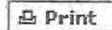


Decompression Sickness Information Packet
Naval Safety Center
Updated 5/28/13
Ms. Kelsey Leo

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SECTIONS Injuries and Poisoning
CHAPTERS Diving and Compressed Air Injuries

Decompression Sickness

Decompression sickness (decompression illness, caisson disease, the bends) is a disorder in which nitrogen dissolved in the blood and tissues by high pressure forms bubbles as pressure decreases.

- Symptoms can include fatigue and pain in muscles and joints.
- In the more severe type, symptoms may be similar to those of stroke or can include difficulty breathing and chest pain.
- People are treated with oxygen and recompression (high-pressure or hyperbaric oxygen) therapy.
- Limiting the depth and duration of dives and the speed of ascent can help with prevention.

Air is composed mainly of nitrogen and oxygen. Because air under high pressure is compressed, each breath taken at depth contains many more molecules than a breath taken at the surface. Because oxygen is used continuously by the body, the extra oxygen molecules breathed under high pressure usually do not accumulate. However, the extra nitrogen molecules do accumulate in the blood and tissues. As outside pressure decreases during ascent from a dive or when leaving a caisson, the accumulated nitrogen that cannot be exhaled immediately forms bubbles in the blood and tissues. These bubbles may expand and injure tissue, or they may block blood vessels in many organs—either directly or by triggering small blood clots. This blood vessel blockage causes pain and various other symptoms (for example, sometimes similar to those of a stroke, such as sudden weakness on one side of the body, difficulty speaking, dizziness, or even flu-like symptoms). Nitrogen bubbles also cause inflammation, producing swelling and pain in muscles, joints, and tendons.

The risk of developing decompression sickness increases with many factors, such as the following:

- Certain heart defects
- Cold water
- Dehydration
- Flying after diving
- Exertion
- Fatigue
- Increasing pressure (that is, the depth of the dive)
- Length of time spent in a pressurized environment
- Obesity
- Older age
- Rapid ascent

Because excess nitrogen remains dissolved in the body tissues for at least 12 hours after each dive, repeated dives within 1 day are more likely to cause decompression sickness than a single dive.

Flying immediately after diving (such as at the end of a vacation) exposes people to an even lower atmospheric pressure, making decompression sickness slightly more likely.

Nitrogen bubbles may form in small blood vessels or in the tissues themselves. Tissues with a high fat content, such as those in the brain and spinal cord, are particularly likely to be affected, because nitrogen dissolves very readily in fats.

Decompression sickness may affect a variety of organs and can range from mild to severe.

Symptoms

Symptoms of decompression sickness usually develop more slowly than do those of air embolism and pulmonary barotrauma. Only half of the people with decompression sickness have symptoms within 1 hour of surfacing, but 90% have symptoms by 6 hours. Symptoms commonly begin gradually and take some time to reach their maximum effect. The first symptoms may be fatigue, loss of appetite, headache, and a vague feeling of illness.

Type I (Less Severe): The less severe type (or musculoskeletal form) of decompression sickness, often called the bends, typically produces pain. The pain usually occurs in the joints of the arms or legs, back, or muscles. Sometimes the location is hard to pinpoint. The pain may be mild or intermittent at first but may steadily grow stronger and become severe. The pain may be sharp or may be described as "deep" or "like something boring into bone." It is worse when moving. Less common symptoms include itching, skin mottling, swollen lymph nodes, rash, and extreme fatigue. These symptoms do not threaten life but may precede more dangerous problems.

Type II (More Severe): The more severe type of decompression sickness most commonly results in neurologic symptoms, which range from mild numbness to paralysis and death. The spinal cord is especially vulnerable. When the spinal cord is affected, symptoms can include numbness, tingling, weakness, or a combination in the arms, legs, or both. Mild weakness or tingling may progress over hours to irreversible paralysis. Inability to urinate or inability to control urination or defecation may also occur. Abdominal and back pain also is common. Symptoms of brain involvement, most of which are similar to those of air embolism, include headache, confusion, trouble speaking, and double vision. Loss of consciousness is rare.

The nerves of the inner ear may be affected, causing severe vertigo, ringing in the ears, and hearing loss. Gas bubbles that travel through the veins to the lungs produce cough, chest pain, and progressively worsening difficulty breathing (the chokes). Severe cases, which are rare, may result in shock and death.

Late Effects: Late effects of decompression sickness include the destruction of bone tissue (dysbaric osteonecrosis, avascular bone necrosis), especially in the shoulder and hip, which produces persistent pain and severe disability. These injuries do not occur among recreational divers but, rather, among people who work in a compressed-air environment and divers who work in underwater habitats. These workers are exposed to high pressure for prolonged periods and may have an undetected case of the bends. Technical divers, who dive to greater depths than recreational divers, may be at higher risk than recreational divers. Bone and joint injuries may gradually progress over months or years to severe, disabling arthritis. By the time severe joint damage has occurred, the only treatment may be joint replacement.

Permanent neurologic problems, such as partial paralysis, usually result from delayed or inadequate treatment of spinal cord symptoms. However, sometimes the damage is too severe to correct, even with appropriate treatment. Repeated treatments with oxygen in a high-pressure chamber seem to

help some people recover from spinal cord damage.

Diagnosis

Doctors recognize decompression sickness by the nature of the symptoms and their onset in relation to diving. Tests such as computed tomography (CT) or magnetic resonance imaging (MRI) sometimes show brain or spinal cord abnormalities but are not reliable. However, recompression therapy is begun before the results of a CT or MRI scan are available, except in cases in which the diagnosis is uncertain or the diver's condition is stable. X-rays are needed to diagnose dysbaric osteonecrosis.

Prevention

Divers can usually prevent decompression sickness by restricting the total amount of gas the body absorbs. The amount can be restricted by limiting the depth and duration of dives to a range that does not need decompression stops during ascent (called no-stop limits by divers) or by ascending with decompression stops as specified in authoritative guidelines, such as the decompression table in the *United States Navy Diving Manual*. The table provides a schedule for ascent that usually allows excess nitrogen to escape without causing harm. Many divers wear a portable dive computer that continually tracks the diver's depth and time at depth. The computer calculates the decompression schedule for a safe return to the surface and indicates when decompression stops are needed.

In addition to following a table or computer guidelines for ascent, many divers make a safety stop of a few minutes at about 15 feet (4.5 meters) below the surface.

Following these procedures, however, does not eliminate the risk of decompression sickness. A small number of cases of decompression sickness develop after no-stop dives, and the incidence of decompression sickness has not declined despite the widespread use of dive computers. The inability to eliminate decompression sickness may be because the published tables and computer programs do not completely account for the variation in risk factors among different divers or because some people fail to obey the recommendations of the tables or computer.

Other precautions also are necessary:

- After several days of diving, a period of 12 to 24 hours at the surface is commonly recommended before flying or going to a higher altitude.
- People who have completely recovered from mild decompression sickness should refrain from diving for at least 2 weeks.
- People who have developed decompression sickness despite following dive table or computer recommendations should return to diving only after a thorough medical evaluation for underlying risk factors, such as a heart defect.

The Divers Alert Network (919-684-8111; www.diversalertnetwork.org) provides 24-hour consultation for diving-related problems.

Treatment

About 80% of people recover completely.

Divers having only itching, skin mottling, and fatigue usually do not need to undergo recompression, but they should be kept under observation, because more serious problems may follow. Breathing 100% oxygen from a close-fitting face mask may provide relief.

Recompression Therapy: Any other symptoms of decompression sickness indicate the need for

treatment in a high-pressure (recompression or hyperbaric oxygen) chamber, because recompression restores normal blood flow and oxygen to affected tissues. After recompression, pressure is reduced gradually, with designated pauses, allowing time for excess gases to leave the body harmlessly. Because symptoms may reappear or worsen over the first 24 hours, even people with only mild or transient pain or neurologic symptoms are treated.

Recompression therapy is beneficial for up to 48 hours after diving and should be given even if reaching the nearest chamber requires significant travel. While awaiting transport and during transport, oxygen is administered with a close-fitting face mask, and fluids are given by mouth or intravenously. Long delays in treatment increase the risk of permanent injury.

Did You Know...

- Flying within 15 hours after diving (common when vacationing) increases the risk of decompression sickness.

Last full review/revision February 2009 by Alfred A. Bove, MD, PhD

Barotrauma Clinical Presentation

Author: Joseph Kaplan, MD, MS, FACEP; Chief Editor: Jonathan Adler, MD

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Updated: Updated: Mar 9, 2011

History

Patients with DCS present with a history of diving, generally within 24 hours of the onset of symptoms. Patients may also have a recent history of occupational pressurization or depressurization. For example, this occurs with aircraft mechanics who must test aircraft windows by working in pressurized aircraft. Air emboli have also occurred in mechanics who maintain training altitude chambers. Recently, military operations involving troops traveling from ground level to high-altitude environments in a relatively short time and operations involving soldiers doing strenuous activities at higher altitudes have resulted in many cases of DCS. Recent studies have indicated that aerobic exercise either prior to a dive or during decompression stops may decrease the post dive gas bubble formation.^[2,3]

Sinus squeeze

Patients usually present with complaints of facial or oral pain, nausea, vertigo, or headache.

Other important information to gather includes any history of recent upper respiratory infections, allergic rhinitis, sinus polyps, and sinus surgeries and whether the pain worsened during descent or ascent.

Middle ear squeeze

Patients often have a history of sudden vertigo, nausea, tinnitus, ear pain, deafness, or headache.

They may have a history of previous diving ear injury or a history of previous or current ear infection.

Decompression sickness type I

Patients often have a history of recent diving followed by a flight home. They may complain of slowly progressing pain or numbness in their limbs or back.

Patients present with joint, muscle, or back pain that worsens over time. The pain worsens with motion but is always present. The pain may range from mild (tickles) to severe (the bends).

Patients may have a history of previous decompression illness and multiple dives in the same day and frequently have not followed the dive tables closely. New dive computers that offer more "bottom time" do so by modifying the US Navy dive tables and possibly place divers at an increased risk for DCS injuries. Divers should

be questioned as to the method of computing bottom and ascent times with safety stops. This information should be recorded as part of the medical record.

Decompression sickness type II

DCS type II usually presents sooner than DCS type I.

Patients may present with shortness of breath (the chokes), chest pain, severe headache, altered mental status, and shock. They also may complain of dizziness or weakness. Patients may rapidly deteriorate without emergent intervention.

Essential history to ascertain includes time since dive ended, the dive profile (see images below), when the symptoms began, and prior medical history. The dive profile consists of prior dives that day, depth of dive, bottom time, decompression stop depth, and length of stop.



Basic US Navy dive table used to compare the patient's dive profile to the standard dive profile. Reprinted with permission of the US Navy.



US Navy dive table for altitude diving used to compare the patient's dive profile with the standard dive profile at altitude. Reprinted with permission of the US Navy.

Diver should be asked about his or her prior dive category.

Inquiry should be made specifically about previous decompression injuries, pulmonary blebs, Marfan syndrome, asthma, congenital pulmonary illnesses, HIV status, chronic obstructive pulmonary disease (COPD), lung tumors, histiocytosis X, cystic fibrosis, pregnancy, and any prior pulmonary injuries or surgeries.

Arterial gas embolism

AGE usually occurs shortly after ascending very rapidly, often from fairly shallow depths. People may be described to scream suddenly and lose consciousness. Onset of AGE often occurs within a few minutes of surfacing. Patients who experience AGE often die before reaching a medical facility. Air emboli have also recently been noted to occur iatrogenically in association with central venous monitoring during surgical procedures. Case reports have shown AGE occurring secondary to occupational rapid decompression in both aircraft maintenance and altitude-chamber maintenance personnel.^[4]

Obtaining a history from these patients can be difficult because they often present with altered mental status or are in shock.

Witnesses often report that divers experience a sudden or immediate loss of consciousness or collapse, usually within minutes of surfacing.

Ask the patient or dive partner about a history of patent foramen ovale.

Abdominal compartment syndrome ^[5]

Divers can develop large amounts of intraperitoneal extraluminal gas, which can compress the intraperitoneal organs. This can lead to venous compression of these organs and secondary compartment syndrome.

Physical

The physical examination should be tailored to the patient's history.

Perform a general physical examination on all patients, with initial emphasis on ears, sinuses, and neck as well as on the pulmonary, cardiovascular, and neurologic systems. AGE often presents with signs and symptoms of acute stroke.

Inspect and palpate the extremities, and test range of motion in all joints.

Sinus squeeze

Inspect nasal mucosa for polyps, hemorrhage, or lesions.

Palpate and transilluminate sinuses to inspect for hemorrhage.

Percuss upper teeth with a tongue blade to inspect for severe sinus tenderness.

Ear squeeze

Carefully inspect the tympanic membrane (TM), looking in particular for the following signs:

- Amount of congestion around the umbo
- Percent of TM involvement
- Amount of hemorrhage noted behind eardrum
- Evidence of TM rupture

Palpate the eustachian tube for tenderness.

Test the patient's balance and hearing.

Evaluate the TM on the Teed scale:

- Teed 0 - No visible damage, normal ear
- Teed 1 - Congestion around the umbo, occurs with a pressure differential of 2 pounds per square inch (PSI)
- Teed 2 - Congestion of entire TM, occurs with a pressure differential of 2-3 PSI
- Teed 3 - Hemorrhage into the middle ear
- Teed 4 - Extensive middle ear hemorrhage with blood bubbles visible behind TM; TM may rupture
- Teed 5 - Entire middle ear filled with dark (deoxygenated) blood

Decompression sickness type I

Inspect for swelling or effusion in the affected joint.

Test for range of motion both actively and passively.

Palpate the affected area for crepitus and compartment tightness.

Evaluate neurovascular status by performing a complete neurologic examination. The examination should include testing motor and sensory functions, cerebellar function, and mental status. The findings from this examination must be recorded and used as a baseline to determine improvement in postdive chamber treatment.

Decompression sickness type II

Evaluate cardiovascular and pulmonary systems.

Note neck vein distention or petechiae on the head or neck.

Palpate the skin for crepitus.

Auscultate the lungs and heart for decreased breath sounds, muffled heart tones, or heart murmurs.

Evaluate neurologic status, including gross motor, sensory, and cerebellar examinations. Tandem walking (heel to toe, with eyes closed) is an excellent method of evaluation.

Document Glasgow Coma Scale and Mini Mental State Examination.

Arterial gas embolism

Use the same examination used for decompression sickness type II.

Causes

The causes of DCS are related to predisposing medical or genetic factors, as listed above, and to diver error. Diver error includes the following practices:

- Multiple daily dives
- Poor adherence to the dive tables
- Breath holding (most common scenario for pulmonary barotrauma)
- Rapid ascent - This can occur from relatively shallow depths. For example, pilots undergoing rapid ascent while performing underwater escape training after flight may experience DCS.
- Flying or traveling to high altitudes within 24 hours after diving
- Occupational causes - These causes include rapid depressurization by maintenance workers and mechanics after working in pressurized aircraft cabins. Reports of altitude chamber mechanics who have depressurized too quickly while working on the altitude chambers have also been documented. Pilots and crewmembers performing high-altitude air drops on military missions and special-operations soldiers involved in such missions have also reported instances of DCS.

Images

Table 9-7. Residual Nitrogen Timetable for Repetitive Air Dives.

Locate the diver's repetitive group designation from his previous dive along the diagonal line above the table. Read horizontally to the interval in which the diver's surface interval lies.

Next, read vertically downward to the new repetitive group designation. Continue downward in this same column to the row that represents the depth of the repetitive dive. The time given at the intersection is residual nitrogen time, in minutes, to be applied to the repetitive dive.

* Dives following surface intervals of more than 12 hours are not repetitive dives. Use actual bottom times in the Standard Air Decompression Tables to compute decompression for such dives.

** If no Residual Nitrogen Time is given, then the repetitive group does not change.

Repetitive group at the beginning of the surface interval

Z	O	N	M	L	K	J	I	H	G	F	E	D	C	B	A
0:10	0:23	0:35	0:49	1:03	1:19	1:37	1:56	2:18	2:43	3:11	3:46	4:30	5:28	6:57	10:06
0:22	0:34	0:48	1:02	1:18	1:36	1:55	2:17	2:42	3:10	3:45	4:29	5:27	6:56	10:05	12:00*
0:10	0:24	0:37	0:52	1:08	1:25	1:44	2:05	2:30	3:00	3:34	4:18	5:16	6:44	9:54	12:00*
0:10	0:23	0:36	0:51	1:07	1:24	1:43	2:04	2:29	2:59	3:33	4:17	5:16	6:44	9:54	12:00*
0:10	0:24	0:39	0:54	1:11	1:30	1:53	2:18	2:47	3:22	4:04	5:03	6:32	9:43	12:00*	
0:10	0:25	0:40	0:55	1:12	1:31	1:54	2:19	2:48	3:23	4:05	5:04	6:33	9:44		
0:10	0:25	0:40	0:55	1:12	1:31	1:54	2:19	2:48	3:23	4:05	5:04	6:33	9:44		
0:10	0:24	0:39	0:54	1:11	1:30	1:53	2:18	2:47	3:22	4:04	5:03	6:32	9:43	12:00*	
0:10	0:24	0:37	0:52	1:08	1:25	1:44	2:05	2:30	3:00	3:34	4:18	5:17	6:45	9:55	
0:10	0:23	0:36	0:51	1:07	1:24	1:43	2:04	2:29	2:59	3:33	4:17	5:16	6:44	9:54	12:00*
0:10	0:23	0:35	0:49	1:03	1:19	1:37	1:56	2:18	2:43	3:11	3:46	4:30	5:28	6:57	10:06
0:22	0:34	0:48	1:02	1:18	1:36	1:55	2:17	2:42	3:10	3:45	4:29	5:27	6:56	10:05	12:00*

Repetitive Dive Depth	Z	O	N	M	L	K	J	I	H	G	F	E	D	C	B	A
feet/meters																
10	3.0	**	**	**	**	**	**	**	**	**	**	797	279	199	68	39
20	6.1	**	**	**	**	**	917	399	279	208	159	120	88	62	39	18
30	9.1	†	†	†	349	279	229	190	159	132	109	88	70	54	39	25
40	12.2	257	241	213	187	161	138	116	101	87	73	61	49	37	25	17
50	15.2	169	160	142	124	111	99	87	76	66	56	47	38	29	21	13
60	16.2	122	117	107	97	88	79	70	61	52	44	36	30	24	17	11
70	21.3	100	96	87	80	72	64	57	50	43	37	31	26	20	15	9
80	24.4	84	80	73	68	61	54	48	43	38	32	28	23	18	13	8
90	27.4	73	70	64	58	53	47	43	38	33	29	24	20	16	11	7
100	30.5	64	62	57	52	48	43	38	34	30	26	22	18	14	10	7
110	33.5	57	55	51	47	42	38	34	31	27	24	20	16	13	10	6
120	36.6	52	50	46	43	39	35	32	28	25	21	18	15	12	9	6
130	39.6	46	44	40	38	35	31	28	25	22	19	16	13	11	8	6
140	42.7	42	40	38	35	32	29	26	23	20	18	15	12	10	7	5
150	45.7	40	38	35	32	30	27	24	22	19	17	14	12	9	7	5
160	48.8	37	36	33	31	28	26	23	20	18	16	13	11	9	6	4
170	51.8	35	34	31	29	26	24	22	19	17	15	12	10	8	6	4
180	54.8	32	31	29	27	25	22	20	18	16	14	11	10	8	6	4
190	59.9	31	30	28	26	24	21	19	17	15	13	10	10	8	6	4

Residual Nitrogen Times (Minutes)

† Read vertically downward to the 40/12.2 (feet/meter) repetitive dive depth. Use the corresponding residual nitrogen times (minutes) to compute the equivalent single dive time. Decompress using the 40/12.2 (feet/meter) standard air decompression table.

Table 9-3. Sea Level Equivalent Depth (fsw).

Actual Depth (fsw)	Altitude (feet)									
	1000	2000	3000	4000	5000	6000	7000	8000	9000	10000
10	10	15	15	15	15	15	15	15	15	15
15	15	20	20	20	20	20	20	25	25	25
20	20	25	25	25	25	25	30	30	30	30
25	25	30	30	30	35	35	35	35	35	40
30	30	35	35	35	40	40	40	50	50	50
35	35	40	40	50	50	50	50	50	50	60
40	40	50	50	50	50	50	60	60	60	60
45	45	50	60	60	60	60	60	70	70	70
50	50	60	60	60	70	70	70	70	70	80
55	55	60	70	70	70	70	80	80	80	80
60	60	70	70	70	80	80	80	90	90	90
65	65	70	80	80	80	90	90	90	100	100
70	70	80	80	80	90	90	100	100	100	110
75	75	90	90	90	100	100	100	110	110	110
80	80	90	90	100	100	100	110	110	120	120
85	85	100	100	100	110	110	120	120	120	130
90	90	100	110	110	110	120	120	130	130	140
95	95	110	110	110	120	120	130	130	140	140
100	100	110	120	120	130	130	130	140	140	150
105	105	120	120	130	130	140	140	150	150	160
110	110	120	130	130	140	140	150	150	160	160
115	115	130	130	140	140	150	150	160	170	170
120	120	130	140	140	150	150	160	170	170	180
125	125	140	140	150	160	160	170	170	180	190
130	130	140	150	160	160	170	170	180	190	190
135	135	150	160	160	170	170	180	190	190	200
140	140	160	160	170	170	180	190	190	200	210
145	145	160	170	170	180	190	190	200	210	
150	160	170	170	180	190	190	200	210		
155	170	170	180	180	190	200	210			
160	170	180	180	190	200	200				
165	180	180	190	200	200					
170	180	190	190	200						
175	190	190	200							
180	190	200	210							
185	200	200								
190	200									
Table Water Stops	Equivalent Stop Depths (fsw)									
10	10	9	9	9	8	8	8	7	7	7
20	19	19	18	17	17	16	15	15	14	14
30	29	28	27	26	25	24	23	22	21	21
40	39	37	36	35	33	32	31	30	29	28
50	48	47	45	43	42	40	39	37	36	34
60	58	56	54	52	50	48	46	45	43	41

Note: — = Exceptional Exposure Limit

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Barotrauma in Emergency Medicine

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Decompression Sickness Clinical Presentation

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<http://emedicine.medscape.com/article/769717-clinical#showall>

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History

When taking the history, remember that symptoms or signs that appear during or following a dive are pressure-related until proven otherwise based on a diagnostic or therapeutic recompression. Therefore, having the forethought to ask about pressure exposure aids in the diagnosis. The following specifics about the dive should be elicited:

- Location of the dive (eg, ocean, lake, river, quarry, or cave)
- Timing of events during the dive and over the prior 72 hours (eg, time dives occurred, length of dives, surface intervals, safety stops, flying, and method of timing used [eg, watch with tables, dive computer])
- Maximum dive depth and the rate of ascent
- Approximate times spent at specific depths
- Work of the patient during the dive (Consider currents, distance swam, water temperature, and primary activity [eg, wreck diving, artifact recovery].)
- Gases and equipment used (compressed air, rebreathing equipment, mixed gases)
- Problems encountered (violation of no-decompression-limit dive tables, equipment, entanglement, dizziness, marine bites or stings)
- Patient's physical condition before, during, and after the dive (eg, fatigue, drug or alcohol intake, fever, vertigo, nausea, overexertion, pulled muscles)
- First aid delivered (eg, oxygen, positioning, medications, fluids)
- Ask the patient about the following symptoms:
 - General symptoms of profound fatigue or heaviness, weakness, sweating, malaise, or anorexia
 - Musculoskeletal symptoms of joint pain, tendonitis, crepitus, back pain, or heaviness of extremities
 - Mental-status symptoms of confusion, unconsciousness, changes in personality
 - Eye and ear symptoms of scotomata (negative then positive), diplopia, tunnel vision, blurring, extraocular motor paresis, tinnitus, or partial hearing loss
 - Skin symptoms of pruritus or mottling
 - Pulmonary symptoms of dyspnea, nonproductive cough, or hemoptysis
 - Cardiac symptoms of inspiratory, substernal, or sharp or burning chest pain
 - Gastrointestinal symptoms of girdle abdominal pain, fecal incontinence, nausea, or vomiting
 - Genitourinary symptoms of urinary incontinence or urinary retention
 - Neurologic symptoms of paresthesia (general or over a joint), paresis, paralysis, migrainous headache, vertigo, dysarthria, or ataxia
 - Lymphatic symptoms of edema

Physical

Physical examination findings may include the following:

- General - Fatigue, shock
- Mental status - Disorientation, mental dullness
- Eyes - Visual field deficit, pupillary changes, air bubbles in the retinal vessels, or nystagmus
- Mouth - Liebermeister sign (a sharply defined area of pallor in the tongue)
- Pulmonary - Tachypnea, respiratory failure, respiratory distress, or hemoptysis
- Cardiac - Tachycardia, hypotension, dysrhythmia, or Hamman sign (crackling sound heard over the heart during systole)
- Gastrointestinal - Vomiting
- Genitourinary - Urinary bladder distention, decreased urinary output
- Neurologic - Hyperesthesia, hypoesthesia, paresis, anal sphincter weakness, loss of bulbocavernosus reflex, spotty motor or sensory deficits, focal seizure, generalized seizure, or ataxia
- Musculoskeletal - Subjective joint pain without objective findings, or decreased range of motion because of muscle splinting of involved joint or tendon
- Lymphatic - Lymphedema
- Skin - Pruritus, mottling/marbling, hyperemia, violaceous color, cyanosis, or pallor
- Diagnostic maneuvers - Pain, frequently musculoskeletal, occurs in 50-60% of DCS cases. Two specific maneuvers can aid the practitioner in diagnosing DCS.
 - Place a large blood pressure (BP) cuff over the area of pain and inflate it to 150-250 mm Hg. In patients with nitrogen bubbling in the joint or tendons, this increase can force some of the nitrogen back into solution, resulting in a temporary decrease in pain.
 - Milking the muscle toward the affected joint may increase pain by pushing more nitrogen bubbles toward the joint.
- Differentiating between AGE and DCS
 - AGE - (1) Any type of dive can cause AGE, (2) the onset is immediate (< 10-120 min), and (3) neurologic deficits manifest in only the brain.
 - DCS - (1) The dive must be of sufficient duration to saturate tissues, (2) the onset is latent (0-36 h), and (3) neurologic deficits manifest in spinal cord and brain.

Causes

Predisposing causes of DCS

- Inadequate decompression or surpassing no-decompression limits (This includes increased depth and duration of the dives and repeated dives.)
- Inadequate surface intervals (ie, failure to decrease accumulated nitrogen)
- Failure to take recommended safety stops
- Flying or going to higher altitude soon (12-24 h) after diving (This increases the pressure gradient.)
- Smoking^[51]

A principal cause of DCS is rapid ascent. A major cause of rapid ascent may be panic. Anxiety traits can be identified during instruction.^[52]

Individual predisposing physiologic characteristics

- Obesity (nitrogen is lipid soluble)
- Fatigue
- Age
- Poor physical condition
- Dehydration
- Illness affecting lung or circulatory efficiency
- Prior musculoskeletal injury (scar tissue decreases diffusion)

Predisposing environmental factors

- Cold water (vasoconstriction decreases nitrogen offloading)
- Heavy work (vacuum effect in which tendon use causes gas pockets)
- Rough sea conditions
- Heated diving suits (leads to dehydration)^[32]

Divers who have been chilled on decompression dives (or dives near the no-decompression limit) and take very hot baths or showers may stimulate bubble formation.

Improper use of decompression tables may increase the diver's risk.

- DCS may occur even if the decompression tables and no-decompression limits are strictly observed.
- The decompression tables and no-decompression limits list the maximum time allowed for a dive based on the maximum depth achieved.
- The limits take into consideration nitrogen saturation of lipid tissues.
- According to the Henry law, once nitrogen has saturated tissues, a standard ascent to the surface with decreasing ambient pressure can allow nitrogen to bubble out of solution.
- Once the no-decompression limit has been passed, 1 or more decompression stops are required during ascent to allow delayed diffusion of nitrogen out of the lipid tissues back into the blood. Nitrogen is then exhaled through the lungs.

- These tables also include calculations based on the surface interval between dives and residual nitrogen offloading during the time between dives. The original tables have the following 3 problems:
 - The tables are based on young, healthy, and fit US Navy volunteers. Since many civilian divers do not fit this profile, the tables have limitations.
 - The rapidly expanding use of dive computers takes into account the actual time spent at each depth. This allows for more time under water and removes a built-in factor that helps keep divers in the conservative range.
 - The number of casual divers is increasing.

See the discussion under Deterrence/Prevention for more information.

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Decompression Sickness

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Decompression Sickness Treatment & Management

Author: Stephen A Pulley; Chief Editor: Joe Alcock, MD, MS

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Prehospital Care

Extricate the patient from water and immobilize if trauma is suspected. Generally, in-water recompression is not believed to be a safe option. Problems with air supply, hypothermia, potential oxygen toxicity, dehydration, and the uncontrolled environment make it less than ideal and increase the risks of drowning.^[61] However, in remote areas without reasonable-distance HBO chamber support, this may be the only option.

- In Thailand, home to the diving Urak Lawoi fishermen, 72.1% exceed the no-decompression limits, yet medical treatment and HBO facilities are distant (10 h and 16 h, respectively). In this population, one third reported having experienced DCS, and in-water recompression has been shown to be an appropriate first-aid measure. Much more research needs to be performed on the concept of in-water decompression, since over half of the Urak Lawoi (not just one third) were classified as experiencing recurring nondisabling DCS and about one quarter as having disabling DCS.^[62, 63, 64]
- A shorter in-water recompression protocol was also developed for use in the remote Northern Pacific Clipperton Atoll in an attempt to address the above concerns.^[61]

Administer 100% oxygen, intubate if necessary, and intravenously administer saline or lactated Ringer solution.

The use of first aid oxygen has proven so beneficial that the Divers Alert Network (DAN) has made a major effort to place oxygen at dive locations, in particular those that are remote with lengthy transport times to the nearest hyperbaric chambers and to ensure that people are trained in its use. A study of the use of first aid oxygen found that the median time to its use after surfacing was 4 hours and 2.2 hours after the onset of DCS symptoms. Forty-seven percent of victims received the oxygen. Complete relief of symptoms was found in 14% of victims. Even more striking was that 51% of victims showed improvement. This was with the oxygen before HBO treatment. Even after a single HBO treatment, those that had received oxygen before the HBO dive, even if many hours earlier, had better outcomes.^[65]

Aspirin is commonly considered and given in diving accidents for antiplatelet activity if the patient is not bleeding. However, there are no current data to support this practice.^[66]

Thus far there is no substantive data showing a benefit for other adjunctive treatments, such as recompression with helium/oxygen and NSAIDs.^[67]

Perform cardiopulmonary resuscitation and advanced cardiac life support, if required, as well as needle decompression of the chest if tension pneumothorax is suspected.

Do not put the patient into the Trendelenburg position. Placing the patient in a head-down posture used to be considered a standard treatment of diving injuries to prevent cerebral gas embolization. This practice should be abandoned. The process actually increases intracranial pressure and exacerbates injury to the blood-brain barrier.^[68] It also wastes time and complicates movement of the patient.

Transport to the nearest ED and hyperbaric facility, if feasible, and try to keep all diving gear with the diver. Diving gear may provide clues as to why the diver had trouble (eg, faulty air regulator, hose leak, carbon monoxide contamination of compressed air).

Emergency Department Care

Administer 100% oxygen to wash nitrogen out of the lungs and set up an increased diffusion gradient to increase nitrogen offloading from the body.

Do not put the patient into the Trendelenburg position. Placing the patient in a head-down posture used to be considered a standard treatment of diving injuries to prevent cerebral gas embolization. This practice should be abandoned. The process actually increases intracranial pressure and exacerbates injury to the blood-brain barrier.^[68] It also wastes time and complicates movement of the patient.

Perform intubation, aggressive resuscitation, and chest tube thoracostomy, if indicated.

Administer intravenous fluids for rehydration until urinary output is 1-2 mL/h. Rehydration improves circulation and perfusion.

Aspirin is commonly considered and given in diving accidents for antiplatelet activity if the patient is not bleeding. However, there are no current data to support this practice.^[66]

Treat the patient for nausea, vomiting, pain, and headache.

Contact the closest hyperbaric facility (or DAN for referral) to arrange transfer and try to keep all diving gear with the diver. The diving gear may provide clues as to why the diver had trouble (eg, faulty air regulator, hose leak, carbon monoxide contamination of the compressed air).

Patients with type I or mild type II DCS can dramatically improve and have complete symptom resolution. This improvement should not dissuade the practitioner from HBO referral or transfer, as relapses have occurred with worse outcomes.

Consultations

Diving medicine and HBO specialists: Symptoms temporally related to diving should necessitate a consultation with a diving medicine specialist or HBO specialist to determine if symptoms are related to diving and if HBO therapy is appropriate.

DAN: DAN is an excellent resource, especially if local support is not available. Visit their Web site at [Divers Alert Network](#). Use of this service is similar to use of a poison control center. DAN maintains a database of diving-related injuries and provides consultation services, including extent-of-injury assessment, recommendations for management, and referral to HBO therapy or local diving medicine specialists. Emergency contact 24 hours per day can be reached at the following numbers:

- DAN America: 1-919-684-8111 or 1-919-684-4DAN (4326) (accepts collect calls)
- DAN Latin America: 1-919-684-9111 (accepts collect calls)
- DAN Europe: 39-06-4211-8685
- DAN Southern Africa: 0800-020111 (within South Africa); 27-11-254-1112 (outside South Africa)
- DAN Japan: 81-3-3812-4999
- DAN SEAP DES New Zealand: 0800-4DES 111
- DAN SEAP Singapore Naval: 6758-1733
- DAN SEAP Malaysia: 05-930 4114
- DAN SEAP Philippines: 02-815-9911
- DAN SEAP DES Australia: 1-800-088-200 (within Australia); 61-8-8212-9242 (outside Australia)

HBO treatment

- Patients with mild type I DCS probably do not require treatment other than breathing pure oxygen at sea level for a short time. Divers with type I DCS symptoms do, however, require close observation, as symptoms may portend the onset of more serious problems requiring hyperbaric recompression. Consult a diving medicine or HBO specialist for all diving-related injuries. The only effective treatment for gas embolism is recompression; other treatments are merely for symptoms.
- Several types of hyperbaric chambers exist, ranging from small monoplace (single person) chambers to complex multiple place, multiple lockout chambers large enough for multiple patients and attendants. All chambers have the ability to maintain critical care monitoring and mechanical ventilation. A major difference with the size of chambers clinically is that some patients experience claustrophobia with the small monoplace chambers. Increased oxygen toxicity issues have been reported with the monoplace chambers because the entire environment is oxygenated, whereas, with the larger chambers, patients breath the oxygen via mask, but the ambient environment is not supplementally oxygenated.
- The basic theory behind HBO therapy is, first, to repressurize the patient to simulate a depth where the bubbles from nitrogen or air are redissolved into the body tissues and fluids. Then, by breathing intermittently higher concentrations of oxygen, a larger diffusion gradient is established. The patient is taken slowly back to surface atmospheric pressure. This allows gases to diffuse gradually out of the lungs and body. The addition of helium to oxygen has been shown to yield an advantage over oxygen alone even in severe neurologic DCS or treatment-refractory DCS.^[69,70]
- Treatment tables govern the exact combination of timing and depths. These were developed primarily by the US Navy with some minor modifications by the US Air Force. Table 6 is most commonly used; however, specific details concerning the tables are beyond the scope of this article. While most will improve with a single HBO treatment, 38.5% will have relapses, half of those within 24 hours. Observation for 24 hours is strongly recommended after HBO treatment.^[71] Another study reported complete resolution of symptoms in 49% with the first treatment and an additional 26.5% with additional treatments. However, 24.5% had long-term residual symptoms.^[72] In Israel, 48% had complete

- recovery with HBO, while another 48% had partial recovery. Unfortunately, 4% did not respond to the therapy.^[73]
- Traditionally, the treatment protocols were staged, meaning that time would be spent at certain depths as the individual was "brought back to the surface." Recent studies suggest that a linear approach is more effective than the staged approach. Other variations on the tables are being researched to try to find shorter-term approaches. In addition, use of combination gases such as Trimix are being looked at in the same regard.
 - Other mentioned adjuncts to HBO include negative-pressure breathing and intravenous perfluorocarbon emulsion.
 - With early recognition and treatment, more than 75% of patients improve. Even with significant delays in recognition and treatment, positive results are obtained.^[74, 75] Studies of the Miskito Indians of Central America highlight this. They are diving seafood harvesters who dive repeatedly without consideration for diving tables or profiles. They have a high prevalence of the bends and neurologic DCS that affects the thoracolumbar spine in particular. Despite very high rates of DCS, and sometimes days' delays in HBO treatment (if sought at all), HBO treatment yields positive results, with 30% regaining strength and many more ambulating. However, HBO treatment is usually only sought for significant neurologic symptoms, while painful DCS, such as the bends, is usually treated with only analgesia.^[76, 77]
 - Differentiating inner ear barotrauma or dysbarism from inner ear labyrinthine or alternobaric vertigo is difficult. The difference is that dysbarism responds well to treatment, and inner ear DCS is less responsive and is associated with a higher frequency of permanent damage. Patients with inner ear DCS may be asymptomatic after treatment yet still have vestibular problems at detailed testing. Therefore, both conditions must be considered in the differential diagnosis, and the patient must be treated for both conditions. A recent recommendation is to perform immediate tympanocentesis and then to follow with HBO therapy.
 - Inner ear DCS is less responsive to HBO treatment than is DCS affecting other sites. HBO typically results in significant improvement in severe neurologic DCS if it is identified early and the patient is rapidly transported to an HBO facility.
 - Rapid treatment is also crucial in the face of AGE. Those with AGE who reach recompression within 5 minutes have a death rate of only 5%. This rapid treatment also results in little morbidity. However, when AGE recompression is delayed 5 hours, the mortality rate approaches 10%. More than 50% of the survivors experience residual signs.
 - An important issue is transport of the patient to the closest hyperbaric facility. This is frequently accomplished by land transport; however, air transportation is occasionally required. Helicopter transport requires the pilot to maintain an altitude of less than 500 ft (152 m) above the *departure point* (which could be more than 500 ft above sea level depending on the dive location).^[78] This can be difficult when there are mountains to traverse in flight. An effort should also be made to minimize the transport time. Fixed-wing transport should be limited to aircraft that can maintain cabin pressure at normal surface pressure of 1 atm (eg, Lear Jet, Cessna Citation, military C-130 Hercules).

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Decompression Sickness

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<http://emedicine.medscape.com/article/769717>

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Excerpts from Recent HAZREPS:

FA-18. No adverse or unusual symptoms were present during flight. Pilot experienced symptoms 30 to 40 minutes post flight. Pilot diagnosed by flight surgeon with Type II decompression sickness and sent to chamber for several rounds of treatment.

FA-18. As pilot climbed through 30,000 feet, ECS and OBOGS surged. Pilot reported a rapid change in cabin pressure based on his ears popping. Emergency procedures followed and 30 minutes after landing the flight surgeon determined he had Type II DCS and he was medevac'd to a chamber ashore. Pilot med-down for 14 days.

FA-18. A loose nut on the cabin air pressure safety valve caused pressurization problems. Once on deck the aircrew were thought to have had hypoxia, but actually had decompression sickness.



DECOMPRESSION SICKNESS: What You Need to Know

BY LCDR. LISA FINLAYSON AND MS. MONA SANIEI

In aviation, decompression sickness (DCS) is a series of symptoms that are due to exposure to decreased altitude, which cause the inert gases in your body to bubble out of solution and into the tissues. There are two types of DCS, type I and type II.

Type I

Musculoskeletal DCS (bends) occurs mostly in the major joints (shoulder, elbow, knee, and ankle). Common symptoms include localized deep pain and

dull aches. The pain can occur at altitude, during descent or hours after being on the ground. The bends must be evaluated even if symptoms disappear upon grounding.

Skin DCS (skin bends or creeps) mainly affects the skin and causes itching. Other symptoms include the feeling of insects crawling over one's body. Severe skin bends include: cutis marmorata, marbled skin and scar-like lesions.

Lymphatic DCS involves swelling and the above skin symptoms.

Type II

Brain DCS symptoms include: confusion, memory loss, headache, changes in vision, fatigue, seizures, dizziness, vertigo, unconsciousness, nausea and vomiting.

Spinal cord and peripheral nervous system DCS result in tingling, numbness, burning, stinging, muscle weakness, twitching, pain and other unusual sensations.

Inner ear DCS affects the inner ear with symptoms of vertigo.

Pulmonary DCS (chokes) is associated with a deep burning sensation inside the chest, painful breathing, shortness of breath and dry cough.

Susceptibility to DCS mainly occurs at cabin altitudes above 18,000 feet and with increased duration at altitude. It also occurs with increased age, previous injury of a joint or limb, excessive body fat, SCUBA diving before flight, increased rate of ascent, repetitive exposure, low ambient temperature and increased physical activity during flight. Dehydration due to any cause, such as excessive heat exposure and alcohol consumption, also increases the onset of DCS.

Preventive measures should be taken to avoid DCS. These include prebreathing 100-percent oxygen, hydration, shortened exposure time, and reducing exercise level while in flight. 

LCDR. FINLAYSON IS THE AVIATION PHYSIOLOGIST WITH THE NAVAL SAFETY CENTER AND MS. MONA SANIEI IS WITH OLD DOMINION UNIVERSITY.

Resources

- OpNavInst 3710.7U discusses hyperbaric exposure in section 8.3.2.13, which states in part, "Under normal circumstances, flight personnel shall not fly or participate in low-pressure chamber flights within 24 hours following scuba diving."

- U.S. Navy Dive Manual
- FAA guidance can be found at: <http://www.faa.gov/pilots/safety/pilotsafetybrochures/media/dcs.pdf>

- Hyperbaric chamber information can be found at: <http://www.hyperbaricinformation.com/HBO-articles/decompression-illness/aviat-space-environ-med-2000-71-115-8-Krause-Effects-of-SL-o.pdf>

- Contact your local Aviation Survival Training Center (ASTC) or Aeromedical Safety Officer (AMSO) for additional information.

What Should You Do If You Suspect Decompression Sickness?

OpNavInst 3710.7U (section 8.2.4.6) provides actions to take when an occupant of any aircraft is observed or suspected to be suffering from the effects of DCS: 1) 100-percent oxygen or available aircraft oxygen will be started. 2) The pilot shall immediately descend to the lowest possible altitude, and land at the nearest civilian or military installation suitable for safe landing and obtain qualified medical assistance. 3) Consideration shall be given to whether the installation is in proximity to a medical recompression chamber. 4) Upon landing, contact your flight surgeon and debrief your symptoms and flight profiles to both the flight surgeon and hyperbaric-chamber personnel. 5) Submit a physiological episode hazrep.

Squadrons Need a Plan

Commander, Naval Air Forces has addressed the DCS situation for FA-18 and EA-18 squadrons in a recent message (dtg 290617ZMAY12) on physiological-episode reporting guidance. Included in this message is the directive, "Squadrons shall incorporate decompression-sickness (DCS) details into their premishap plan and duty binders. At a minimum, include location of the two closest hyperbaric chambers with POC information for 24/7 assistance and a transportation plan for the aircrew to get to the chamber, whether they are on or off base when it is determined that chamber assistance is needed." Preferred transportation for DCS is by ground and, most often, directly to the chamber. Realizing that ambulances routinely transport to the nearest medical facility, this can result in delays beginning recompression treatment. Unless the aircrewman is actively in need of CPR, it is often best to take them directly to the hyperbaric chamber. Flight surgeons can contact the NMOTC Det NOMI hyperbaric chamber hotline (answered 24/7) at (850) 449-4629, or their local hyperbaric chambers for assistance with evaluation, diagnosis or transportation issues. If a helicopter is used, do not exceed 1,000 feet.

Local Hyperbaric-Chamber Information

The hotlines for local hyperbaric chamber information are provided by the Diver Alert Network (DAN) at: (919) 684-9111 or (800) 446-2671.

Why I Made So Many Mistakes

I had experienced a minor case of DCS and a moderate case of AGE in the lungs and brain. The AGE was most likely aggravated at altitude, as I tried to clear my right ear while the pressure was cycling.

BY LT. MICAH PORTER

Iwould have noticed my cognitive problems earlier, but my ear hurt so badly that it distracted me. And to explain why my ear hurt, I need to go back to the beginning.

I was in sunny San Diego, supporting CVW-11's Strike Fighter Advanced Readiness Program (SFARP), and fly as a strike-fighter tactics instructor (SFTI) with a great F-18C squadron. I had been scheduled for a midafternoon flight, which gave me plenty of time to hit the gym before heading to work.

At 12:50 p.m., the flight lead hacked the clock and started the brief for an unopposed, day division,

self-escort strike in the Superior Valley training range. After a brief of admin, tac-admin and flight conduct, we wrapped up and walked on our jets. During the maintenance logbook review, I saw a gripe in the aircraft-maintenance book (AMB) for a sudden loss of cabin pressure at roughly 25,000 feet. I also noticed the maintenance-action form had been signed-off by another pilot, who had flown the jet the previous day with no follow-on issues.

Soon after takeoff, Los Angeles Center told us to climb, maintain FL290 and proceed direct to the R-2508 complex. During the transit, I looked around in awe at the clear skies. You could see the Sierra Nevada Mountains rising in the distance from 80 miles away. Approaching R-2508, we were instructed to hold outside the airspace while other flights exited the target area. At about 3:20 p.m., our flight lead, realizing that

fuel was an issue, slowed to max endurance, and began a slow, left turn through north at 29,000 feet.

I suddenly felt my lungs fully deplete of air. It felt like a hand grabbed hold of my lungs and instantly squeezed out all the oxygen. With my mask on and no warning or caution lights, I became very confused and concerned. Initially, I thought my mind was playing tricks on me. I took a deep breath. My right lung felt like it had ruptured. Quickly scanning my DDIs, nothing seemed out of the ordinary until the pressure in my lungs cycled again.

Scanning my cabin-pressure gauge, I saw the needle swing through 29,000 feet, while my right ear felt like it had just burst. In the time it took me to execute my immediate-action items, the pressure had cycled from 8,000 feet to 30,000 feet at least four more times. Realizing I was in big trouble, I initiated my immediate-action items to get emergency oxygen and neutralize the cabin pressure.

I started a steep dive for the deck. After rapidly descending below 10,000-foot cabin-pressure altitude, I focused on clearing my right ear, which still was

The UCSD hypobaric chamber.



painful. I did the Valsalva maneuver multiple times, trying to equalize the pressure. I couldn't clear my ear, so I passed the section lead to Dash 4, an experienced flight lead. He started to coordinate our return to MCAS Miramar.

After discussions between flight leads on whether to divert into China Lake, the decision was made to get the jet back to Miramar. We'd return low at below 10,000 feet. Once Joshua Control gave us return clearance, I turned my attention back to equalizing the pressure in my right ear.

DURING THE RETURN FLIGHT, early symptoms of decompression sickness (DCS) and arterial gas embolism (AGE) began to surface. An early indicator of the deterioration of my cognitive skills was when the flight lead had to continually walk me through radio-frequency changes. My formation-keeping skills had eroded to the point where I had fallen two to three miles in trail. After several questions about my position from flight lead, I quickly turned my attention back to flying formation and closed the distance. In my mind, I chalked up these mistakes to task saturation brought on by flying form, trying to equalize pressure in my right ear and changing radio frequencies.

As we got closer to Miramar, we were directed to contact tower, who cleared us to descend and maintain 3,000 feet. We lined up for the visual approach to runway 24R. Still in pain, I told flight lead that I would need a very gradual descent to try to clear my right ear. He obliged, and finally, as I approached 3,500 feet, my right ear cleared and the pain stopped.

Relieved, I now thought the worst was over and landing would be a piece of cake. We decided that I would fly my approach first and lead would take separation on final. Detaching around 10 miles from the threshold of runway 24R, I initiated my landing checklist.

I reported to Miramar tower, "Three down and locked."

I started my descent and was surprised when lead asked me if I planned to land or take it around. I said that I intended to land on that pass. Immediately, my wingman told me I was high and to start my descent. If

I wasn't confused before this call, I definitely was now. After scanning my instruments, I quickly realized I was still at 3,000 feet, 210 knots, and my flaps were in the up position.

I decided to make a play for the deck. I dumped the nose and threw my flaps to full, then proceeded to push the landing. As I started my descent around three miles from the threshold, my airspeed crept up. Over the threshold, I realized I was not only high but also very fast. Good judgment would have dictated a go-around, but I wanted to put the aircraft on deck. Flaring early, I worked off airspeed and landed halfway down the runway.

Miramar Tower directed me to use the parallel taxiways and proceed to de-arm. Again, this direction was very confusing and led me to try to take a left onto runway 24L. With direction from lead, I rolled to the end of 24R and taxied clear. After pulling into de-arm, I became violently sick and vomited in my helmet bag and the cockpit.

I gathered myself, and we taxied to the line and shut down. The flight lead met me at the bottom of the ladder. He said my eyes were bloodshot and I looked drunk. Fresh air surrounded me, and I immediately felt better.

We debriefed with maintenance control and went to the ready room to call the flight doctor. After a full examination, the doc said I'd been hypoxic and should feel better if I stayed hydrated and ate dinner.

My mind continued to play tricks on me as I made my way back to the ready room. For the life of me, I couldn't remember whether I had turned in my classified material, or if I had placed my ejection seat in the safe position. Maintenance had checked and confirmed that my seat still was armed. I called them and apologized for my actions. I finished my required paperwork for SFARP accounting purposes.

At 7:30 p.m., with paperwork complete and stomach empty, I decided it was time for a little dinner before my next scheduled nonflying night event. I headed to my car, agitated and frustrated at how forgetful I had become. Not only had I forgotten my keys, but I had left my cover in the ready room. After 15 minutes, I

squared myself away and headed toward Rubio's for their delicious fish tacos. Having just been there the night before, I was familiar with the area.

I headed out the main gate and quickly became disoriented and lost, which sent me over the top. I remember thinking, "Wow, this is not going well." After 30 minutes of searching, I finally located the restaurant, ordered my food and headed back to the squadron. I ate dinner and prepared the paperwork for my next event.

After 15 minutes, my head began to hurt. I felt like I was going to pass out. Pushing through the pain, I prayed that if I could just finish the debrief without vomiting in front of the flight, this would be a mission success. At some point in the debrief, someone asked if I felt OK. I don't remember being asked, but apparently my response was slow and slurred. A few minutes later, I felt like my head was about to explode. I quietly excused myself and went outside to vomit. The squadron XO followed me out and heard me. He immediately called the flight doctor. The XO and flight surgeon decided to hustle me over to Balboa Naval Hospital.

Emergency-room doctors put me on IVs and 100-percent oxygen. One doctor thought I had a simple stomach virus. However, after hours of tests, I was on my way to a hypobaric chamber at the University of California at San Diego (UCSD), where a team evaluated my symptoms and subjected me to multiple cognitive-skill tests (which I failed miserably). The team struggled to diagnose either DCS or AGE. After running another chest X-ray and finding damage to my lungs, they quickly set up the hypobaric chamber.

Finally, 12 hours after the incident occurred, I was placed in the chamber and started my descent. Seeing as I was roughly 30,000 feet in elevation at the time of decompression, this was equal to three atmospheres or 60 feet in depth for my treatment table. Upon completing my treatment seven-and-a-half hours later and being reevaluated, I passed all cognitive tests, and my lungs, brain and heart were functioning at 100 percent.

Final Diagnosis

I had experienced a minor case of DCS and a moderate case of AGE in the lungs and brain. The AGE was most likely aggravated at altitude, as I tried to clear my right ear while the pressure was cycling.

What is an AGE?

It occurs when air bubbles are pumped into the arteries or veins due to rapid decompression. It is usually seen in divers, but as I proved, can easily attack the body at any altitude. Common symptoms are signs of a stroke or heart attack. For me, the signs pointed to a stroke with the loss of cognitive skills and reasoning.

Top Five Lessons Learned

If in doubt, execute your immediate-action items. Aircrew often lean on their experience and symptoms without fully understanding all of the aeromedical factors in play. We are aircrew, not doctors, so pull the emergency-oxygen green ring.

Aircrew should never treat a rapid decompression at altitude as trivial. Although you may not instantly feel the symptoms of DCS or AGE, they can debilitate your cognitive skills to the point that you aren't thinking clearly, and you can't make timely, accurate decisions.

Wingman responsibilities are not done once boots are on deck. Fortunately, I had an experienced wingman who recognized that something was not right and encouraged me to go to the flight doctor for evaluation. Even after being evaluated have someone shadow you for several hours to evaluate your cognitive skills. Do not go home alone.

Never allow yourself to get behind the wheel of a vehicle without being 100 percent. This decision could have had a tragic ending if I had experienced the same symptoms in a motor vehicle that I experienced a few hours later in the debrief.

Be proactive with medical care. Chamber rides are free. The effects of DCS or AGE can be permanent, even lethal. 

LT. PORTER IS A STRIKE FIGHTER TACTICS INSTRUCTOR WITH STRIKE FIGHTER WEAPONS SCHOOL PACIFIC (SFWSAPAC).



Same Ol' Emergency

BY LTJG. PATRICK BELL

Every time we prepare for a flight, we give as thorough a brief as possible without being so meticulous that we lose focus. Factors affecting our flight such as weather, fuel, closest divert airfield, time of day or night, operational risk management (ORM) and human factors are just a few of the items discussed. A realistic emergency scenario, along with an applicable NATOPS discussion is always encouraged. This helps provide aircrew possible answers to some of the “what ifs,” so they have a plan, rather than thinking about an emergency for the first time over enemy territory.

No one can predict when an emergency will occur. Regardless of its severity, it always happens at the wrong time and place. Our emergency happened during our first month supporting Operation Enduring Freedom (OEF), following a compressed (yet successful) work-up cycle. Although the jet that night had a history of cabin-pressurization problems and environmental-control-system (ECS) failures, our maintainers had spent several hundred man-hours working to resolve these issues. After a few successful "confidence" flights, everyone was sure the aircraft's troubles were a thing of the past.

We had a late afternoon launch and headed north toward Afghanistan, on a scheduled six-hour combat mission. Everything went as briefed until we were about to join on our second tanker. At 23,000 feet, five miles behind the tanker in a left hand turn, the digital-flight-control system (DFCS) stability augmentation (stab aug) kicked offline and the altitude hold would not reengage. At the same time, we felt a massive rush of air, accompanied by a popping sound in the aircraft.

A quick look at the cabin pressurization gauge showed an ambient reading of nearly 24,000 feet. We had a complete cabin-pressurization failure, which resulted in a rapid decompression. All four of us read-

justed our oxygen masks and decided to expeditiously tank as we had only 9,000 pounds of gas. This action would increase the number of options we had while we worked through the situation at hand. As we began to take fuel, we knew our tasked mission was over. We would have to descend as soon as we could.

mately would determine how we handled the situation. While tanking and running through the checklist, we noted 12 liters of oxygen remaining which, according to our oxygen-duration chart, gave us a conservative three hours of oxygen for a crew of four. This amount should have been plenty to get us back to the carrier, about one hour away. To expedite our transit, ECMO-1 requested the tanker drag us to the southern portion of the tanker track to get us heading in the general direction to the carrier.

We knew that flying at 24,000 feet in an unpressurized cockpit could lead to decompression sickness, so once we were clear of the tanker, we immediately descended. With the situation now under control, we completed our emergency checklist. We also noted that our canopy seals had deflated, the same problem this jet had several times before.

On our transit to the carrier, the three hours of oxygen we had initially planned for quickly evaporated into less than one hour of usable oxygen. A short while later, the OXYGEN caution light illuminated, indicating less than three liters of usable oxygen remaining or that the oxygen pressure is less than 50 psi. With at least 30 minutes of transit to go, the mission commander and I, in the backseats, decided to take off our masks to allow the pilot and ECMO-1 to share the remaining oxygen.

All four of us readjusted our oxygen masks and decided to expeditiously tank as we had only 9,000 pounds of gas.

justed our oxygen masks and decided to expeditiously tank as we had only 9,000 pounds of gas. This action would increase the number of options we had while we worked through the situation at hand. As we began to take fuel, we knew our tasked mission was over. We would have to descend as soon as we could.

The recent maintenance history of our aircraft ulti-

Without oxygen, we were concerned about hypoxia, so we monitored ourselves for any symptoms.

Just before going feet wet, we descended to 10,500 feet and communicated with the ship via the E-2 from our air wing. We also requested the flight deck stay open for an extra 15 minutes. We didn't want to aggravate the situation by running low on gas, because we

wouldn't arrive during the normal recovery time. We descended to a safe altitude, and the rest of the flight proceeded uneventfully.

AFTER LANDING AND DEBRIEFING maintenance, we chalked the situation up to another pressurization failure, assuming the DFCS issue was unique and not related. We couldn't think of any relationship between the two failures that would have indicated the same malfunction, such as a weight-off-wheels (WOW) failure, because many items we should have lost with a left WOW failure were still available. Later that night, the data recorder from the jet revealed there was a partial left WOW failure because of a partially failed microswitch. This resulted in the aircraft sensing an incorrect weight-on-wheels condition for certain situations. Interestingly, once the landing gear came down the switch worked as advertised. The Prowler's left WOW switch provides nearly all the indications that differentiate between an in-flight and on-deck condition. Two of the items that are inoperable when the left WOW switch is on deck are the canopy seals and DFCS altitude hold.

Here's a few notes to take away from our flight. The first is to evaluate every scenario before taking any actions. Even if you think you've experienced the same problem over and over, it is possible that you're just seeing what you want to see. In any other jet, we might have talked about the weight-off-wheel switch, but because we were in this particular jet, we were programmed to assume we were dealing with a repeat pressurization problem. The rapid decompression was only a symptom of the real problem. It's hard to diagnose a malfunction when it only occurs for part of the flight. In our case, the left WOW failure occurred

well into the flight, in a clean configuration and fixed itself while dirty. If the failure had remained present once dirty, we might have been more adept at diagnosing the problem.

Second, we must fall back on the most basic training that we are given from day one: aviate, navigate, communicate and checklist. We had control of the aircraft and made sure we were receiving oxygen to continue tanking. At the same time, we got the jet headed in the right direction by letting the tanker know we had a problem that required us to return to the boat. As we continued, we finished the checklist to make sure we did all we could to handle the emergency.

In any emergency, it is critical to get as far ahead of the jet as possible, without being unsafe or causing any confusion in the cockpit. It's disconcerting to have trouble breathing while running low on oxygen and fuel at night over enemy territory. Solid crew resource management (CRM) and foresight helped us conclude we needed to coordinate with the carrier, so we wouldn't have to wait more than an hour for the next opportunity to land.

Finally, this situation was a relatively minor emergency that could have quickly deteriorated. What if there were no tankers available for us at the time? What if we had even less oxygen than we thought but couldn't descend because of weather or terrain? What if? Obviously, there is no way to discuss every situation that you may one day find yourself in, but it is important to always analyze what has happened to your aircraft, and not just assume that you already know the answer. 

LTJG. BELL FLIES WITH VAQ-131.



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)	<ul style="list-style-type: none"> • 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	<ul style="list-style-type: none"> • 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	<ul style="list-style-type: none"> • 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	<ul style="list-style-type: none"> • Urinary and rectal incontinence • Abnormal sensations, such as numbness, burning, stinging and tingling (paresthesia) • Muscle weakness or twitching
CHOKES	Lungs	<ul style="list-style-type: none"> • Burning deep chest pain (under the sternum) • Pain is aggravated by breathing • Shortness of breath (dyspnea) • Dry constant cough
SKIN BENDS	Skin	<ul style="list-style-type: none"> • 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.

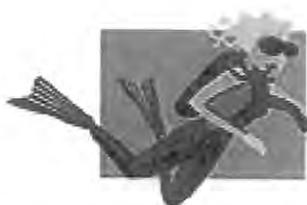
Exercise

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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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

The Effectiveness of Ground Level Oxygen Treatment for Altitude Decompression Sickness in Human Research Subjects

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KRAUSE KM, PILMANIS AA. *The effectiveness of ground level oxygen treatment for altitude decompression sickness in human research subjects.* *Aviat Space Environ Med* 2000; 71:115-8.

Background: Current therapy for altitude decompression sickness (DCS) includes hyperbaric oxygen therapy and ground-level oxygen (GLO). The purpose of this paper is to describe the Air Force Research Laboratory experience in the extensive use of GLO for the treatment of altitude DCS in research subjects. **Methods:** Data were collected from 2001 altitude chamber subject-exposures. These data, describing DCS symptoms, circulating intracardiac venous gas emboli, and treatment procedures used were collected for each subject exposure and stored in an altitude DCS database. **Results:** In the database of 2001 subject exposures, 801 subjects (40.0%) were diagnosed with altitude DCS. Subjects reporting DCS symptoms were immediately recompressed to ground level. Of the 749 subjects who received 2 h GLO, 739 (98.7%) resolved completely and required no further treatment. **Conclusions:** Although not an operational study, these data provide indirect support for the current USAF guidelines for the treatment of altitude DCS with GLO.

Keywords: decompression sickness; treatment; oxygen.

DECOMPRESSION SICKNESS (DCS) results from exposure to reduced environmental pressure. DCS can occur in diving, as divers return to sea level pressure from the increased pressure at depth, or during aviation, as flightcrews are exposed to decreased pressures of altitude. In general, DCS is the result of inert gas (i.e., nitrogen) evolving from tissues during the exposure to reduced pressure. This evolved gas forms bubbles that are directly and/or indirectly responsible for the symptoms of the disease, ranging from mild joint pain to serious neurological manifestations. However, it is generally accepted that the symptoms of altitude DCS are less severe than those observed in diving (6).

The primary countermeasures to reduce the risk of altitude DCS include cabin and/or suit pressurization to increase the ambient pressure, and denitrogenation. Denitrogenation is accomplished by breathing 100% oxygen prior to and during the altitude exposure. This results in decreased nitrogen levels in the tissues and, thus, less evolved gas during the exposure.

Current therapy for altitude DCS includes hyperbaric oxygen (HBO) and ground-level 100% oxygen (GLO) (5,6). Historically, the use of HBO therapy for altitude DCS evolved from diving DCS experience (2). How-

ever, major differences exist between diving and altitude DCS (5,6). The USAF allows the use of 2 h GLO for the treatment of Type-I DCS that occurs at altitude and resolves completely on descent (4). HBO has been used for more serious symptoms, or Type-1 DCS that does not resolve. The origins of the 2 h GLO procedure are obscure and data in support of it limited. Rudge (7) reported the effective use of GLO in a limited sample of patients. A preliminary report from our laboratory (3) also supported this procedure. In 1998, Dart and Butler (2) published a review paper advocating the development of specific therapies for altitude DCS, including the 2 h GLO procedure. The purpose of this paper is to describe the Air Force Research Laboratory (AFRL) experience in the use of GLO for the treatment of altitude DCS in research subjects.

METHODS

Data were collected from altitude chamber subject exposures at Brooks AFB from January 1983 through July 1998. These data, describing DCS symptoms, circulating intracardiac venous gas emboli (VGE), and treatment procedures, were collected for each subject exposure and stored in an ongoing computerized altitude DCS database. There were 399 subjects who participated in 2001 exposures over this time period. All subjects passed the appropriate subject physical examination, and were representative of the USAF rated aircrew population in terms of age, height, and weight. Informed consent was obtained from each subject and the use of human subjects for all exposures was approved locally by the Advisory Committee for Human Experimentation and by the USAF Surgeon Generals

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Office according to USAF AFI 40-402. These exposures were part of several research studies designed to investigate various aspects of altitude DCS such as the effect of exercise, preoxygenation schedules, sex, and age. The altitude of the exposures ranged from 2,743–10,668 m (9,000–35,000 ft). Preoxygenation duration ranged from 0–240 min. Activity at altitude ranged from rest to heavy exercise. The experimental endpoints, however, were consistent throughout all of the subject exposures, and were as follows:

1. A time limit, as set by the study, had elapsed. This limit typically ranged from 3–6 h at simulated altitude.
2. The subject experienced symptoms of DCS. If the symptom was joint pain, the pain was required to be constant in character, so as to minimize confusion with spurious aches.
3. A medical condition other than DCS occurred.
4. The subject requested termination of the experiment.

It is important to note that, based on these endpoints, we are describing the treatment of the initial symptoms of altitude DCS under controlled experimental conditions.

Non-invasive monitoring for VGE was done with echocardiography using Hewlett Packard SONOS 500 or 1000 Echo Imaging Systems. This method provides both visual images and audio Doppler of circulating intravascular bubbles, which are used as semi-objective measures of decompression. However, VGE scores were not used as an end-point for the exposures (10). The 5-point Spencer Scale for grading VGE was used (9).

Subjects reporting DCS symptoms were immediately recompressed to ground level. All exposures were attended by a medical monitor (with no involvement in the research protocol), who determined the disposition of the research subject: either GLO or referral to Hyperbaric Medicine Division immediately adjacent to the altitude chamber. In general, subjects presenting with pain, paresthesia, and/or skin symptoms of DCS that resolved completely on descent were treated with GLO. Subjects with neurologic and/or respiratory symptoms or pain, paresthesia, and/or skin symptoms that persisted at ground level, were referred to Hyperbaric Medicine. However, the final determination of course of treatment was at the discretion of the medical monitor and the Hyperbaric Medicine staff. Treatment with GLO was considered successful if symptoms resolved completely during descent or during GLO treatment and no further symptoms were reported.

RESULTS

In the database of 2001 subject exposures, 801 (40.0%) resulted in altitude DCS. All symptoms resolved and no sequelae have been found. Fig. 1 breaks down the treatments used and the treatment results for all DCS cases. Of the 801 cases of DCS, 794 (99.1%) of the initial symptoms occurred at altitude. Of the 801 cases, 749 (93.5%) were treated with 2 h GLO. Of those 749 cases treated with 2 h GLO, 728 (97.2%) were asymptomatic

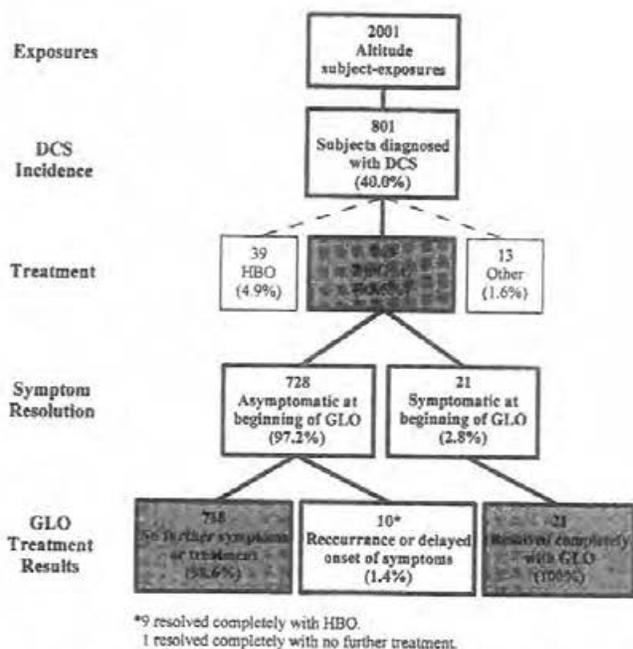


Fig. 1. Treatment breakdown for the DCS cases in the AFRL DCS Database. Percentages are given as a percent of the box above. NOT as a percentage of the total number of DCS cases.

at the beginning of the GLO treatment, and 21 (2.8%) resolved during the treatment. Of the 728 cases that were asymptomatic at the beginning of GLO, 718 (98.6%) required no further treatment and 10 subjects had recurrence of symptoms or delayed onset of symptoms. Therefore, of the total 749 DCS cases treated with GLO, 739 (98.7%) were considered successfully treated and 10 (1.3%) were considered unsuccessful. Of the 801 cases of DCS, 48 subjects required HBO therapy; 2.4% of all subject-exposures, and 6.0% of all subjects diagnosed with DCS.

The symptomatology resulting from these exposures has been described in detail elsewhere (8). Briefly, the 801 cases of DCS resulted in 1,119 individual symptoms of DCS. Joint pain represented the vast majority of these symptoms (815, 72.8%) and paresthesia was the second most represented symptom (141, 12.6%). No other individual symptom accounted for more than 4% of the total. Operational diagnostic focus is on the more serious conditions, such as neurologic and respiratory symptoms. These potentially more serious cases were more likely to be treated with HBO. Pain, paresthesia, and skin symptoms were more likely to be treated with GLO. Of the 801 cases of DCS observed, 774 (96.6%) were cases with pain, paresthesia, and/or skin symptoms and 27 (3.4%) were cases with neurologic and/or respiratory symptoms. Of the 774 DCS cases with pain, paresthesia, and/or skin symptoms, 734 were treated with 2 h GLO. Only 9 (1.2%) of these required additional treatment with HBO. Seven of these had pain, paresthesia, and/or skin symptoms recur after GLO and were successfully treated with HBO. Two subjects had neurologic or respiratory symptoms occur after GLO treatment and were successfully treated with HBO. Of the 27 cases of DCS with neurologic and/or respiratory symptoms, 15 were treated with 2 h GLO.

Six of these were described as neurologic, and nine were respiratory symptoms. All 15 were asymptomatic when the chamber reached ground level and no additional treatment beyond the GLO was administered.

The 739 DCS cases successfully treated with 2 h GLO had a total of 907 individual DCS symptoms. A few of these symptoms (33, 3.6%) resolved at exposure altitude before recompression was initiated. The majority of the symptoms (852, 93.9%) resolved during recompression. The median exposure altitude was 8,992 m (29,500 ft), the median altitude of symptom resolution was 5,791 m (19,000 ft), and the mean time \pm SEM to resolution was 2 min 17 s \pm 6 s. Lastly, 22 (2.4%) of the symptoms resolved at ground level. For those symptoms, the median exposure altitude was 8,687 m (28,500 ft) and the mean time \pm SEM to resolution at ground level was 28 min 41 s \pm 7 min 57 s.

Of the 749 DCS cases that were treated with 2 h GLO, 136 (18.2%) had no observable VGE while 613 (81.8%) had VGE present. Of the 613 DCS cases with VGE, 353 (57.6%) were categorized as incomplete and not used in subsequent analyses. The reason that these are incomplete is that during the majority of subject exposures, two subjects were in the chamber at one time. If the first subject reported symptoms of DCS and was recompressed to ground level, it was not possible to collect further VGE data on that subject. Complete VGE data are available for 260 (42.2%) of the 613 DCS cases with VGE. Of these, 10 (3.8%) subjects had VGE resolve at altitude before recompression and 69 (26.5%) had VGE resolve either during descent (mean descent time = 6 min 22 s \pm 21 s) or at ground level before the first ground level VGE data were obtained (mean time at ground level before VGE data recorded = 6 min 51 s \pm 1 min 21 s). In the majority of cases (181, 69.6%), VGE resolved at ground level. The mean time at ground level when the last VGE were observed was 8 min 42 s \pm 50 s.

DISCUSSION

Analysis of the AFRL database shows that GLO has been 98.7% effective in the treatment of 749 cases of altitude DCS. These data provide validation for the current USAF guidelines for the treatment of altitude DCS.

Briefly, DCS results from evolved inert gas bubbles when subjects are exposed to reduced atmospheric pressure. Historically, this condition was observed in underground workers and divers when they were returning to ground level pressure from being at an increased pressure. Treatment of this type of DCS consists of recompression to an increased pressure and then a slow staged decompression back to ground level. Altitude DCS is unique in that the return to ground level pressure is in itself recompression. In fact, the return from 9,144 m (30,000 ft, 4.3 psi) to ground level produces a greater reduction in gas bubble diameter than U.S. Navy Treatment Tables 5 and 6 (Fig. 2). Therefore, it is not surprising that descent in itself is an effective treatment for altitude DCS. Currently, we are conducting studies comparing the use of GLO and ground level air for DCS cases that resolve on descent. This will

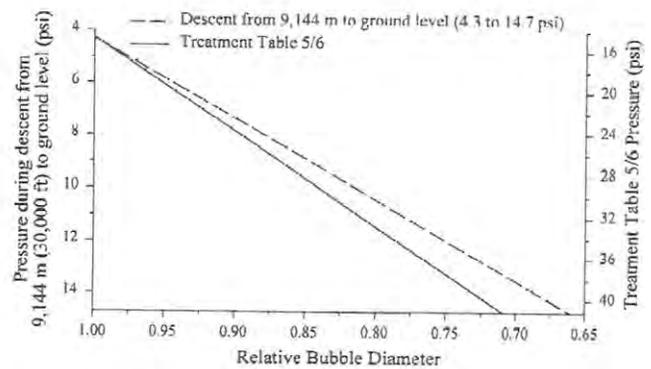


Fig. 2. Gas bubble size reduction comparison for descent from 9,144 m (30,000 ft, 4.3 psi) to ground level and for U.S. Navy treatment Tables 5 and 6.

determine if GLO is necessary for the prevention of late-onset and recurring altitude DCS symptoms.

Rudge (7) examined the use of GLO in 176 altitude DCS cases. In 49 (27.8%) of these subjects, symptoms failed to resolve with GLO and the subjects were treated with HBO. However, as noted by Rudge, his subject population can be divided into two distinct sub-populations; attendants and trainees during training flights, and research subjects. These sub-populations showed very different DCS symptom onset and resolution characteristics. In the 56 research subjects studied by Rudge, 100% had symptom onset at altitude, 54 were asymptomatic at the beginning of GLO, and only 3 required HBO. These data, and the success rate of GLO of 94.6%, are more consistent with the current findings also studying research subjects. Attendants and trainees during training flights demonstrated far different results. In the 120 attendants and trainees during training flights studied by Rudge, only 42 (35%) had symptom onset at altitude, while 78 (65%) had DCS symptoms occur at ground level, and a total of 46 subjects (38.3%) required HBO.

Both attendants and trainees during training flights and research subjects undergo hypobaric exposures under controlled chamber conditions. Why then would the two groups have such markedly different DCS symptom onset and resolution characteristics? One possible explanation lies in the incidence of DCS for the two groups. In the current study, we report a DCS incidence of 40.0%. These altitude exposure profiles were designed to study various aspects of DCS, and therefore, were expected to produce DCS symptoms. In contrast, Baumgartner and Weien (1) report a DCS incidence rate of 0.118% for 239,343 training flight exposures over a 2-yr period. Indeed, training profiles are designed to avoid DCS and it is likely that those subjects experiencing DCS during training exposures are at the extremely DCS-sensitive end of the population. Therefore, it follows that these subjects may have required more aggressive treatment for the DCS symptoms to resolve, and are not indicative of USAF rated aircrew population. The current data, derived from 801 cases of DCS, may more accurately describe the effectiveness of GLO for a research subject population.

As stated above, all hypobaric exposures in our database were terminated as soon as DCS was diagnosed.

Therefore, these results reflect the treatment of the initial symptoms of altitude DCS. The treatment of DCS symptoms that have been allowed to progress is not explored in this paper. The symptoms were subdivided into pain, paresthesia, and/or skin symptoms and neurologic and/or respiratory symptoms. Not all pain, paresthesia, and/or skin symptoms were treated with GLO and not all neurologic and/or respiratory symptoms were treated with HBO. Although the majority (95.6%) of pain, paresthesia, and/or skin symptoms were treated with GLO, if symptoms persisted at ground level, the subject was referred to Hyperbaric Medicine. The final determination of course of treatment was at the discretion of the medical monitor and the Hyperbaric Medicine staff. In 15 DCS cases with neurologic and/or respiratory symptoms in which GLO was used, all symptoms had fully resolved on descent and no further treatment was administered. Therefore, in this limited number of DCS cases with neurologic and/or respiratory symptoms, which had resolved on descent, GLO was 100% effective.

The majority of DCS cases in the AFRL database that were treated with GLO resolved early during recompression. Again, this is most likely due to the endpoints used in the database. Since minor symptoms were not given time at altitude to progress into more intense or serious symptoms, resolution was achieved more rapidly than if symptoms were allowed to progress. VGE, however, did not follow the same pattern. Of the DCS cases treated with GLO, 18.2% did not have detectable VGE. These findings corroborate our previous findings that not all DCS cases are accompanied by VGE (10). In those cases in which complete VGE data were available, 69.6% had VGE present at ground level following the exposure. The length of time that VGE remained at ground level ranged from 1 to 93 min (mean: 8 min 42 s \pm 50 s). Given the broad range of VGE resolution time, factors other than simple Boyle's Law bubble dynamics must be involved. Future work will be required to determine the factors that contribute to VGE resolution with recompression.

CONCLUSIONS

This paper reports the treatment of 749 cases of altitude DCS with 2 h GLO, as recorded in the AFRL DCS database. These cases occurred during 2001 subject exposures to simulated altitude, conducted over a 15-yr period at the Air Force Research Laboratory, Brooks Air Force Base, TX. In this database, GLO has been 98.7%

effective in the treatment of the initial symptoms of altitude DCS. These data provide indirect support for the current USAF guidelines for the treatment of altitude DCS. It is emphasized that these data are based on research exposures in which subjects were immediately recompressed once DCS was diagnosed. Operational scenarios in which crewmembers remain at altitude with symptoms might be expected to produce DCS cases that require more aggressive treatment than GLO.

ACKNOWLEDGMENTS

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8.3.2.13 Hyperbaric Exposure

Under normal circumstances, flight personnel shall not fly or participate in low-pressure chamber flights within 24 hours following scuba diving, compressed air dives, or high-pressure chamber evolutions. Where an urgent operational requirement dictates, flight personnel may fly within 12 hours of scuba diving, provided no symptoms of pulmonary overinflation syndrome or DCS develop following surfacing and the subject is examined and cleared by an FS. Personnel participating in dynamic SEBD (or equivalent egress device) training may fly as passengers without restriction. Participation in flight duties is prohibited for 12 hours following dynamic SEBD (or equivalent egress device) training. The hyperbaric exposure flight restriction is not applicable to routine ground pressurization checks conducted in P-3 and C-130 aircraft when completed without incident.

8.3.2.14 Beards

Beards interfere with the proper use of oxygen masks both for routine use (e.g., tactical aviation) and emergency use (e.g., quick-don masks, walk around bottles). Beards also interfere with the effective use of chemical, biological and radiological (CBR) protective ensembles. Beards are prohibited for those who use oxygen masks routinely in the performance of flight duties; prohibited for those aircrew who would use oxygen and are required to perform tasks during emergency duties; and prohibited for those who would be required to wear CBR ensembles during the performance of aircrew duties. For military personnel, Navy uniform regulations also apply. In accordance with Navy policy, beards are not authorized for military except when member has been diagnosed with Pseudofolliculitis Barbae (PFB) or other similar medical condition by competent medical authority. Any aircrew member with PFB who needs to wear an oxygen mask shall have his mask fit by a trained aviation life support equipment (ALSE) technician. If a proper fit is not possible, the member shall be found "not physically qualified" (NPQ) for flight duties.

8.3.2.15 Corrective Lenses for Vision

Corrective lenses or soft contact lenses shall be worn as prescribed. The requirement to wear corrective lenses will be annotated on NAVMED 6410/2.

8.3.2.16 Dehydration

Of all causes of fatigue, one of the most treatable is dehydration. Early stages of dehydration can lead to emotional alterations and impaired judgment. Ingestion of plain water throughout the day will reduce probability of dehydration and resultant fatigue. Heat and dehydration information is available as NASTP adjunctive training (appendix E) and can be provided by an NAP, AMSO, or FS.

8.3.2.17 Simulator Sickness

Simulator exposure can cause perceptual sensory changes that may compromise safety. The experience of symptoms such as nausea, disorientation, and sweating has occurred in fighter, attack, patrol, and helicopter simulators. Symptoms of simulator sickness may occur during simulator flight and last several hours after exposure. In some cases, the onset of symptoms has been delayed as much as 18 hours. The symptoms have occurred in both full motion

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INFO COMSTRKFIGHTWINGLANT OCEANA VA

COMSTRKFIGHTWINGPAC LEMOORE CA

COMVAQWINGPAC WHIDBEY ISLAND WA

FLTREADCEN SOUTHWEST SAN DIEGO CA

COMNAVAIRSYSCOM PATUXENT RIVER MD

COMNAVSAFECEN NORFOLK VA

CG FIRST MAW ALD

CG SECOND MAW ALD

CG THIRD MAW ALD

CG FOURTH MAW ALD

MALS ELEVEN

MALS THREE ONE

MALS TWELVE

BT

UNCLAS

PASS TO:

FLTREADCEN SOUTHWEST SAN DIEGO CA//F18FST/4.3.5.1.0// PEOTACAIRPATUXENT RIVER
MD//PMA265/PMA202// MALS ELEVEN//AMO// MALS TWELVE//AMO// MALS THREE ONE//AMO//
MALS FOUR ONE//AMO// SECINFO/-/-// MSGID/GENADMIN,USMTF,2008/COMNAVAIRFOR SAN
DIEGO CA// SUBJ/INTERIM TYCOM PHYSIOLOGICAL EPISODE REPORTING GUIDANCE FOR
/FA-18 A THRU F AND EA-18G SQUADRONS//

REF/A/MSGID:DOC/OPNAVINST 3750.6R/YMD:20090408//

REF/B/MSGID:DOC/NAVAIR/YMD:20120524//

REF/C/MSGID:DOC/NAVAIR/YMD:20120524//

REF/D/MSGID:DOC/NAVAIR/YMD:20120524//

REF/E/MSGID:DOC/NAVAIR/YMD:20110819//

REF/F/MSGID:DOC/COMNAVAIRFORINST 4790.2/YMD:20091110// NARR/REF A IS NAVAL
AVIATION SAFETY PROGRAM. REF B IS F/A-18 AND EA-18G PHYSIOLOGICAL EVENT-(PE)-
AIRCREW EI DATA SHEET, PART A. REF C IS F/A-18 AND EA-18G PHYSIOLOGICAL EVENT-
(PE)-MAINTENANCE EI DATA SHEET, PART B. REF D IS F/A-18 AND EA-18G PHYSIOLOGICAL
EVENT-(PE)-FLIGHT SURGEON EI DATA SHEET, PART C. REF E IS OBOGS-ECS EI DATA SHEET
AND SHOULD BE CONSIDERED OBSOLETE. REF F IS THE NAVAL AVIATION MAINTENANCE
PROGRAM. ALL PREVIOUSLY PROMULGATED PARTS A,B AND C DATED 20110819 ARE CONSIDERED
OBSOLETE AND SHOULD NOT BE USED FOR REPORTING.// GENTEXT/REMARKS/1. THIS IS A
COORDINATED CNAL AND CNAP MESSAGE.

2. AIRCREW PHYSIOLOGICAL EVENTS SUCH AS HYPOXIA, TOXIC EXPOSURE, DECOMPRESSION
SICKNESS, AND OTHER RELATED CONDITIONS PRESENT A SERIOUS SAFETY CONCERN FOR NAVAL
AVIATION. NAVAIR HAS SEVERAL INITIATIVES IN DEVELOPMENT, HOWEVER, ADDITIONAL
INFORMATION IS REQUIRED TO ENSURE RISKS TO AIRCREW SAFETY ARE SUFFICIENTLY
MITIGATED. THIS ACTION PLAN BALANCES NAVAIR NEED FOR ACCURATE DATA AND CRITICAL
FAILURE EVIDENCE WITH THE FLEETS REQUIREMENT FOR RETURNING AN ACFT TO SERVICE AS
SOON AS POSSIBLE FOLLOWING A PHYSIOLOGICAL EVENT.

3. IAW REF A, CHAPTER 4, EVERYONE ASSOCIATED WITH NAVAL AVIATION HAS AN
OBLIGATION TO REPORT HAZARDS. IT IS ESSENTIAL THAT COMMANDING OFFICERS ENCOURAGE
AND COMMAND SAFETY PROGRAMS FOSTER HAZARD REPORTING. THE OCCURRENCE OF A
PHYSIOLOGICAL EVENT AS INDICATED IN PARA 1 OF THIS MESSAGE MEETS THE CRITERIA FOR

HAZREP REPORTING. REF A SECTION 401 SPECIFICALLY STATES THAT A PHYSIOLOGICAL EPISODE

(PHYSEP) REQUIRES A HAZREP. PHYREPS ARE DEFINED IN REF A SECTION 404 AND INCLUDE HYPOXIA, EITHER PROVEN OR SUSPECTED, CARBON MONOXIDE POISONING OR OTHER TOXIC EXPOSURE, DECOMPRESSION SICKNESS, HYPERVENTILATION, SPATIAL DISORIENTATION, LOSS OF CONSCIOUSNESS, UNINTENTIONAL RAPID DECOMPRESSION, AND OTHER PHYSIOLOGICAL, PATHOLOGICAL, OR PHYSICAL PROBLEMS.

4. REFS B, C, AND D ARE HEREBY PROMULGATED TO ASSIST IN CRITICAL DATA GATHERING AND COLLECTIVELY SUPERSEDE REF E PREVIOUSLY PROMULGATED IN AUGUST 2011. REF E IS NO LONGER IN USE AND SHOULD BE CONSIDERED OBSOLETE.

5. PARTS A, B AND C HAVE INCORPORATED NUMEROUS REVISIONS. DISCARDING OF PREVIOUS EDITIONS IS PARAMOUNT. PART C VERSION 20120524 IS A MAJOR REVISION. BASED ON INFORMATION GATHERED FROM PREVIOUS PART C'S TO DATE, PART C VERSION 20120524 WILL COLLECT ADDITIONAL INFORMATION AND DIRECT EXPANDED BLOOD TESTING. THIS WILL ALLOW FOR MORE DETAILED ANALYSES IN AN EFFORT TO EXPEDITE EFFICIENT DETERMINATION OF CAUSAL FACTORS FOR THE PHYSIOLOGICAL EVENTS THAT CONTINUE TO PLAGUE THE COMMUNITY. SQUADRON FLIGHT SURGEONS PLAY A CRITICAL ROLE IN THIS PROCESS. FLIGHT SURGEONS SHALL ENSURE PART C'S ARE ONLY SUBMITTED AS PER DIRECTIONS ON PAGE 9 OF THE FORM. MAJOR CHANGES AND QUICK REFERENCE ITEMS ARE BOLDED IN THE UPDATED PART C FORM. SQUADRONS SHALL INCORPORATE PART C VERSION 20120524 INTO THEIR PREMISHAP PLAN. IT IS STRONGLY RECOMMENDED THAT THEY DO A PREMISHAP DRILL TO ENSURE THEY ARE PREPARED FOR THE NEW BLOOD TESTING PROCEDURES AND HAVE THE NECESSARY COORDINATION IN PLACE WITH THE LOCAL CLINIC/HOSPITAL/LAB/MAILING FACILITY. DO NOT CONFUSE PART C REQUIREMENTS FOR PHYSIOLOGICAL EVENTS WITH OPNAVINST 3750 REQUIREMENTS FOR CLASS A, B, AND C MISHAPS. OPNAVINST 3750 REQUIREMENTS FOR MISHAPS HAVE NOT CHANGED. HOWEVER, IF A PHYSIOLOGICAL EVENT BECOMES A MISHAP, THE FLIGHT SURGEON SHALL INCLUDE THE ADDITIONAL BLOOD TESTING REQUIREMENTS FROM PART C IN THEIR AEROMEDICAL ANALYSIS FOR THE MISHAP INVESTIGATION.

ADDITIONALLY,

SQUADRONS SHALL INCORPORATE DECOMPRESSION SICKNESS (DCS) DETAILS INTO THEIR PREMISHAP PLAN AND DUTY BINDERS. AT A MINIMUM, INCLUDE LOCATION OF THE TWO CLOSEST HYPERBARIC CHAMBERS WITH POC INFORMATION FOR 24/7 ASSISTANCE AND A TRANSPORTATION PLAN FOR THE AIRCREW TO GET TO THE CHAMBER, WHETHER THEY ARE ON OR OFF BASE WHEN IT IS DETERMINED THAT CHAMBER ASSISTANCE IS NEEDED.

6. ALTHOUGH AN ACFT CAN BE IMPOUNDED OR QUARANTINED ONLY BY TYCOM (CNAL, CNAP, CNAFR AND AIR 5.0D) OR AMB DIRECTION, ANY ACFT, WHERE MISSION RESULTED IN A PHYSIOLOGICAL EVENT, IS DOWN UNTIL THE FOLLOWING OXYGEN COMPONENTS ARE REMOVED FROM ACFT: BREATHING REGULATOR (CRU-103A/P) AND HOSE, OXYGEN MASK AND HOSE, LOX CONVERTER OR OBOGS CONCENTRATOR AND SOLID STATE OXYGEN MONITOR (SSOM)(CRU-99/A), AS APPLICABLE TO ACFT. TYCOM CAN WAIVE THIS REQUIREMENT BASED ON OPERATIONAL NEEDS.

7. TESTING AND TROUBLESHOOTING (T&T) OF THE ACFT SHALL NOT BE PERFORMED UNTIL OXYGEN COMPONENTS ARE FIRST REMOVED DUE TO THE RISK OF LOSING CRITICAL EVIDENCE.

8. OXYGEN COMPONENTS SHALL NOT BE SUBMITTED TO INTERMEDIATE LEVEL MAINTENANCE.

9. IAW REF F, PARAS 10.9.4 AND 10.9.5, HMR/EI REQUESTS SHALL BE SUBMITTED WHEN SAFETY ISSUES ARE INVOLVED OR TO REPORT MATERIAL DEFICIENCIES WHICH, IF NOT CORRECTED, COULD RESULT IN DEATH OR INJURY TO PERSONNEL, OR LOSS OF ACFT.

ACCORDINGLY, OXYGEN COMPONENTS SHALL BE SUBMITTED FOR ENGINEERING INVESTIGATION (EI) VIA JOINT DEFICIENCY REPORTING SYSTEM (JDRS) HMR/EI REQUEST IAW REF F.

10. ADDITIONALLY, ANY OTHER SYSTEM COMPONENTS SUSPECTED CAUSAL TO THE PHYSEP SHALL BE SUBMITTED FOR EI VIA JDRS HMR/EI REQUEST IAW REF F.

DO NOT TURN IN REPAIRABLES NORMAL BCM OR DISCARD CONSUMABLES.

11. FLEET ACTIVITIES ARE REQUIRED TO COMPLETE REFS B, C, AND D, WITH IMMEDIATE EMPHASIS ON AIRCREW EVALUATION BY FLIGHT SURGEON IAW REF D. REF B MAY BE COMPLETED AS SOON AS PRACTICABLE FOLLOWING THE VISIT WITH FLIGHT SURGEON. REF C IS TO BE SUBMITTED AS SOON AS POSSIBLE POST T&T.

12. UNLESS OTHERWISE DIRECTED, THERE IS NO REQUIREMENT TO WAIT FOR EI RESULTS. ACFT IS CLEARED TO FLY UPON REPLACEMENT OF COMPONENTS, COMPLETION OF T&T, AND ALL REQUIRED SYSTEM TESTS ATTESTING TO THE AIRWORTHINESS OF THE ACFT IAW APPLICABLE MAINTENANCE PUBLICATIONS.

13. REFS B, C, AND D CAN BE OBTAINED FROM POCS LISTED BELOW A. COMNAVAIRFOR:

(1) F-18 CLASS DESK, CODE N421B3, MR. D. BERRY, TEL: DSN 565-7658 OR COML (757) 445-7658, EMAIL: DENNIS.BERRY1(AT)NAVY.MIL.

(2) F-18 CLASS DESK, CODE N421B1, MR. D. OBRIEN, TEL: DSN 565-7741 OR COML (757) 445-7741, EMAIL: DAVID.OBRIEN2(AT)NAVY.MIL.

B. NAVAIR. CODE 4.6.7.4, MR. DENNIS GORDGE, TEL: COML (301)342-8419, EMAIL: DENNIS.GORDGE(AT)NAVY.MIL.

C. PMA202 AIRCREW OXYGEN SYSTEM ISSC PATUXENT RIVER, MD, CODE 6.6.4.2, MR. S. NELSON, TEL: DSN 342-8405 OR COML (301) 342-8405, TEL:FAX: (301) 862-2634, EMAIL: CHARLES.S.NELSON(AT)NAVY.MIL.

D. ISSC NORTH ISLAND CA, F18FST.4, CODE 4.3.5.1.0, MR. M. GODWIN, TEL: DSN 735-3751 OR COML (619) 545-3751,

TEL:FAX: (619) 545-3433, EMAIL: MICHAEL.W.GODWIN(AT)NAVY.MIL.

E. NAVSAFCEN: AEROMEDICAL DIVISION, CODE 14, LCDR L. FINLAYSON, TEL: DSN 564-3520 X7229 OR COML (757) 444-3520 X7229, EMAIL:

LISA.FINLAYSON(AT)NAVY.MIL//

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Decompression Sickness Information Packet

Naval Safety Center

Updated 5/28/13

Ms. Kelsey Leo

Military operational planners can use the Divers Alert Network (DAN) to identify hyperbaric chambers capable of treating DCS worldwide for home base, deployment and cross country flights. Send the following information from a military email to medic@dan.org to request these chamber locations worldwide. There is a 24 hour turnaround excluding weekends.

Military operational planners can use the Divers Alert Network (DAN) to identify hyperbaric chambers capable of treating DCS worldwide for home base, deployment and cross country flights. Send the following information from a military email to medic@dan.org to request these chamber locations worldwide. There is a 24 hour turnaround excluding weekends.

Locator Request for Hyperbaric Chambers Capable of treating DCS

Name:

Telephone Number:

Fax Number:

Military Email Address:

Requested Location(s) for hyperbaric chambers capable of treating DCS:

NOTE: DAN will provide the locations of hyperbaric chambers capable of treating DCS but your command must verify their operational status.

NOTE: DAN will provide the locations of hyperbaric chambers capable of treating DCS but your command must verify their operational status.

Decompression Sickness Information Packet
Naval Safety Center
Updated 5/28/13
Ms. Kelsey Leo

Squadron Pocket Checklist Go-by

NOTE: DCS pre-mishap plans must be site specific and will vary from base to base, and also for home base, divert fields, deployment, and the ship.

- Two closest hyperbaric chambers capable of treating DCS
 - Address
 - POC information for 24/7 assistance
 - Hours of operation
 - Map to include the chamber's location on base or civilian campus
 - Transportation plan to the chamber whether aircrew is on or off base when determining that chamber is needed
- POC Squadron Duty Officer (SDO)
- POC Squadron Flight Surgeon (FS)
- POC Duty FS
- POC Dive Medical Officer (DMO)
- POC NMOTC NOMI DET DMO Hyperbaric Chamber Hotline
- POC Diver Alert Network (DAN)
 - Emergency Assistance: (919) 684-9111 or (800) 446-2671
 - To request locations of hyperbaric chambers capable for treating DCS when doing operational planning, email medic@dan.org from a military email account. There is a 24 hour turnaround excluding weekends.
- Pre-mishap Plan and/or SOP

Decompression Sickness Information Packet
Naval Safety Center
Updated 5/28/13
Ms. Kelsey Leo

Flight Surgeon (FS) Pocket Checklist Go-by

NOTE: DCS pre-mishap plans must be site specific and will vary from base to base, and also for home base, divert fields, deployment, and the ship.

- Two closest hyperbaric chambers capable of treating DCS
 - Address
 - POC information for 24/7 assistance
 - Hours of operation
 - Map to include the chamber's location on base or civilian campus
 - Transportation plan to the chamber whether aircrew is on or off base when determining that chamber is needed
- POC Squadron Duty Officer (SDO)
- POC Duty FS
- POC Dive Medical Officer (DMO)
- POC NMOTC NOMI DET DMO Hyperbaric Chamber Hotline
- POC Diver Alert Network (DAN)
 - Emergency Assistance: (919) 684-9111 or (800) 446-2671
 - To request locations of hyperbaric chambers capable for treating DCS when doing operational planning, email medic@dan.org from a military email account. There is a 24 hour turnaround excluding weekends.
- Part C Folders prepared (1 per air crew flying F/A-18 and E/A-18 only)
- Blood order forms prepared and pre-signed (1 per air crew flying F/A-18 and E/A-18 only)
- Pre-mishap Plan and/or SOP
- Access to U.S. Navy Dive Manual
- Access to Naval Flight Surgeon's Aeromedical Reference and Waiver Guide