwater divers who must surface after breathing compressed air for long periods of time, and flyers of unpressurized aircraft above 18,000 feet (flyers should already be breathing oxygen well before this altitude, which aids in removal of nitrogen from the body in addition to preventing hypoxia) are the usual victims of this illness, which is caused by nitrogen gas bubbles which block blood vessels and press on tissues. The result is pain and often permanent damage to body organs.

Four distinct types of DCS exist, and each can occur in flight following scuba diving.

Nitrogen constitutes 78 percent of the air we breathe and that gas is forced into solution, especially into the body’s fatty tissues, when it is breathed under pressure. It is a less diffusible gas than oxygen and carbon dioxide, so the body is not able to equilibriate it at the same rate with outside air.

The scuba diver can be exposed to very high pressures, with every 33 feet of underwater depth being equivalent to one additional atmosphere of pressure (sea level pressure is 760 mm Hg). A recreational diver making a dive to 66 feet is exposed to a pressure of 2,280 mm Hg (Figure 1). The result of this increased pressure is a dramatic increase in the volume of nitrogen in the body. For instance, at sea level a person has approximately one liter of nitrogen dissolved in body tissues and fluids; at 66 feet underwater, a diver would have a volume of three liters dissolved nitrogen. The degree of saturation is a factor of both the depth and length of time at that depth.[1]

Thus, in order to avoid the consequences of exposure to rapidly decreasing air pressure, scuba divers, under certain conditions, must make decompression stops during their ascent to the surface to allow brief periods of time for “off-gassing” to prevent the formation of nitrogen gas bubbles. Standardized decompression tables, based upon time and depth, provide divers guidance to make a trouble-free ascent.

The majority of recreational dives are not likely to require decompression stops. For example, according to the U.S. Navy, at depths less than 33 feet, there is no limit to bottom time — the elapsed time from leaving the

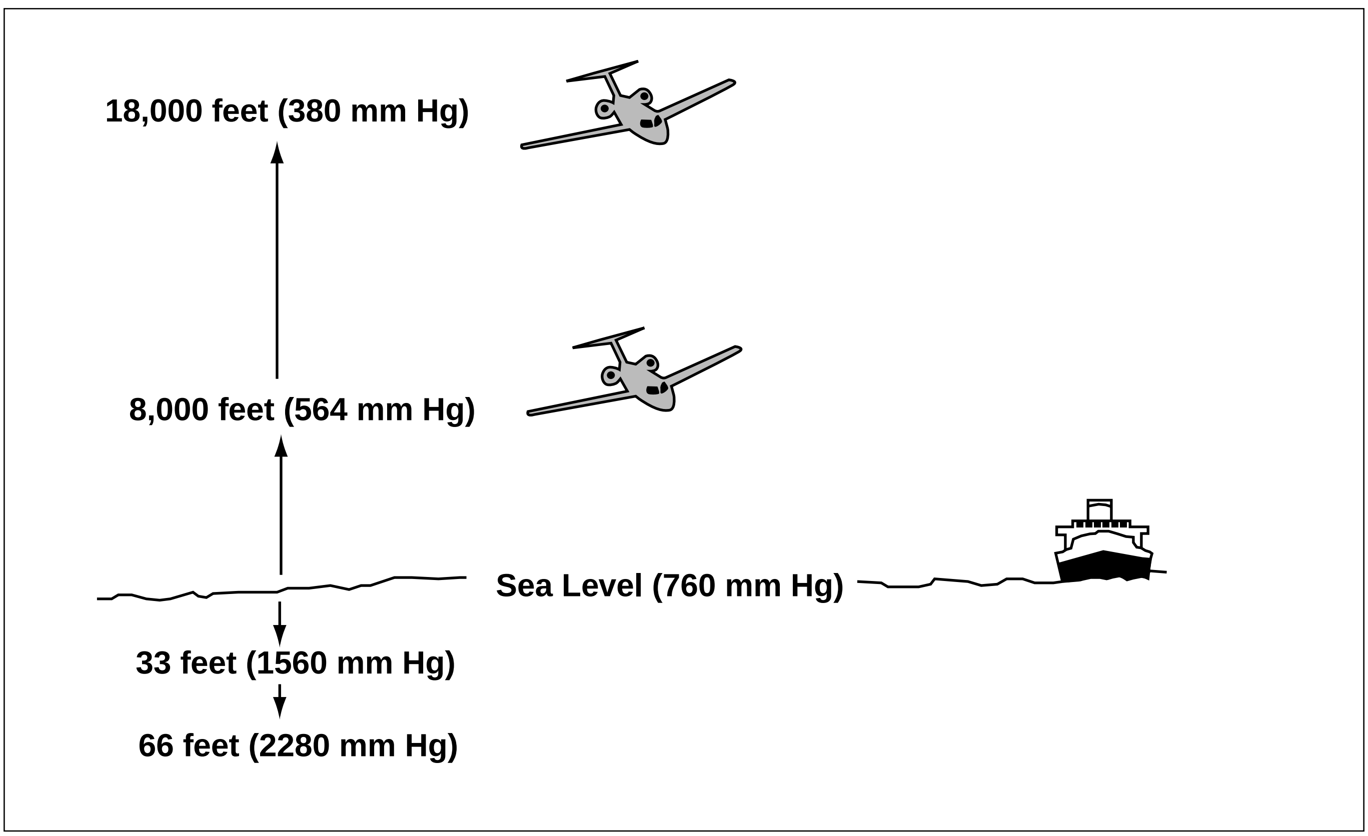

Figure 1

surface to the moment the ascent begins — and no decompression is necessary. However, a single dive to 100 feet would allow a maximum bottom time of 25 minutes without decompression. A 30-minute bottom time would require a decompression stop of three minutes at a depth of ten feet. Multiple dives that require decompression during the same day or succeeding days, demand careful calculations to properly decompress.

However, once the diver reaches the surface, it becomes necessary to wait a period of time before being subjected to further pressure decreases, such as those one may experience in flight. Figure 1 shows the extent of the pressure changes to which a diver could be exposed by flying immediately after diving. The diver going down to 33 feet of water depth, and only a few hours later flying at an 8,000-foot cabin altitude, may experience DCS. Flight soon after diving may generate further bubble formation or cause existing non-symptom producing bubbles to increase in size and create problems. Bubble formation can occur without producing symptoms; usually these tiny bubbles will slowly dissipate during a period of 72 hours. However, if the pressure on the body is reduced by further ascent, such as in an aircraft, the bubbles will increase in size and may cause DCS symptoms. The symptoms depend upon where bubbles form in the body and may range from mild sensations to severe problems depending upon bubble size, number and body area affected. Four distinct types of DCS exist, and each can occur in flight following scuba diving. These include the bends, skin disorders, central nervous system disorders and lung problems.

Flying after diving has generated many conflicting recommendations about the safest methods to integrate the two activities, short of avoiding flying after diving.

The bends is the most common form of DCS and accounts for approximately 89 percent of all reported cases; it is characterized by pain in one or more joints of the body. It can range from a mild, dull, aching sensation to an incapacitating pain.

Skin manifestations are caused by bubble formation under the skin that results in a red, mottled rash and itching. Although mild in nature, this form of DCS can be spread by scratching, and it can lead to more serious problems.

Central nervous system disorders (CNS) account for about five percent of all cases. This form of DCS is the result of bubble formation in the brain and spinal fluid which causes a variety of symptoms including headache (which can vary in intensity), visual problems up to total loss of vision, and partial or total paralysis.

The most severe form of DCS is the "chokes" which is found in about two percent of all cases. It is a result of bubble formation in the lungs and causes severe pain in the center of the chest; a dry, hacking, painful cough; and breathing difficulty. A diver must be aware that seemingly minor symptoms require immediate treatment, because they can progress into serious life-threatening disorders. Factors such as body build, exercise, hydration, age and individual susceptibility may influence the occurrence of symptoms. It is believed that cases of DCS go unreported because the symptoms, which are usually minor, are not associated by the victim with DCS.

One of the earliest reported cases involving scuba diving and flying occurred in 1961 when the crew of a commercial airliner experienced DCS while flying at 8,000 feet to 10,000 feet cabin altitude following scuba diving. [Flight Safety Foundation's *Business Pilots Safety Bulletin,* May 1961] The three-man crew had spent a day diving together no deeper than 30 feet before flying that same day. The pilot and copilot were incapacitated by DCS during flight, less than four hours after completing their last dives. The flight engineer, who had also been diving, managed to land the aircraft safely. His symptoms were delayed about 12 hours after completing his dive. This incident also illustrates individual tolerance to DCS.

More recently, the copilot of a single-engine, non-pressurized turboprop aircraft, operated for regular cargo flights in Europe, suffered decompression sickness [*Aviation, Space, and Environmental Medicine*, October 1989]. Breathing oxygen during cruise above FL 260 during the 2.5 hour first leg of the two-leg flight, he suffered the chokes shortly after level-off. The copilot had flown the route six times weekly for the previous year and he had experienced DCS symptoms during the most recent six months. He recognized his problem as DCS-related and wrote a message to the pilot that he had DCS before he became unconscious. The pilot made an emergency descent to 10,000 feet, where the co-pilot regained consiousness and the flight was continued to the destination.

The copilot was later hospitalized and sucessfully treated by fluids and oxygen. The pilot reported no DCS symptoms and was not treated. Although this case did not involve scuba diving, it illustrates susceptibility to DCS in high-altitude flight without pressurization; cumulative exposure also increases the likelihood of DCS.

Flying after diving has generated many conflicting recommendations about the safest methods to integrate the

Guidelines for Flying After Diving

Dive Schedule	Surface interval before flight at cabin altitudes up to 8,000 feet
No-decompression Dives	**Hours**
(Diver is without DCS symptoms)	
a. Less than two hours total accumulated dive time (surface to surface time) in the last 48 hours	12
b. Multi-day, unlimited diving	24
Dives That Require Decompression Stops	
(Diver is without DCS symptoms)	24-48*

* Flying must be delayed for 24 hours and if possible 48 hours.

Source: Undersea and Hyperbaric Medical Society

Figure 2

two activities, short of avoiding flying after diving. Of course, flight crews must adhere to the appropriate regulations that govern their flying.

For example, the U.S. Federal Aviation Administration, in its *Airman's Information Manual (AIM)*, recommends at least a four-hour waiting period after scuba diving, which has not required decompression, before flying to a cabin altitude of 8,000 feet or less, and a wait of at least 24 hours after diving which has required decompression. The waiting time before flight to cabin presssure altitude above 8,000 feet should be 24 hours after any scuba diving.

The FAA Civil Aeromedical Institute, recommends a more conservative approach — wait 24 hours after one day of scuba diving before flying at a cabin altitude of 8,000 feet and wait 48 hours before flying after a week of diving.

There can never be a flying after diving rule that is guaranteed to prevent decompression sickness.

Conservative times add a safety factor in an unpressurized aircraft that may be required to fly higher than 8,000 feet for weather avoidance or for air traffic control (ATC) considerations (supplemental breathing oxygen will not prevent DCS), or in a pressurized aircraft that could experience loss of cabin pressure in flight.

The U.S. military has long followed the policy of no flying within 24 hours after any scuba or compressed-air diving. Many researchers have advocated such a policy; however the plethora of advice available for the diver has been overwhelming, if not confusing, until recently.

In order to provide the diver with clear advice on flying after diving, the Undersea and Hyperbaric Medical Society (UHMS) sponsored a workshop in 1989 to develop guidelines for flying after diving. These are shown in Figure 2. These UHMS guidelines are considered to be "best estimates" based upon current scientific information and expert opinion and are considered to be safe intervals to spend on the surface between diving and flying for the vast majority of divers[2]. Corporate and charter pilots and cabin crew members also should provide this information to passengers for their comfort and safety.

Guidelines recommended by organizations such as DAN are based on safe but conservative estimates that are applicable to the majority of divers. It has been reported that more than 30 different flying after diving recommendations have been presented to recreational divers since World War II, as scuba diving developed.

DAN's current position on flying after diving grew out of the results of the UHMS workshop. DAN has modified the results of the workshop's initial recommendations and has just issued the following guidelines for U.S. recreational divers; they also should be of interest to flight crews:

1. A minimum surface interval of 12 hours is required before ascent to altitude in a commercial jet airliner (cabin altitude up to 8,000 feet). [Note: the workshop participants did not discuss the risk of flying or driving to lower elevations, or the effect of dives at altitude, e.g., mountain lakes. These guidelines may not be conservative enough for these applications.]

2. Divers who plan to make daily, multiple dives for several days or make dives that require decompression stops should take special precautions and wait for an extended surface interval beyond 12 hours before flight. The greater the duration before the flight, the less likely decompression sickness is to occur.

3. There can never be a flying after diving rule that is guaranteed to prevent decompression sickness. Rather, there can be a guideline that represents the best estimate for a conservative, safe, surface interval for the vast majority of divers. There will always be an occasional diver whose physiological makeup or special diving circumstances will result in bends.

4. Further research is recommended to provide significant data upon which to provide more specific guidelines for the future.

Although prevention is the best medicine, being prepared to deal with a DCS incident is equally important. The steps below can be followed to treat anyone suspected of developing DCS in flight. This is a medical emergency, and medical assistance will be required once the aircraft is on the ground.

1. The person with suspected DCS should be placed on 100 percent oxygen, if it is available.

2. Fly at a low altitude if the aircraft is unpressurized; however, do not sacrifice flight safety. In a pressurized cabin, keep the cabin altitude at the lowest possible altitude but no lower than the landing site pressure altitude. This will avoid exposing the person to additional pressure changes which could exacerbate the symptoms, i.e., do not use sea level cabin pressure if the destination airport is 1,000 feet above sea level.

3. Land at the nearest airport where medical assistance is available. Ideally, the person should be seen by medical personnel familiar with the treatment of DCS.

4. Once on the ground, the person should remain on oxygen.

Treatment for DCS usually requires recompression in a hyperbaric chamber. Treatment is usually successful, but the treated person should avoid flying for several days to prevent any reoccurrence of problems. A medical evaluation may be recommended for crew members who have experienced serious DCS problems before returning to flying duties.

Flying and scuba diving have been described as two of life's most exhilarating experiences. Proper safety precautions and adherence to recommended guidelines will allow flight crew members and passengers to combine scuba diving and air travel with a greatly reduced risk of DCS. ♦

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