Flying After Diving

In 1989, DAN participated in the first flying after diving (FAD) workshop. It was sponsored by the Undersea and Hyperbaric Medical Society and reported on diving injury cases collected by DAN and flying after diving experiments conducted in the laboratory at Duke University Medical Center (1-3). After the '89 meeting, the workshop published consensus guidelines for flying after diving. These guidelines recommended waiting for 12 hours before flying after as little as two hours of no-stop diving in one day; in addition, they recommended waiting for 24 hours after multiday unlimited no-stop diving.
DAN suggested a more conservative wait of 24 hours after any form of diving. The recreational diving industry objected, however, on the grounds that they believed the risk of decompression sickness (DCS) from flying after diving was too low to warrant a 24-hour wait and would result in lost business for island diving resorts. DAN revised its guidelines in 1991, recommending at least 12 hours after a single no-stop dive and longer than 12 hours after repetitive dives, decompression dives and multiple days of diving (4, 5). Since that time, DAN has conducted two laboratory studies of flying after diving. DAN has also conducted one additional study using data reported from injured divers as well as investigations of those flying with symptoms and flying after recompression therapy.

Experimental Studies of Flying After Diving
A review of data from the 1989 workshop indicated there was insufficient empirical evidence to support any proposed guideline. To develop such evidence, DAN began experimental FAD trials at the Duke Hyperbaric Center in 1992 with simulated flights at 8,000 feet (2,438 meters). The trials ended in 1999, with 40 DCS incidents in 802 exposures. The 1999 U.S. Navy FAD procedures were based on these data, as were the consensus guidelines for flying after recreational diving, which were formulated in a 2002 DAN-sponsored workshop. The experimental study and workshop proceedings were published in 2004 (6, 7). The revised flying after recreational diving guidelines stated:
(a) For a single no-decompression dive, a minimum preflight surface interval of 12 hours is suggested.
(b) For multiple dives per day or multiple days of diving, a minimum preflight surface interval of 18 hours is suggested.
(c) For dives requiring decompression stops, there is little evidence on which to base a recommendation, but a preflight surface interval substantially longer than 18 hours appears prudent.

The DAN trials were designed to estimate the preflight surface intervals needed after the longest expected recreational no-stop limits for a single dive or for repetitive diving. A second study began in 2002 under Navy sponsorship and is continuing. Its objective is investigating short no-stop dives and decompression dives that were previously untested. To date, four DCS incidents and seven "niggles"(marginal DCS, or minor symptoms that persist for less than one hour.) have occurred in 368 exposures.

Case-Control Study of Flying After Diving
The relationship of DCS risk to the surface interval before flying was also investigated in a case-control study with 382 cases from the DAN injury data and 245 injury-free control divers from Project Dive Exploration (8). Case-control studies cannot measure absolute risk since the total population at risk is unknown, and test to see if a potential risk factor occurs more frequently in cases than in controls. Diver and dive profile characteristics were controlled statistically. As in the experimental trials, the risk of DCS increased as the preflight surface interval decreased and was found to increase with the maximum dive depth on the last day of diving.

Case-control studies measure changes in risk relative in one condition relative to the risk at some other

condition. For example, the analysis found that if the relative risk of DCS after a 60-fsw (18-msw) dive and 24-hour surface interval was defined as one, the relative risk after a 60-fsw dive and a 12-hour surface interval was 2.5 times greater, and the relative risk after a 130-fsw (40-msw) dive and 12-hour surface interval was seven times greater. Of the 382 FAD DCS cases in the case-control study, 34 percent had waited for longer than 24 hours before flying. This is inconsistent with the consensus FAD guidelines, where, based on chamber trials, it was concluded that 18 hours was safe for repetitive diving.

Since the experimental trials were conducted with dry, resting subjects, one might ask if recreational divers are at greater risk of DCS than the experimental subjects in the chamber trials? If so, at what increased risk? The case-control study provides some insight. If the relative risk of DCS after a 60-fsw dive and 36-hour preflight surface interval was defined as one, the relative risk after a 24-hour surface interval was 1.7 times greater and after a 12-hour surface interval was 4.2 times greater. This, the case-control study of recreational divers suggests that additional protection might be afforded by waiting longer than 24 hours, but with diminishing returns at even lower risk as the surface interval grows longer.

Flying with DCS Symptoms

One study of DAN data from 1987-1990 showed that 5.6 percent of 1,159 DCS incidents occurred during or after flight, while 13.8 percent had symptoms before flying (9). The DAN Diving Reports for 2000-2004 indicated that 7.1 percent of 2,438 DCS incidents occurred during or after air travel, while 10 percent had symptoms before flying (10-14). Since flying is an added decompression stress, the effects of flying with symptoms were investigated on case severity and treatment outcome (9). Case severity was measured by a final diagnosis of Type II DCS as opposed to Type I DCS, and treatment outcome was measured by complete relief after the first recompression and by residual symptoms three months after all recompressions.

These measures of DCS severity were compared for divers who were recompressed and did not fly and for divers who developed symptoms during or after flying and were then recompressed. All three measures of severity were adversely affected by flying with symptoms: Type II DCS was 1.6 times more likely, incomplete relief was 1.8 times more likely, and residual symptoms were 2.7 times more likely. A similar analysis for divers who waited less than 24 hours before flying assessed treatment outcome by residual symptoms after all recompressions (15). The reference group was divers who did not fly.

There were two comparison groups: (a) divers with symptoms before flying; and (b) divers with symptoms after flying.

Of divers who did not fly, 38 percent had residual symptoms after all recompressions, compared with 49 percent residuals for divers who flew with symptoms (OR=1.5) and 46 percent residuals for divers who developed symptoms after flying (OR=1.3). Divers with constitutional symptoms (fatigue, nausea, vertigo) had a 31 percent incidence of residuals. Divers with pain had a residuals incidence of 40 percent and an odds ratio (OR) of 1.5, with constitutional symptoms as the reference group. Divers with mild neurological symptoms had 40 percent residuals with an OR of 1.4, and those with severe neurological symptoms had at 45 percent residuals with an OR of 1.8.

Flying with symptoms is a matter of diver education (i.e., "Don't do it!") but is also relevant to air evacuation of injured divers from remote dive sites to recompression facilities (16). The question is whether all divers with suspected decompression injuries must be transported by air ambulance at

artificial sea level pressure or whether divers with mild symptoms can be transported in commercial aircraft (standard cabin altitude, lower pressure than sea level). The effect of time to flight may be important in this regard. One hundred twenty-six divers who flew with symptoms were divided into two groups: those who waited less than 24 hrs before flying, and those who waiting longer than 24 hours before flying.

The comparison group was 1,509 cases who did not fly. The divers were stratified by case severity. When the effect of preflight surface interval was examined, recompression was equally successful for divers who waited more than 24 hours before flying (73 percent complete relief) as for divers who did not fly (71 percent). Divers who waited less than 24 hours before flying, however, had only 34 percent complete relief among those with serious neurological symptoms, while 53 percent of those divers with mild neurological symptoms had complete relief. Time to flight did not appear to affect pain.

Flying After Recompression Treatment

Flying after treatment (FAT) occurs when a diver who has already been treated for DCI (decompression illness, which includes both DCS and arterial gas embolism) undergoes a secondary decompression during altitude exposure (17). The important question is how long must a diver wait after being treated before he or she can fly in a pressurized commercial aircraft. The most commonly recommended delay to flight is three days after treatment. The effect of flying on relapse after treatment appears to stabilize in three to four days, but this observation is based on data of questionable quality. For divers who have persistent symptoms after recompression, however, it appears clear that three days is inadequate to avoid worsening of symptoms during flight. A more definitive understanding of the FAT problem will require further data on: (a) the relapse rate in the absence of flying and the effect of flying on the severity, and (b) persistence of symptoms that relapse in comparison with non-flying relapse.