Decompression Illness

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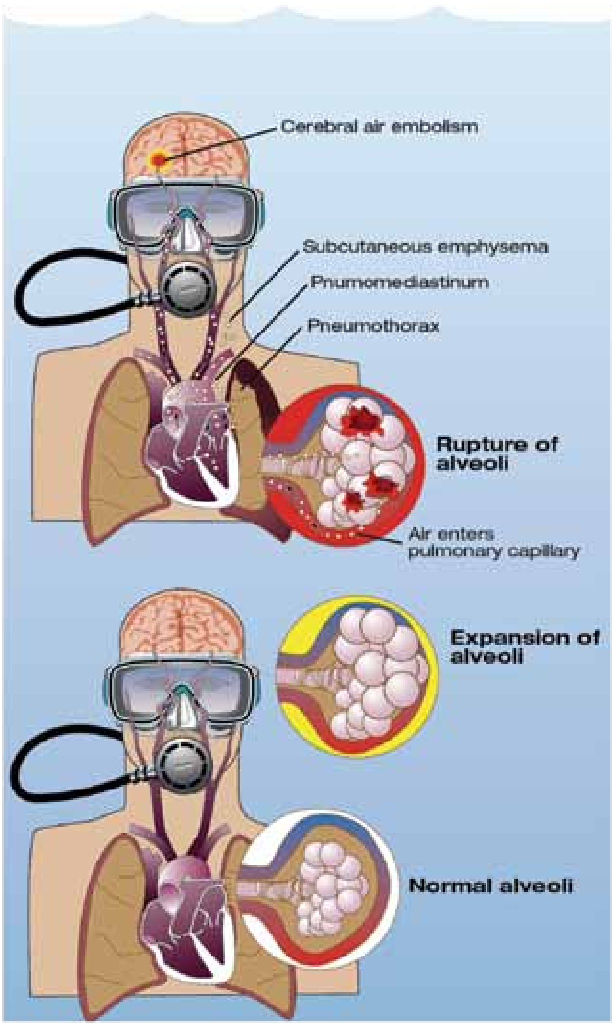
Decompression Illness (DCI) is a fascinating condition that lurks in the shadows of divers' minds, reminding us that we are vulnerable, and that our push to explore is tempered by potential consequences. Whether ascending from depth or traveling to high altitudes, as we move outward and upward from Earth's center, ambient pressure decreases; under the right circumstances, this can initiate the complex interplay between physics and physiology that can lead to injury.

For divers, there are two decompression related injuries, decompression sickness (DCS) and arterial gas embolism (AGE). Collectively, these conditions are often lumped together and referred to as decompression illness (DCI). Their common origin is the process of decompression, but the underlying mechanisms of injury are quite different.

Understanding AGE

AGE is the disabling injury in 29 percent of diving fatalities and is often associated with insufficient gas supplies, which account for about 41 percent of diving accident triggers. Emboli are actual or potential blood vessel blockages from material that travels within blood vessels. These can be composed of gas, blood clots, fat, tumors, amniotic fluid or bacterial vegetations. Among divers, gas emboli within the arterial system result from lung overexpansion or pulmonary barotrauma (lung injury resulting from pressure changes). In this setting, gas escapes from the small air sacs (alveoli) and enters the arterial system.

Boyle's law, which states that the volume occupied by a given quantity of gas will proportionally increase as ambient pressure decreases, explains lung overexpansion on ascent.



The reverse is also true: the volume of a given quantity of gas will proportionally decrease as ambient pressure increases on descent. Divers are at the highest risk for pulmonary barotrauma in shallow water. The greatest pressure difference experienced in the water column relative to that at the surface is within the first 10 to 15 feet of sea water.

In the case of diving injuries, expansion of gas can result in lung tissue damage and enable air trapped in the lungs to escape into the blood supply that returns oxygenated blood to the heart (pulmonary veins). In these cases, the escaped air can quickly enter the heart and traverse to the brain, where acute neurological injury can occur. The speed with which this happens, explains the rapid onset of symptoms at or near the surface. Pulmonary barotrauma can also manifest as free air within the mediastinum (area in the chest, between the lungs), a condition known as pneumomediastinum, or result in a pneumothorax (air within the chest cavity, but outside the lungs). The greatest threat to divers is an AGE that reaches the brain, a condition known as cerebral arterial gas embolism (CAGE).

Symptoms of CAGE manifest at or near the surface and approximately 50 percent of divers who suffer CAGE experience sudden unconsciousness. Others may have acutely altered mental status and loss of coordination or strength – all signs and symptoms of stroke. Those who survive the initial insult may spontaneously revive within minutes, express varying degrees of neurological injury or may quickly regain normal function. Regardless of apparent normality, all victims of pulmonary barotrauma, AGE and CAGE should be evaluated urgently in an emergency department. Neurological symptom recurrence is known to occur in patients who appeared to have a full recovery. The consensus among hyperbaric physicians is that all cases of neurological injury associated with diving should receive hyperbaric oxygen therapy. Head CT scans are often part of the initial evaluation of such patients when they reach an emergency department. The possibility of brain lesions and stroke are important processes to assess prior to initiating hyperbaric treatment. This is not because hyperbaric treatment will worsen the condition, but because if intracranial bleeds are present, they require emergent surgical intervention. Chest x-rays are also recommended prior to hyperbaric oxygen treatment (HBOT) to determine if a pneumothorax is present. If so, these require stabilization prior to HBOT.

DCS – Bubble Trouble

DCS is a condition associated with tissue absorption of inert gas (nitrogen or helium) followed by ascent to lower ambient pressures, where the process of gas elimination may result in bubble formation, which promotes inflammation and tissue trauma. Integral to understanding this disease are the gas laws of Boyle, Henry and Dalton. Boyle's law explains why, in order for our bodies to maintain intrathoracic (within our chest) pressures equal to the ambient environment, that we must inhale progressively

Boyle's Law: At a constant temperature, the volume of a given gas is inversely proportional to the surrounding ambient absolute pressure.

To maintain a neutral lung volume as we descend on scuba, we inhale proportionally more gas molecules per breath.

Dalton's Law: The total pressure exerted by a gas mixture is equal to the sum of the partial pressures of each individual gas.

As we breathe more gas molecules per breath on descent, the potential impact of elevated partial pressures becomes important. Nitrogen narcosis is the result of elevated nitrogen partial pressures.

Henry's Law: At a constant temperature, the amount of a given gas that dissolves into a liquid is directly proportional to the partial pressure of that gas above the liquid. In physiological terms, this gas pressure exists within our lungs relative to the gas pressure within our blood.

The greater the gas pressure within our lungs, the more gas will dissolve into our blood and body tissues. This is the basis of decompression sickness.

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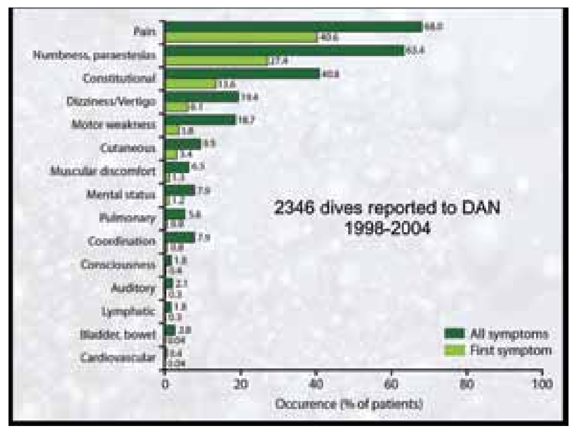
greater numbers of gas molecules per breath as we descend. The increased number of gas molecules in our lungs, relative to those in our blood and tissues, creates a diffusion gradient, which according to Henry's law, drives the gas molecules into solution. Which and how many of these molecules we absorb is defined by Dalton's law.

The longer and deeper we dive, the more gas we absorb. When sufficient quantities of physiologically inert gas come out of solution and form bubbles on ascent, local and systemic inflammatory and vascular reactions may ensue and can lead to a broad range of clinical manifestations. Unlike AGE, DCS bubbles exist primarily in the venous system and within tissues, and symptom presentation may not occur for several hours.

DCS is linked to the presence of inert gas loads (decompression stress) and intravascular bubbles. High bubble scores evaluated by ultrasound, though not diagnostic of DCS, indicate considerable decompression stress and have a higher association with DCS symptom onset as compared to lower scores. Symptom onset times are roughly correlated with inert gas load, with higher gas tensions associated with symptoms that present sooner and progress more rapidly. A fascinating aspect of DCS is that symptom onset often occurs well after bubbles are detectable; therefore, while bubble detection is an indicator of decompression stress, it is not a diagnostic criterion.

Current research into DCS is focused on biological markers that can be detected in our blood. Investigators are exploring the potential association between the presence of membrane microparticles (membrane-bound vesicles shed from a variety of cell types) in the blood and decompression stress. Microparticle levels increase in association with many physiological disease states as well as the shear stress caused by intravascular bubbles. The working hypothesis is that microparticles (possibly induced by inert gas bubbles) may indicate elevated levels of inflammation associated with DCS, and may therefore be of use either diagnostically or used as a marker of decompression stress. This investigation goes beyond the pure bubble model. While intravascular bubbles certainly play a key role in the development of DCS, their presence, or lack thereof, doesn't reliably predict DCS symptom onset. Investigating this process at the molecular level, may help us to learn a great deal more about DCS – insights that will hopefully improve the efficacy of both prevention and treatment.

Fortunately, DCS occurs infrequently. Based on DAN's Project Dive Exploration (PDE) data, the overall incidence of DCS is 2 to4 cases per 10,000 dives. Among warm water resorts and liveaboards this incidence rate drops to 0 to2 per 10,000 dives, and rises to 10 to12 per 10,000 dives in sample populations of deep technical divers from northern Scotland. The table below breaks down DCS symptoms into frequency of presentation.



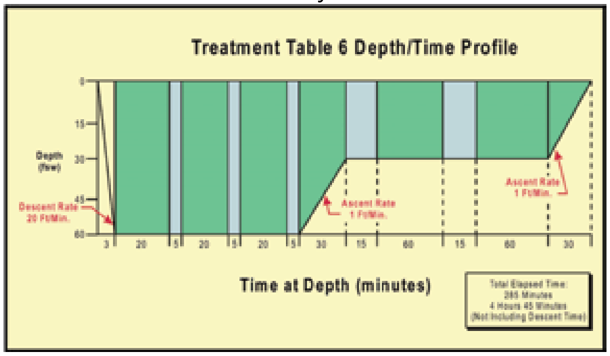
Treatment

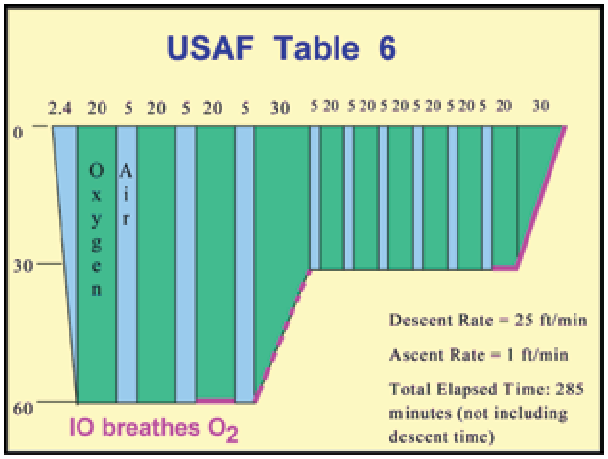
Hyperbaric oxygen (HBO)is the definitive treatment of DCS and AGE.

Prior to definitive care, the provision of emergency oxygen can expedite inert gas washout, reduce symptom severity and enhance treatment effectiveness. The most common and accepted initial treatment protocol is the U.S. Navy/U.S. AirForce Treatment Table 6.

While these two tables differ slightly, the overall oxygen dose is the same. Depending on patient status, these treatments may be extended or repeated. DCI is treated with equal effectiveness in both monoplace and multiplace chambers. Monoplace chambers treat one person at a time and patients are unaccompanied by medical staff. Multiplace chambers enable medical staff accompaniment and the simultaneous treatment of multiple patients.

US Navy Table 6





Evacuation

Dive accidents can be frightening and once DCI is suspected, we often find that few other possible explanations for presenting symptoms are considered. To ensure that other emergent diagnoses are evaluated, we recommend that injured divers seek medical evaluation at the nearest appropriate medical facility. If DCI is indeed the diagnosis, timely transfer to an available and appropriate hyperbaric department can be facilitated.

Diving accidents prompt many questions. After you have contacted local emergency services, contact the DAN Emergency Hotline at +1-919-684-9111 or encourage the treating facility to do so. DAN can provide pertinent medical information and also assist with evacuation planning and coordination.

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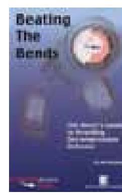
Recommended Reading

For more information on decompression illness (DCI), we recommend the following books. ***www.bestpub.com***

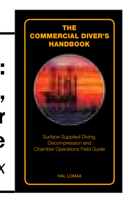
Assessment Of Diving Medical Fitness For Scuba Divers And Instructors
By Peter B. Bennett, Frans J. Cronje and Ernest S. Campbell

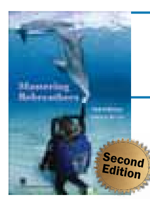
Basic Decompression Theory and Applications, 3rd Edition
By Bruce R. Wienke



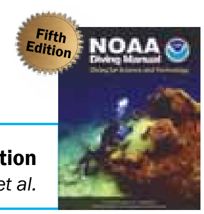
Beating the Bends
By Alex Brylske

The Commercial Diver's Handbook: Surface-Supplied Diving, Decompression, and Chamber Operations Field Guide
By Hal Lomax



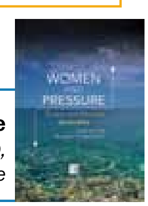


Mastering Rebreathers
By Jeffrey E. Bozanic



NOAA Diving Manual, 5th Edition
Edited by: NOAA et al.

On-Site Management of Scuba Diving and Boating Emergencies
By Wesley Y. Yapor, M.D.



Women and Pressure
By: Caroline E. Fife, M.D, Marguerite St. Leger Dowse

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