A Few Things Your Sport Diving Instructor May Not Have Told You About Deeper Diving

by Larry "Harris" Taylor, Ph.D.

There is an incredible fascination with diving on intact shipwrecks. In the quest for this thrill of diving unmolested wrecks, some divers in the Great Lakes are diving on compressed air in the vicinity of 200 Ft or deeper. A few of these "sport divers" have taken years to develop skills, technique and equipment that allow them to survive these penetrations into that deep, dark, cold and silent world that lies beneath the sport diving limit of 100 - 130 Ft. A few are truly highly skilled diving adventurers. Some would call them pioneers. Others would call them something less dignified. It is true that some walk with a noticeable limp, stand a little funny (numbness in the legs), have difficulty remembering things or seem to have somehow slowed their thinking and speech processes. None-the-less, many of these diving adventurers have seen splendors that not many will ever know. Other diving "adventurers" have found unique pains and death.

Divers new to our sport often do not realize that the successful deep diver has generally taken a decade or more to develop the necessary skills, equipment and technique to survive consistently this deeper diving. Make no mistake, some of these divers are highly skilled and physically fit. That exceptional proficiency, however, was not acquired in only a few days or even years. Although most are self-taught, many of these deep divers were trained when diving courses were longer and discussions on diving physics and physiology were more extensive. Thus, they have had access to information often missing in today's shorter curriculum... material that is essential to make informed risk/benefit assessments. There are distinct physiological problems associated with deep diving. Since divers do not breathe water, the physiological impairments caused by deep diving can be (and have been) life threatening. Sport "deep diving" courses are simply insufficient training for diving to depths "below the limits." Divers compelled to dive below 100 Ft should consider commercial or military dive training - depths below 100 Ft are beyond the realm of sport diving... Sport diving equipment and techniques no longer are adequate! In addition, the training agencies will not, for a variety of reasons, address the question of training for diving below 100-130 Ft.

There are those who earn their livelihood diving at depths below 100 feet. Many of these commercial

divers would consider sport divers foolhardy for diving under conditions a professional would consider to be too dangerous. Note that commercial operations are conducted under federal/state OSHA regulations. Recreational and scientific diving are specifically exempted from these regulations. (Scientific diving, however, operates under similar guidelines promulgated by the American Academy of Underwater Sciences.) Whenever any employer/employee relationship exists, these rules do apply. This means even if the diver is volunteering services and equipment, non-recreational, non-scientific diving may be subject to federal/state occupational safety regulations. These federal regulations decree that all dives more than 130 Ft (some states have tougher regulations; Michigan, for example, places the limit at 100 feet) or any dive requiring decompression be conducted with a tender for each diver, a stand-by safety diver, a surface decompression chamber on the dive site, and an adequate supply of breathing gas for the diver, the stand-by diver and the recompression chamber. The law specifies that the vessel used as a diving platform be Coast Guard approved and commanded by a Coast Guard licensed operator. The diving must be controlled by a designated "diving supervisor" who must insure that all OSHA regulations are met during the dive operation. There are additional requirements specifying the first aid equipment, including oxygen, that must be on the dive site. The law also requires that a complete time/event log be maintained. The British government mandates that all diving more than 165 Ft under their jurisdiction be done on mixed gas. In today's liability conscious society, most legitimate diving contractors will exceed the minimum OSHA standards.

Since federal diving safety regulations prohibit non-recreational scuba operations below 130 Ft, commercial/scientific diving is often a single diver down mode with a tended tether, surface supplied breathing gas and some sort of dry face mask/helmet equipped with hard wire communications. This equipment significantly increases the safety of the diver. The communication system allows the surface support personnel to monitor the diver's psychological and physiological status. Surface control of the entire dive operation minimizes task loading on the diver. This insures that potential life threatening/saving decisions are made by narcosis free surface support personnel. The dry mask/helmet provides mechanical and thermal protection for the diver's head and face. More importantly, it gives the diver a dry atmosphere that is breathable if a blackout occurs.

Commercial operations must be conducted with redundant equipment and personnel. It is this contingency for the unexpected that increases diver safety. This redundancy is most often missing in deep sport diving excursions. (This equipment is beyond the finances and training of most in the sport diving community.) Thus, the deep sport diving adventurer has very little, if any, margin for human error.

There are significant physiological problems in deeper diving. These include:

- BLACKOUT: Divers have been known to suddenly lose consciousness. This may be from carbon dioxide toxicity, carbon monoxide poisoning, severe decompression sickness, drowning (loss of regulator because of malfunction; more likely a result of snag or hindered regulator exchange at depth; vomiting from seasickness followed by aspiration of seawater, etc.), hypoglycemia, hyperthermia, hypothermia, hypoxia from equipment malfunction or miscalculation of breathing gas composition, severe nitrogen narcosis, oxygen toxicity, pulmonary barotrauma of ascent (air embolism), or syncope of ascent.

Each specific loss of consciousness under water may be due to a unique combination of environmental, equipment or diver physiology factors. It is not possible to predict each diver's vulnerability in absolute terms. Conditions which may increase the likelihood of unconsciousness include: low blood sugar, either from dieting or sustained workload, fatigue from lack of rest or sustained workload, being too warm or too cold, dehydration, drugs, particularly anything that has a warning label about "not operating machinery," anxiety/fear and inexperience. Surveys have shown that the inexperienced diver often is the most at risk. If a commercial/scientific diver loses consciousness, he/she continues to breathe a dry gas inside the mask/helmet; the lack of diver response alerts the surface communicator that a problem has occurred. Often, the communicator is aware of a problem before the diver and can initiate steps to alleviate the problem. Two-way communication is a vital safety feature often missing in sport diving situations. If a sport diver loses consciousness, there is concern that a sport diver's regulator will fall out of the mouth. The sport diver then attempts to breathe water and drowns. In addition, the unconscious diver must depend on a buddy, if present, to insure return to the surface.

The cave diving community has noted a condition where the diver simply appears to fall asleep. The eyes remain open; The diver does nothing but breathe. In these cases, the regulator, for unknown reasons, has remained in the mouth. The victims, rescued by their buddies, recall no warning signs. In the 15 reported cases, all victims were on their deepest ever dive.

- CARBON DIOXIDE (CO_2) TOXICITY: Carbon dioxide is the normal waste product of human metabolism. As more work is done, more CO_2 is generated. A person in poor physical condition may generate 2-4 times the amount of CO_2 as someone who is in excellent physical condition while doing the same work load. At depth, the density of the breathing gas increases. This increases the work associated with breathing and may lead to inadequate pulmonary ventilation. It is important for divers to realize that on scuba the CO_2 comes from internal body chemistry, not from the gas being breathed. It is the inability of the body to eliminate this waste product that creates the problem. This means that CO_2 can be a significant problem in deeper diving.

  Symptoms of high CO_2 usually begin with increased rate of respiration. There is often the feeling that the regulator cannot supply enough air. This may lead the diver to conclude falsely that an out-of-air emergency exists. This feeling of inadequate respiration may be accompanied by a feeling of constriction around the chest, heavy perspiration, lightheadedness, or headache. The headache commonly is an intense pain in the center of the forehead. This "CO_2 hit," the feeling of total inadequacy to breathe, can be a terrifying experience. Underwater "CO_2 hits" can easily lead to panic. Panic can lead to an uncontrolled "escape" to the surface. This paniced ascent can cause a fatal cerebral air embolism. A diver doing work at depth, however, may have little, if any, warning of CO_2 problems before losing consciousness. Again, loss of consciousness under water in sport diving equipment has a low probability of survival. In addition, it is believed that high CO_2 increases the likelihood of decompression sickness, nitrogen narcosis and oxygen toxicity.

  If the diver is aware that a CO_2 problem is beginning to occur, the diver should stop all activity and initiate slow, deep breathing until perceived symptoms are eliminated. It is wise to continue

resting a bit once relief is felt and to proceed at a slower pace. Note that most experienced divers develop a slow breathing pattern that means a routinely high CO2 level during diving activities. Work, coupled with poor physical condition, aggravates the problem.

- CARBON MONOXIDE (CO) TOXICITY: Despite the tendency to blame diver unconsciousness on this malady, it is rarely observed. Carbon monoxide is primarily generated from incomplete combustion. It can be present in the air supplied from faulty compressors (electric, as well as gas driven) or taken into the compressor intake from a CO source such as a kerosine heater, gas or diesel engine exhaust or cigarette smoke. The CO binds to hemoglobin about 200 times tighter than oxygen. This means the hemoglobin that has reacted with CO will not carry oxygen. Lack of oxygen can be fatal. The uptake of CO is dependent on the concentration of CO in the breathing gas, on respiration rate and the time of exposure. Symptoms may include: frontal headache, nausea, tingling in the fingers and toes, lightheadedness, vision disturbances or loss of consciousness with no warning. The often quoted cherry red lips or fingernails are a very unreliable sign and may only be visible at autopsy. At depth the increased partial pressure of oxygen may mask some of the hypoxia created by the oxygen deprived carboxyhemoglobin. On ascent, the hemoglobin will still be compromised, but the decreased pO2 will no longer compensate and unconsciousness occurs without warning.

  Finally, the U.S. Navy pure air standards for breathing compressed air allow only 20 ppm CO in scuba air. Smoke from an American cigarette typically contains about 4% (20,000 ppm) CO. The average inhalation of a smoker contains about 500 ppm CO. This means that finishing a cigarette just before a dive will make about 3 -7% of the hemoglobin in the blood unable to carry oxygen. The oxygen carrying capacity of the red blood cells will be diminished for 5-8 hrs after the last exposure to smoke. Breathing smoke, actively or passively, will decrease the ability of the blood to carry oxygen and this decrease in efficiency may contribute to decreased performance at depth.
- DECOMPRESSION SICKNESS: The risk of permanent tissue injury increases with depth. Many sport divers have been given the impression that "the bends" is a benign disease. That simply is not true. The bends can kill, but most often it cripples. The DAN numbers show more than 500 divers a year now enter the chamber for treatment. After 3 months post treatment, 13% of those treated still show some residual impairment. Severe sport diver bends hits most often show spinal cord involvement. This means that anything "South" of the lesion will be impaired. The spinal cord mediated functions most often tainted are walking, urinating, defecating, and sexual response. So, if you like to walk without a cane or wheelchair, go to the bathroom unassisted or to have sex, it is worth your while to develop some understanding of decompression sickness and its prevention. (A recent national survey reported in Skin Diver magazine noted that approximately 60% of those in the sport diving community surveyed could not recognize the symptoms of the bends and almost every survey of divers done recently suggests that more than 50% of sport divers cannot plan dives using decompression tables.)

  A real danger of decompression sickness is that it is often a progressive disease; it may continue to get worse until treated. In North America the time from onset of recognizable symptoms to chamber treatment is often more than 12 hours. It is this delay that can be so devastating. It is believed that the longer the delay between onset of severe symptoms and treatment, the less the

chance for total recovery. During the delay the bubbles formed continue to impair or destroy body functions. The key to successful recovery from the bends is immediate recognition of symptoms and the prompt administration of the highest possible concentration of O2 (preferably by demand mask). Medical consultation/treatment should always be sought. Not recognizing or ignoring the symptoms may allow the disease to do more damage. Although there are anecdotal stories of acute relief of decompression sickness symptoms without medical treatment, there is a lingering question of the potential for long term damage even though immediate clinical signs were absent or simply went away.

The problems linked to decompression sickness can primarily be called "bubble trouble". Whenever bubbles form, they obstruct normal body function. This may prevent normal exchange of nutrients and oxygen and allows waste products to accumulate. This can, over time, create destruction of body cells. Medical evidence is beginning to accumulate that suggests there may be gradual deterioration of nervous system tissue upon repeated exposure to deep diving. It is believed that this damage can occur without ever showing gross clinical signs (ie. joint pain, etc.) classically associated with decompression sickness hits. Although still far from complete, early studies seem to imply that there is a marked deterioration in short-term memory and reasoning skills in commercial divers aged 24-39. Autopsy studies of three deep divers who died of non-diving related causes indicated that there was a marked degradation of spinal cord tissue. It is believed that the spinal cord lesions were created from diving. Although controversial, there is some evidence that deep diving can block retinal blood flow and create vision problems due to a damaged retina. Additional studies measuring blood chemistry and urine of divers imply that the liver, as well, may be damaged in divers diving as shallow as 30 meters (98 feet).

The body is a remarkable biochemical machine with much redundancy. It can sustain some tissue damage that can be compensated for by this redundancy. However, repeated exposure to tissue-damaging conditions will ultimately result in loss of function.

Bottom line: The DAN numbers suggest that diving below 80 ft is a significant risk factor for sport divers (more than 70% of DAN treatments involved sport dives to depths below 80 ft). The deeper and more often this deep diving occurs, the more the risk for long term neurological damage. It is not possible to predict the type and severity of this physiological impairment.

- NITROGEN NARCOSIS: Many sport divers consider the "high" associated with narcosis to be a desirable event. This reflects a lack of understanding of the dangers associated with breathing compressed air at depth. Nitrogen is physiologically inert (not consumed in metabolism), but it does dissolve in body tissues. As more and more nitrogen dissolves (Remember: Henry's Law), the abundance of nitrogen interferes with the nervous system. The more nitrogen present, the greater this loss of performance. The result is impairment of intellectual capacity, degradation of neuromuscular performance and changes in mood and behavior. The narcosis effect poses a significant danger to the diver because as it increases the risk of an accident due to inability to perform at depth, it decreases the diver's perception that any problem may exist. Direct injury (aside from short term memory loss) from narcosis is unlikely. The danger is people do not breathe water. Under the influence of narcosis, divers may make inappropriate decisions that place them at

risk. (Such observed diver decisions have included removal of life-support equipment at depth.) The degradation of performance and perception caused by narcosis is often claimed to be the primary reason for the sport diving limit of 100-130 Ft. (Historically, however, this limit was considered by the US Navy as the maximum depth that divers could do useful work while breathing from a two hose style regulator (state-of-the-art at the time the limit was imposed.))

There is a marked variation in susceptibility to narcosis. This variation is not predictable. Thus, it is not possible to equate absolutely symptoms observed with depth. Some divers may be affected at 80 - 90 Ft or even shallower. The effects may vary within the same diver from day to day. The physiological degradation begins within moments of reaching depth and increases with further descent. The higher mental functions such as ability to reason - to make potential life-saving judgements, to remember recent events, to learn new tasks and to focus concentration on a specific task are first affected. (One reason for commercial hard wire communications is so that surface personnel can monitor a diver's ability to function and remind the diver what is to be done.) In warm, clear water divers may first feel euphoric and overconfident... sort of like the "Do what you will, you can't hurt me feeling" that arises from breathing nitrous oxide (laughing gas) at the dentist's office. In cold, limited visibility water or in water where neither the surface or the bottom is visible, the diver may develop a sense of foreboding or impending doom. This sense of doom may escalate to terror and panic. As depth increases, progressive impairment of both physical and mental skills increases. The diver may feel drowsy. Idea fixation and hallucination may occur. Some divers may note a narrowing of vision, like looking through a narrow tube. It is common for a "narced" diver to forget the reason for the dive. One reason that deep diving sport divers take pictures is that often they can't remember what they saw on the dive. Short term amnesia is a common aftereffect of narcosis. The photos (if recognizable) tell them that they were at least somewhere near a wreck. The severity of narcosis is aggravated by high CO2 levels, anxiety, cold, fatigue and medications, particularly sedatives (anti-motion sickness remedies?) and alcohol. There are anecdotal reports that women will show shallower onset and increased severity of symptoms when diving during periods of normal fluid retention.

Narcosis is easily avoided by liberal applications of common sense. Simply confining dives to shallower than 90 Ft will most likely eliminate most narcosis problems. Ascent when symptoms are recognized will relieve the physiological compromises that narcosis generates. Relief is generally rapid on ascent.

Bottom line: If you are human and dive below 90 Ft breathing compressed air, then your normal human physiology will be impaired and it is impossible to predict the severity of your inability to perform.

- OXYGEN TOXICITY: Oxygen is a component of the air we breathe. The body uses chemical reactions based on oxygen to generate heat and chemical energy. It is this process called metabolism that keeps us alive. Oxygen reacts chemically with many different substances. The rate at which oxygen will react (oxidation) with another chemical compound in the body is determined, in part, by the partial pressure of the oxygen in the breathing gas mix. As we descend in the water column, we increase the partial pressure of all gases, including oxygen. Reactions with oxygen

will therefore increase. Some of these oxidation products can have harmful effects on human beings. The exact mechanism of these harmful effects is not yet understood.

High oxygen concentrations affect the central nervous system in a variety of ways. Observed symptoms, which may appear alone or in any combination, include: nausea, vomiting, lightheadedness, dizziness that may increase to vertigo, ringing in the ears, a feeling of impending collapse, excessive perspiration, slowing of the heart rate, tunnel vision, muscle twitching, particularly around the mouth and facial area, dilation of the pupils, generalized peripheral muscle twitching, hiccups, amnesia, hallucination and mental confusion. The symptoms can lead into a "grand mal" epileptic-type seizure. This seizure may appear without warning. A grand mal convulsive seizure at depth in sport diving equipment is not considered to be a survivable event. Increased physical activity, excitement or anxiety, and being too warm at depth appears to increase the risk of an oxygen toxicity problem. The susceptibility of individual divers to oxygen toxicity cannot be predicted. It is now believed to be dependent on the individual's body chemistry on the actual day of diving. The once-used "oxygen tolerance test" is no longer considered reliable.

It used to be believed that if the diver were breathing a gas containing less than 2 ATA partial pressure of O2, that potential oxygen toxicity problems would be eliminated. This corresponds to a depth of 33 Ft for breathing 100% O2. That is no longer current thinking. Current practice is to avoid breathing gas that has a partial pressure of more than 1.8 ATA O2 (26 Ft on 100% O2; 249 Ft on air) with many diving authorities wanting the pO2 limit to be lowered to 1.6 ATA (19 Ft on 100% O2; 218 Ft on air) or to even a lower pO2. Oxygen toxicity seizures have been observed in divers breathing compressed air in the 220 Ft range. This observation suggests to avoid acute oxygen toxicity hits, dives on compressed air should not exceed 180 Ft.

There are other problems that could result from the practice of breathing pure O2 at depth (during decompression stops?). There are some medical authorities who consider 100% O2 at elevated pressures a cellular toxin. Breathing pure O2 at elevated pressures for extended times can induce abnormalities in the red blood cells that carry O2 to the body. High O2 concentrations can constrict blood vessels in the eye and lead to visual problems. In addition, high O2 can create a mild hearing loss that may appear hours after the dive and take a day or so to disappear. High pO2 has also been proposed as contributing to dysbaric osteonecrosis ("bone death"- usually seen in deep diving commercial divers; this malady may eventually require surgery to replace bone joints with artificial devices.)

Bottom line: The potential for grand mal seizure and subsequent death caused by oxygen toxicity makes diving below 180 Ft in sport diving equipment on compressed air an extremely high risk activity. Below 200 Ft many diving authorities believe that oxygen toxicity poses a greater risk to the diver on compressed air than nitrogen narcosis.

- SYNCOPE OF ASCENT: This refers to the unexpected transient loss of consciousness that may be due to partial breathholding during ascent. It is believed to be caused by the expansion of gases within the thoracic cavity that interferes with venous blood return. This lack of returning blood to the heart reduces cardiac output. The reduced blood flow to the head causes loss of consciousness.

In sport diving equipment, this loss of consciousness could lead to loss of regulator and subsequent drowning.

- UNEXPLAINED BEHAVIOR: The effects of pressure on human physiology and psychology are often unpredictable. Hyperbaric medicine is not yet an exact science. Divers have been known to exhibit, for no known reason, behavior that is contrary to survival. For example, I was with a diver along a sheer rock wall at a depth of about 25 feet of water. We had been down for 18 minutes (following a 2 hr and 10 min surface interval from a wreck dive of 15 minutes in 40 F water at a maximum depth of 108 feet.) We exchanged "time-to-turn-around-and-head-for-the-dive-boat" signals (a touch to the watch and the "thumbs up") and the diver's "O.K." The diver then turned and headed straight for the bottom. The diver was near 60 feet before I re- established contact and asserted control. When I caught the diver, I grabbed the shoulder and rotated the diver so that I could see the face. It was as if I were waking the diver from a deep sleep. The diver, even when prompted with eye-witnesses' accounts, has no recollection of the entire episode. After several years, the event is still unexplained.

RISK: REAL OR THEORETICAL? There is a wreck, the Gunilda, that lies at 256 Ft in the Great Lakes. Since it has historical significance and lies close to the Canadian shore, the diving activity on this vessel has been monitored. To date, there have been 26 divers who have visited this wreck. Twelve of these divers (operating under commercial-type protocols) account for 136 dives on this vessel. Within this group, 1 dive required treatment for severe decompression sickness (to a diver who had 34 dives on this wreck) and there were no fatalities. There have been 14 sport divers on compressed air that have accounted for 33 dives. Of these 33 dives, 9 (27%) have resulted in severe decompression sickness that required chamber treatment, 5 dives (15%) were aborted due to severe narcosis that required the diver to be rescued, and there were two fatalities (6%). In addition, two of these surviving divers, one from each group, have subsequently died on another deep wreck.

The population of sport divers who visited this wreck is small. These divers have seen an awesome spectacle. Not all divers have been visibly injured. However, there were two sport diving fatalities and a high percentage of sport divers requiring treatment for severe decompression sickness. It would appear from this admittedly small survey that diving to 250 Ft on compressed air does, indeed, pose a significant risk to the recreational diver.

It is most interesting to listen to these deep diving adventurers post- treatment. One diver, after leaving the chamber against medical advice, stated that he had experienced "no narcosis problem" at 256 Ft on compressed air. (Remember, short-term amnesia is a common after effect.) This diver went on to state that the bends had produced only a "mild" pain. (Perhaps the "mildness" of the pain could be attributed to the morphine that was administered to this diver by the emergency medical team on the flight to the chamber.)

FINAL THOUGHTS: No one has the right to restrict your personal style of recreational diving. Lee Somers, Ph.D., Diving Safety Officer for the University of Michigan and one of the Founding Fathers of our sport, calls this "THE RIGHT TO DIvE!" Dan Orr, Training Co-ordinator for DAN, calls deep sport diving "an exercise in natural selection". The decision to risk life and spinal cord for the sake of

recreational adventure rests with each diver. This risk (loss of life or maybe only a slight compromise in mental faculties, the ability to walk, go to the bathroom unassisted or to have sex) / benefit (adventure, thrill, status, or fame) decision should, however, be based on knowledge and evaluation of the actual risks incurred and not solely on the perceived status of survival.

I once asked a very highly skilled and well known Great Lakes deep sport diver about diving to extreme depths on compressed air without the redundancy of commercial equipment and personnel. My question, "What do you do alone at 250 Ft under the influence of narcosis to deal with an equipment emergency?" His answer, "I die!" Enough said! The decision to dive to "adventurer depths" rests with the individual diver. Choose wisely!

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