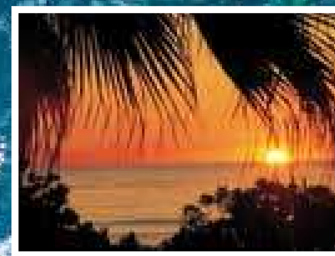
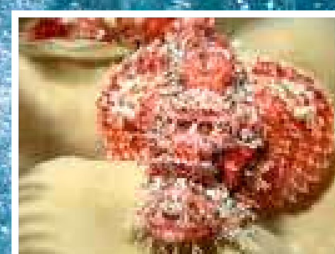
DAN
YOUR DIVE SAFETY ASSOCIATION





DIVE AND TRAVEL MEDICAL GUIDE

Revised February 2015

Attention

Attention Physicians and Emergency Medical Personnel

Those bringing this Guide to you are concerned about the possibility of a pressure-related underwater diving injury. Part 3 of this Guide (Page 68) provides information that medical personnel may find useful in dealing with scuba diving-related injuries, especially if they are not familiar with them.

Divers Alert Network (DAN) is prepared to assist you in patient treatment. Call +1-919-684-9111 (see Page 1) to consult a physician experienced in managing scuba diving injuries.

International telephone numbers are also at the top of Page 1 for the convenience of travelers in those areas.

DIVER INFORMATION

Full Name____

Date of Birth ___________Known Allergies ___________________

Other Medical Problems____________________________________

____

Daily medications____

____

DAN Member Number: _____________________________________

DAN Insurance* (Circle): Preferred Master Standard

Other Insurance (Company & Policy Number)

____

NOTIFY IN EMERGENCY

Name_____________________________Relationship____________

Address____

____

Telephone ( )____

* DAN members are eligible to purchase optional DAN Insurance.

The DAN *Dive and Travel Medical Guide*

Fifth edition, Guy de Lisle Dear M.B., FRCA; Neal W. Pollock, Ph.D.; with contributions from Richard E. Moon, M.D.; Daniel Nord; Matías Nochetto, M.D.; Paul Auerbach, M.D.; and Eric Douglas. **Fourth edition**, Guy de Lisle Dear, M.B., FRCA; and Neal W. Pollock, Ph.D.; with contributions from Richard E. Moon, M.D.; Donna M. Uguccioni, M.S.; Jeff Myers and Eric Douglas; **Second and Third editions**, E.D. Thalmann, M.D.; **First edition**, G.Y. Mebane, M.D.

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Acknowledgments: Center for Disease Control and Prevention and the World Health Organization.

FOR EMERGENCIES

DAN EMERGENCY HOTLINE

+1-919-684-9111

Available 24/7 for diving
and non-diving emergencies
(including *TravelAssist* services).

DAN MUST ARRANGE ALL TRANSPORTATION PRIOR TO EVACUATION.

Collect EMERGENCY calls are accepted.

DIVE AND TRAVEL INFORMATION RESOURCES

DAN Medical Information Line:
+1-919-684-2948
medic@DiversAlertNetwork.org

Worldcue® Planner Travel Intelligence® Resource

- Login to your member account at www.DiversAlertNetwork.org
- Click the Worldcue Planner link under "Resources"

DAN Mailing Address:
DAN, 6 West Colony Place, Durham, NC 27705 USA

Website:
www.DiversAlertNetwork.org

Resources

DIALING TOLL-FREE NUMBERS FROM OUTSIDE THE UNITED STATES

AT&T Direct™ Service can help you reach toll-free numbers from outside the United States. DAN has arranged for toll-free calling through AT&T Direct.

Toll-free number calling instructions:

1. Enter the AT&T Direct Access Number for the country you are in. (Find access numbers at **www.usa.att.com/traveler/index.jsp.**
2. An English-language voice prompt or an AT&T Operator will ask you for the number you are calling.

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WHAT IS DAN?

Divers Alert Network is an international nonprofit scuba diving safety association. DAN's primary function is to assist scuba divers in the treatment of diving injuries by providing 24-hour emergency telephone access to medical professionals skilled in dive medicine.

Other functions include education on dive safety issues, incident and accident data collection, and dive safety-related research. DAN collects and analyzes data on diving and freediving injuries to understand their causes. The ultimate goal is to improve diver safety by increasing awareness, reducing risk and improving incident management.

Emergency calls to the DAN Emergency Hotline — +1-919-684-9111 — trigger a page to the medical professional on call for DAN. That medical professional trained in the management of dive accidents responds to the call and assists in evaluation and referral to the appropriate treatment facilities. A physician who is an expert in dive medicine is immediately available and can assist with diagnosis and initial treatment of the accident as well as chamber referrals.

DAN does not maintain a treatment facility and does not directly provide treatment, but is a service that complements existing medical systems and acts as a referral center to appropriate medical facilities. DAN's most important function is facilitating the entry of the injured diver into the hyperbaric care system by coordinating the efforts of everyone involved in the care of injured divers.

DAN also works with partners to aid travelers who have serious medical conditions that need urgent treatment or evacuation. In addition to the hotline, DAN provides a nonemergency service for questions related to all phases of dive medicine and safety, including physical qualifications for diving, travel issues, medications and diving, and many other topics. The service operates Monday through Friday from 9 a.m. to 5 p.m. Eastern Time USA [Standard Time, subtract four or five hours Greenwich Mean Time, depending on U.S. Daylight Savings Time]. These information calls go to the DAN Medical Information Line at 919-684-2948. Nonemergency questions can be submitted electronically at any time at medic@DiversAlertNetwork.org, or you may visit the medical section of the DAN website at www.DiversAlertNetwork.org.

DAN does not provide chamber availability information as part of predive preparation, as chamber status changes frequently. If you need information on locating a recompression chamber, call DAN.

WHY THIS GUIDE?

Traveling to different parts of the world requires knowledge and preparation. This guide is not intended just as a general travel guide; it is written to help deal with diving aspects of the trip and presents information that may not be covered in other travel guides — especially conditions that require recompression. This guide is divided into four sections. **Section I** covers necessary preparations before the trip and prevention of common travel-related diseases; **Section II** has treatment information on conditions that do not require recompression; **Section III** covers the recognition and treatment of dive-related injuries for which recompression therapy is needed; **Section IV** covers basic first-aid skills.

This manual is intended as a guide for the diver, paramedic, first aid provider or physician for the recognition and initial management of an injured diver. The information is presented in a simplified manner and is not intended to cover the complete treatment of an injured diver. Definitive treatment of dive injuries should be planned through consultation with medical personnel trained and experienced in dive medicine.

Divers have specialized medical needs, because serious diving injuries are rare. Relatively few physicians are highly trained in the diagnosis and treatment of dive injuries, so the recreational diver must be able to recognize the signs of injury and seek additional diving medicine help when it's needed. Diver training programs may stress this knowledge, but divers may forget this aspect of their training, because it is so seldom required.

Detailed expert medical advice on recompression therapy is continuously available through the DAN Emergency Hotline. Keep this guide in your dive kit. If an injury occurs, send it with the injured diver to the nearest medical facility.

DIVER RESPONSIBILITIES
DIVE PLANNING

Responsible divers plan each dive and determine in advance whether a proposed dive or site requires more personal skills or assets than they possess. In addition, divers should determine the level of training and expertise of their dive buddy.

Recreational diving is a social activity and is rarely conducted alone (DAN and major scuba training agencies recommend that you always dive with a buddy). Each diver assumes some degree of responsibility for companions, with essential skills required that go beyond diving.

ESSENTIAL SKILLS

Prepared divers should be able to perform basic first aid procedures, cardiopulmonary resuscitation (CPR), provide emergency oxygen first aid and conduct in-water rescue. Because many dive sites are found in remote locations, knowing how to assist an injured diver until trained medical help arrives can mean the difference between complete recovery and permanent injury.

Rescuer provides oxygen first aid to an injured diver.

Cardiopulmonary Resuscitation (CPR)

CPR is an essential skill for everyone and especially for divers. Although basic CPR is easy to learn, it requires several hours of training and regular skill-refresher courses. Rescuers should know the key steps of CPR, including the head-tilt / chin-lift method of opening an airway as well as other critical skills taught in these courses.

CPR skills require instruction and practice under the supervision of a certified instructor. Hands-on course instruction is the best way to attain the skill level necessary to conduct CPR in the field. Do-it-yourself manuals or following written instructions without having had supervised training can result in providing ineffective aid.

Basic First Aid

Basic first aid skills are necessary for divers for the same reason CPR skills are essential: Knowing how to position an injured person, control bleeding and prevent further injury until medical help arrives can be immensely useful. Contact your local dive center for CPR and first aid course information.

The most important goal in first aid is to support life by assisting an injured or ill person until advanced life support is available. Divers must understand the limitations of their knowledge and first aid procedures they use, however, in order to do no further harm.

Supplemental oxygen is a valuable adjunct in CPR, in drowning, and in a serious accident/injury that impairs the body's ability to transport oxygen to the tissues.

Oxygen First Aid

The ability to provide emergency oxygen is a skill recommended for every diver. Learning to use oxygen is not difficult, but it does require proper instruction and practice with the equipment under the direction of a qualified instructor. DAN has developed an Oxygen Provider Course that teaches emergency oxygen first aid. The principles of providing emergency oxygen are reviewed later in this manual, but divers cannot consider themselves ready to use oxygen in resuscitation or first aid until they have completed adequate training.

Water Rescue

Water rescue is a special subject requiring study, training and frequent practice in order to gain the necessary knowledge and proficiency. Every diver should participate in the scuba lifesaving and accident management courses offered by virtually every diver certification agency.

Do not attempt any procedure beyond your ability.

The most important goal in first aid is to support the life of an injured or ill person until trained medical help is available.

For more information on principles of first aid, oxygen first aid and CPR/Basic Life Support, see pages 81-88.

SECTION I: Trip Planning and Prevention of Travel-Related Disease

I

MEDICAL FITNESS TO DIVE

Are you medically fit to dive?

DAN can put you in contact with a doctor who can help you make that decision. DAN dive medical experts can talk with local physicians over the telephone in helping them make a fitness-to-dive determination. Planning is key — seek medical clearance well before your trip.

To help determine your fitness for diving, you should discuss with your physician any change in your health status, any injury, or recent surgery. The physician may in turn wish to contact DAN and discuss the condition with one of DAN's medical experts. Your doctor may provide you with a letter stating that you are fit to dive. If the physician has had formal training in dive medicine, this should be pointed out in the letter. If not, then the individuals (and their qualifications) with whom any problems have been discussed should be noted.

This letter may be useful in convincing an anxious resort operator that you are fit to dive. Diabetes and asthma are two diseases that raise questions for many dive resort owners or boat captains. Having written evidence of a proper evaluation may prevent frustration and save time. Remember, the resort operator or boat captain is ultimately responsible for all the divers in their charge and usually has discretion over who dives and who does not. There may also be national policies or trends that will affect your ability to dive. Check with DAN if you have questions.

TRAVEL-RELATED ILLNESS

DAN members travel to dive sites in remote countries as well as in more developed countries. There are certain illnesses associated with travel anywhere, many of which can be prevented, but some of which may be life-threatening. Appropriate prophylaxis and counseling by professionals can reduce the health risk. You may need to make a visit to a physician or a travel clinic, as well as doing some research and planning in advance.

DAN and resources available through DAN can also provide this type of information for DAN Members. Plus, as a DAN Member, you are eligible to access health and travel information by logging into your online member account.

In addition, you can obtain a comprehensive travel medical guide from your local bookstore. Or contact DAN for the most recent edition of *International Travel Health Guide*, a useful book of travel health advisories (published annually by Elsevier). The traveling diver should be current with guidelines provided by the Centers for Disease Control and Prevention (CDC) in Atlanta (USA) — an invaluable resource that's easy to obtain — and at no cost. Read on.

CDC Information Service

The CDC website (www.cdc.gov/travel) contains the latest information on immunization information and country-specific health information. The information is also downloadable in several formats.

A detailed publication giving immunization guidelines and travel information, called "Health Information for International Travel," or the "Yellow Book," is available on the website and updated annually.

Other useful websites are the International Society of Travel Medicine at www.istm.org/ and the American Society of Travel Medicine and Hygiene at www.astmh.org/. These websites include directories of travel medical clinics throughout the United States. Check with your local hospital, as these listings may not include all the clinics in your area. Other sites with country-specific health information are the World Health Organization (WHO) at www.who.int/en/ or www.nathnac.org.

Prophylactic Treatment and Counseling

If you're planning to visit a travel medicine clinic, ask the staff there to review your complete itinerary to determine the precautions needed: Disease exposure differs according to destination. Schedule your visit at least four to six weeks ahead, as some vaccinations need time to become effective, or they may be given in a series. Lifestyles, pre-existing illnesses and current medications can all influence risk assessment, and this requires knowledge of what the diver will do abroad. We have suggested some drugs you may wish to consider to take with you and have supplied the generic names for these therapies.

Certain factors are associated with an increased risk of acquiring a travel-related illness. Make a complete review of your itinerary and relate the planned activities to the specific risk of acquiring disease for each location and activity. For instance, a planned scuba trip may include the risk of contracting malaria; a bicycle trip can have a higher risk of sustaining traffic injury; a mountain climbing or trekking trip may include the risk of altitude sickness. There are other considerations as well, including pre-existing illnesses or lifestyles.

The lifestyle of the diver is important: For example, the college student helping to build schools in undeveloped areas of an equatorial country is at much greater risk than the diver on a well-organized dive boat operating over the coral reefs of the same area. What this can mean is that there may be very little risk of acquiring a tropical disease aboard the dive boat offshore but a very high risk for the land-based diver/traveler.

One's lifestyle while abroad may include other risks, such as work or study in a tropical area, living with indigenous populations, sleeping in tents or boarding houses, and spending prolonged periods in areas with poor sanitation. Pre-existing illness and medication use must also be considered as risk factors in areas of marginal medical facilities.

RISK FACTORS

- Chronic illness
- Lifestyle while abroad:
  - Living or having unprotected sex with anyone unknown or with an unknown sexual/medical history
  - Sleeping in tents or boarding houses
  - Prolonged stay in area with poor sanitation
- Visit to sub-Saharan Africa
- Travel to the tropics
- Driving a motorized vehicle in a less developed country
- Wading or swimming in fresh water
- Being immuno-compromised from diseases or treatment such as diabetes, HIV or chemotherapy

Pre-Travel Precautions

The four most important categories of pretravel precautions are:

- Vaccinations and immunizations;
- Malaria prophylaxis;
- Diarrhea management;
- Behavioral counseling.

Immunizations

As more than 90 percent of travelers are repeat travelers you might consider vaccinations as an investment for the future. Giving general recommendations on vaccinations and immunizations is difficult, and detailed recommendations are beyond the scope of this guide. However, you should carefully review your immunization status, especially the routine vaccinations such as **tetanus / diphtheria (DTaP), measles (MMR), polio, hepatitis B, Varicella and influenza**, with your physician well before starting your trip. A current test for **tuberculosis** exposure (PPD) is advised. **Yellow fever** vaccination is the only one currently required by the WHO, but some countries still require proof of **cholera** vaccination. Other vaccinations will depend on the itinerary, lifestyle and length of the trip. Check with DAN at +1-919-684-2948, the CDC website or your doctor for the latest recommendations.

Cholera is transmitted through food or drinking water contaminated with the bacteria *Vibrio cholerae*. Modern sanitation practices have drastically reduced its incidence. A cholera vaccination is still required by some countries, but it is not medically recommended, as travelers rarely develop cholera even in endemic areas (2 cases per 1 million travelers to endemic areas). The vaccine is no longer available in the USA. There are two current manufacturers of an oral vaccine in other countries.

Hepatitis A is a worldwide problem associated with food and water contamination. The most luxurious resort in a major nation or a humble dwelling in a poor nation can be the source of an infection. Indigenous populations acquire most cases of hepatitis A. These generally happen early in life and consequently are subclinical infections. However when an adult traveler from North America or Western Europe contracts hepatitis a serious illness can result. There are two inactivated virus vaccines licensed in the United States — HAVRIX® and VAQTA®. Immune globulin may be used in those allergic to the vaccine but will provide protection for only three months.

For travel longer than three months, the CDC has recommended extended dosage schedules. In persons previously vaccinated or exposed to the disease, screening for antibodies to hepatitis A virus (HAV) may be useful to prevent unnecessary immunization or prophylaxis. It takes approximately four weeks after vaccination before full protection can be assumed, so individuals traveling sooner should consider receiving a dose of immune globulin in addition to the initial vaccination, but at a different injection site.

Hepatitis B is transmitted through activities that involve contact with blood or blood-derived fluids. The vaccine is advised for anyone who will have close personal or sexual contact, blood transfusions, needle sharing, tattooing and use of unsterilized surgical or dental instruments within populations harboring asymptomatic carriers.

Hepatitis C is transmitted through blood exchanged with infected individuals, as with sharing of needles. Symptoms are usually mild or may be absent. No vaccine is available. The risk to travelers is low but they should consider the health risks of engaging in the activities mentioned above for Hepatitis B.

Hepatitis E is transmitted by the oral-fecal route, mainly through contaminated drinking water. It can be distinguished from other forms of hepatitis by serological (blood) testing. The best prevention is to avoid potentially contaminated water or food in endemic areas.

Japanese B encephalitis is mosquito-borne. A vaccine is available in the United States but should only be considered for individuals who will be visiting high-risk areas for 30 days or longer. This disease is relatively rare and generally confined to certain areas of Southeast Asia.

IMMUNIZATIONS		
Depending on destination divers should consider immunization for:		
Chickenpox (Varicella)	Influenza	Polio
Cholera	Japanese Encephalitis	Rabies
Diphtheria	MMR (Measles, Mumps, Rubella)	Tetanus
Hemophilus B	Meningococcal Meningitis	Typhoid
Hepatitis A & B	Pneumococcus	Yellow fever
(A tuberculin skin test — PPD — is not an immunization but should be done to document tuberculosis exposure status.)		

Meningococcal meningitis is endemic in various areas, and the CDC should be consulted for weekly advisories. This bacterial infection can be fatal.

Rabies, transmitted via animal bites, is prevalent in developing countries and should be considered a risk for individuals spending time in villages in Africa, Asia or Central and South America.

Smallpox vaccination is no longer required or given.

Tuberculosis, with airborne transmission, is always a risk, especially in developing countries. The TB vaccine has variable efficacy and is not available for travelers. A tuberculin skin test (PPD) will tell if a person has been exposed; it may be required before a trip, with a repeat test about 12 weeks following the trip if the first test is negative. If a negative test turns positive after a trip, prophylactic treatment may be indicated. If the initial test is positive, reinfection is unlikely unless immunity is impaired (as with **human immunodeficiency virus — HIV** infection or the use of corticosteroids such as prednisone).

Typhoid fever is still endemic in many countries of the world, where it is predominantly a disease of school-age children and is a major public health problem. Contracting typhoid fever is unlikely, but divers who will be exposed to potentially contaminated food or water for long periods of time in rural or less traveled areas should be immunized. Current CDC advisories should be consulted with regard to specific areas. There are currently three types of vaccines available, one oral and two parenteral or given by injection. The CDC provides dosage schedules in its “Health Information” publication. Since these vaccines only provide protection in 50-80 percent of recipients, one should still be careful in selecting food and water for consumption.

Yellow fever is a mosquito-borne viral illness that is potentially fatal and for which there is no known treatment. The vaccine is advised for a visitor to any country in the yellow fever endemic zone, although some countries in this zone do not require a yellow fever certificate. A few countries outside the high-risk zone require vaccination of a traveler coming from that zone.

AVOID MOSQUITO BITES!

Stay in screened areas when indoors — especially from dusk to dawn.
Sleep under mosquito netting.
Wear adequate clothing when outdoors.
Use "DEET" (N,N-diethyl-meta-toluamide).

Malaria

Malaria has caused more deaths worldwide than any other infectious disease: it is the most serious infectious disease hazard to divers traveling to the tropics. The disease is found primarily in subtropical and tropical regions of the world, where environmental conditions favor stable, infected Anopheles mosquito populations. Malaria occurs in large areas of Central and South America, Hispaniola, sub-Saharan Africa, the Indian subcontinent, southern and Southeast Asia, the Middle East, Mexico, Haiti, the Dominican Republic and Oceania. Major cities in Asia and South America are nearly malaria-free, though cities in Africa, India, and Pakistan are not. There is less risk of malaria at altitudes above 4,900 ft / 1,500 m.

Malaria Prophylaxis

The serious health risk represented by malaria cannot be overemphasized. Prophylaxis is essential and includes both the prevention of mosquito bites and drug prophylaxis. The malaria parasite, a protozoan, is transmitted to humans by the bite of an infected female Anopheles mosquito, usually dusk to dawn.

Personal protection is the best way to prevent malaria and other insect-transmitted diseases. This means staying in well-screened areas while indoors, wearing clothes that cover most of the body when outdoors, and using mosquito nets when sleeping. Insect sprays and repellents for clothing, tents and nets should be used as well as personal repellents containing at least 30 percent DEET (Note: concentrations above 30 percent do not add significantly to the protective effect or duration). Standard preparations last about four hours; longer-acting preparations are available. Picaridin is an alternative and effective agent.

Travelers to malarious areas should also take prophylactic drugs, which must be obtained by prescription. Recommendations may vary depending upon drug susceptibilities of local malaria strains. Most of the drugs used for prophylaxis are safe and well tolerated. However, as with any drug, some serious side effects and toxic reactions may occur occasionally.

The severity of malaria, however, entails temporary mild side effects. Mefloquine (Lariam®) in particular rarely causes symptoms that can mimic DCI. Divers taking mefloquine are prohibited from diving in some countries, in which case another drug should be substituted.

If a diver traveling to an area with a high risk of malaria is unable to take preventive medications against malaria because of side effects, the trip should be canceled: the risk is too great that the diver may contract malaria and even die because he/she did not take appropriate prophylaxis.

Regardless of preventive measures, malaria may still be contracted. Malaria may not develop until long after the trip, and prophylaxis must be continued for an appropriate length of time. If flu-like symptoms (any illness with chills, fever and headache) develop during a trip in malarious areas or within several months after the last exposure, obtain medical attention immediately. It is important to mention your possible exposure to malaria when seeking further medical attention.

Amebiasis

This disease is caused by the protozoan *Entamoeba histolytica*. The most common symptom is diarrhea, which may become painful and bloody. The disease is transmitted by person-to-person contact through the fecal-oral route, by ingesting contaminated food or water. Eating or drinking in areas of poor sanitation will put one at increased risk. There is no vaccine, and treatment should be obtained through a specialist in infectious disease or tropical medicine specialist.

Dengue Fever

Dengue is a viral disease transmitted by the mosquito *Aedes aegypti*. It has a sudden onset, with fever, severe frontal headache, and joint and muscle pain. Nausea, vomiting and a rash may also occur. The disease is usually self-limited and benign, but it may require a long convalescence. Dengue fever can also occur as a severe fatal form, called dengue hemorrhagic fever. Dengue fever occurs worldwide, especially in tropical areas. There is no vaccine available and preventive measures should be targeted at avoiding mosquito bites, particularly between dusk and dawn. This can be done by remaining indoors, wearing clothing covering arms and legs and by using repellents such as DEET.

Giardiasis

A parasitic disease caused by *Giardia intestinalis*, symptoms occur one to two weeks after ingestion; they include diarrhea, abdominal cramps, bloating, fatigue, weight loss, flatulence, anorexia or nausea in various combinations, usually lasting more than five days. There is no vaccine or prophylaxis. Those who eat and drink in areas with poor sanitation are at increased risk. For treatment, consult a specialist in infectious disease or tropical medicine specialist.

When you travel, if you eat and drink in areas with poor sanitation, you increase your risk of diseases like giardiasis and travelers diarrhea.

Leishmaniasis

This is a parasitic disease transmitted by the bite of phlebotomine sand flies. The skin form of the disease is characterized by open or closed sores that can develop weeks to months after a bite. The visceral form (affecting internal organs) is manifested by fever, enlargement of the liver and spleen, and anemia, developing months to years after infection. There is no vaccine; the disease requires treatment from a specialist in tropical diseases.

Individuals at risk are those who engage in outdoor activities at night in endemic areas. High-risk areas are Bangladesh, Brazil, India and Nepal. Cases have also been reported from northern Argentina to southern Texas, northern Asia, Middle East, and eastern and northern Africa. Preventive measures include wearing long-sleeved clothing, using insect repellents (DEET on skin and permethrin-containing insecticides on clothing) and avoiding outdoor activities at night when sand flies are active.

Leptospirosis

Leptospirosis is found worldwide, with a higher incidence in tropical climes. It is a disease that affects humans, wild and domestic animals and is caused by bacteria of the genus Leptospira. The animals excrete the organism in their urine and feces, contaminating soil and water. Symptoms can mimic other tropical diseases and include fever, chills, myalgias (muscle spasms), nausea, diarrhea, cough and conjunctival suffusion (redness of the membrane covering the eye). Severe disease may result in renal failure.

Travelers participating in recreational water activities in local areas are at increased risk, especially during flooding. There is no vaccine. The CDC recommends that travelers who might be at increased risk consider prophylactic doxycycline (200 mg weekly) beginning one to two days before exposure.

Travelers Diarrhea

USE THE PEACE CORPS RULE — ***Boil it, cook it, peel it or forget it***

- Hot and steaming is safe.
- Bread is safe.
- Rice and noodles are safe if cooked and steaming hot.
- Fruit is safe if freshly peeled by the consumer.
- Factory-sealed bottled water is safe.
- Factory-sealed carbonated drinks are safe.

AVOID these items . . .

- Buffets
- Room-temperature foods
- Previously peeled fruit, raw produce and salads
- Raw or poorly cooked seafood
- Unboiled tap water, even for brushing teeth
- Beverages not in factory-sealed containers
- Ice cubes, unless made with safe water
- Milk products, unless boiled or pasteurized

Travelers diarrhea (TD) is the most common complaint of the tourist and can be encountered anywhere in the world. All travel involves a risk of acquiring diarrhea. The CDC estimates that 30-50 percent of travelers will develop TD in a one- to two-week stay in certain areas. The best defense is to develop safe eating and drinking habits when in high-risk areas.

Most cases of travelers diarrhea can be avoided by eating food that is steaming hot (not merely cooked), has a high acid content (like citrus: orange, grapefruit, etc.), a high sugar content (jellies and syrups), or one that is dry (bread).

Anything that is moist and warm or at room temperature is unsafe. This includes sauces, salads and anything on a buffet. Citrus fruits and all fruits that can be peeled by the consumer are safe (hands must be clean, however). Unpeelable fruits (e.g., grapes, berries) are not safe. An unpeeled tomato is not safe, but a tomato peeled by the consumer is safe. Watermelon is sometimes injected with water to make it heavier and therefore may be unsafe.

Untreated water is not safe, but bottled drinks, wine and beer can be considered safe. Bottled water must have an intact seal at the time of purchase to be considered safe. Children sometimes refill water bottles at a town well and resell them as safe water.

These simple precautions will give a better-than-even chance that the traveler will avoid diarrhea, even in the worst circumstances. Medications can slightly improve the chances, but are not without risk. Thirty to 50 percent of travelers who do not take preventive medications in high-risk areas get diarrhea. Not taking a medication has obvious advantages: it is more convenient, avoids drug side effects and costs nothing.

While travelers diarrhea may cause discomfort, it is not usually life-threatening, is easily treated by over-the-counter medications and will even go away (eventually) without treatment. Most travel physicians do not advise antibiotics to prevent diarrhea, because serious reactions to the antibiotic are about as common as serious diarrhea.

Life-threatening drug reactions occur in as many as one in 10,000 individuals. Most important, the widespread use of antibiotics has led to significant resistance on the part of the organisms, making treatment more difficult for individuals once they become ill.

The CDC advice is "prophylactic antimicrobial agents are **NOT** recommended for travelers" to prevent TD. However, once an individual has contracted TD, the CDC has recommended some specific medications.

Because bacterial causes of TD far outnumber other microbial causes, practical treatment with an antibiotic directed at intestinal bacterial pathogens remains the best therapy. The effectiveness of a particular antimicrobial depends on the etiologic agent (the microbe causing the ailment) and its antibiotic sensitivity. For treatment of a specific bacterial pathogen, first-line antibiotics include ciprofloxacin or levofloxacin. Increasing microbial resistance to the fluoroquinolones may limit their usefulness in some destinations such as Thailand and Nepal. (Note: The FDA recently issued a black-box warning about these drugs. There is a significant risk of tendon rupture. [Several Achilles ruptures have been reported to DAN.] With sudden exercise, please read the hazard warning supplied.) An alternative in this situation is azithromycin. Rifaximin has been approved for the treatment of TD caused by noninvasive strains of *E. coli.*

The standard treatment regimens consist of three days of antibiotic, although when treatment is initiated promptly shorter courses, including single-dose therapy, may reduce the duration of the illness to a few hours.

Bismuth subsalicylate (Pepto-Bismol®) has been shown to decrease the incidence of diarrhea significantly when taken prophylactically (2 ounces four times daily or two tablets four times daily; it should not be used for longer than three weeks). Pepto-Bismol is also useful in the treatment of diarrhea, but less so than antibiotics. The dosage for TD is 1 ounce every 30 minutes for eight doses, not to exceed 8 ounces in 24 hours or eight doses. Wait at least two hours after taking antibiotics before taking Pepto-Bismol since it will retard antibiotic absorption.

Avoid Pepto-Bismol if these conditions exist:

- If you're allergic to, or intolerant of, aspirin
- If you are taking an anticoagulant (blood thinner)
- If you have renal insufficiency, gout, or are taking probenecid or methotrexate
- If you have any type of bleeding disorder
- If you have a history of peptic ulcer

Do not use Pepto-Bismol for children under 12 years of age or under 19 with chicken pox or flu because of the possible risk of Reye's syndrome. Self-treatment of traveler diarrhea, if it occurs, is possible with a little preparation. The following items are required: a thermometer, an antidiarrheal medication (e.g., loperamide, diphenoxylate), Pepto-Bismol and an antibiotic prescribed by a physician.

Any sign of illness requires quick reaction. Immediately after a watery stool occurs, determine the body temperature. With fever (100°F / 38°C) or a bloody stool, take only the antibiotic. If there is no fever or bloody stool, take both Pepto-Bismol (1 oz. liquid or two chewable tablets every 30 minutes for eight doses) and/or an antidiarrheal. If nausea, vomiting and/or cramps are present, an antibiotic may be taken along with the Pepto-Bismol and an antidiarrheal. This will usually relieve symptoms in 12-15 hours. Avoid using antidiarrheals for children under 2 years of age.

Significant dehydration usually will not occur in adults, and safe fluids should be encouraged. If you are having fewer than eight episodes of watery stool per day, continue with your regular diet supplemented with clear broth, salted crackers and 2-3 liters of clean water daily. Avoid dairy products and beverages that contain high levels of sugar, as most nondiet soft drinks do.

Rehydration beverages containing electrolytes such as Gatorade® are appropriate in cases of TD. The best solution is to take liberal quantities of oral rehydration solutions (ORS), such as World Health Organization ORS solutions, which are widely available at stores and pharmacies in most developing countries, and may be purchased at outdoor stores.

If symptoms do not improve within 48 hours, medical attention is recommended because of the possibility of a parasitic infection. Note: Treatments for travelers diarrhea do not eradicate *Giardia intestinalis* (giardiasis); antimicrobial drugs are needed.

SELF-TREATMENT of TRAVELERS DIARRHEA

NEED

- Pepto-Bismol®
- Antidiarrheal [Lomotil® (diphenoxylate) or Imodium® (loperamide)]
- Antibiotic prescribed by physician
- Thermometer

IF you have diarrhea and fever or bloody stool:

- Take antibiotic only.

IF you have diarrhea without fever:

- Take Pepto-Bismol and/or antidiarrheal medicine.
- Get medical attention if symptoms persist 48 hours.

Schistosomiasis

The *Schistosoma* parasite has a life cycle involving a freshwater snail. The disease is found in rural tropical and subtropical areas, including the Middle East, Africa, eastern South America, especially Amazonia, and parts of the Caribbean, including Puerto Rico and St. Lucia. A person bathing in or drinking fresh water harboring the snail may encounter larvae that can penetrate skin. Schistosomiasis can have serious consequences. Chlorinated and salt water are usually safe for swimming, but swimming or bathing in fresh water in endemic areas is not. Heat water for bathing to hotter than 122°F / 50°C for more than five minutes. You can also chemically treat water or allow it to stand for more than 48 hours. (Let cool before bathing; water hotter than 113°F / 45°C may cause burns.)

SEAFOOD and TRAVEL

Many marine creatures are always poisonous when ingested, and others are toxic only during certain seasons. Whenever a person develops an unexplained illness on an island trip, it is important to obtain an accurate dietary history. Problems involving diagnosis and treatment of a marine toxin may occur anywhere due to air travel and the universal distribution of seafood.

Ciguatera

The most serious of marine toxins and most commonly reported, ciguatera is mainly a tropical disorder, but does occur in semitropical and temperate areas when contaminated, imported fish are consumed. Occasionally a traveler will return home with an undiagnosed illness that turns out to be ciguatera. Distribution is widespread, and the ciguatera-toxic fish are found between latitudes 35 degrees north and 35 degrees south. The fish are usually large predatory reef fish, but are not identifiable as toxic by external appearance. The dinoflagellate *Gambierdiscus toxicus* — which forms part of plankton — is thought to be the originator of the toxin, which is harmless to fish and moves up through the food chain. The toxin is heat-stable, and neither cooking nor freezing will destroy it.

Clinical Features

Symptoms begin within two and 12 hours after ingestion, with generalized nonspecific symptoms and mild weakness. Symptoms increase in severity, with dull aches, cramps and numbness around the mouth, tongue and throat. Gastrointestinal symptoms include loss of appetite, nausea, vomiting and diarrhea. Neurological symptoms include delirium, lack of coordination, difficulty walking, reversal of temperature perception, convulsions, coma and, in rare instances, death.

The main symptoms clear up in one to two days, but residual weakness, alteration of temperature perception and other symptoms may persist for months. The symptoms might resemble those of neurological decompression illness, making the differential diagnosis difficult at times. Ingestion of alcohol can precipitate a recurrence of the symptoms even months after the illness. A reddened skin area, with burning sensation developing after alcohol consumption, is a characteristic of the disease. Symptoms can also recur after stress or eating certain fish. Immunity does not develop, and a subsequent poisoning may be more severe. Diagnosis depends on history of travel and exposure to fish, followed by developing symptoms, though there are other more complex — but not so readily available — diagnostic procedures which require examining the suspected food or stomach contents.

Prevention

Local knowledge is not always reliable in reference to toxic fish; follow it, however, if some species in the area are considered toxic. Here are some preventive measures.

AVOID EATING:

- Viscera (internal organs)
- Large reef predators and other species implicated in poisoning: barracuda, grouper, snapper, sea bass, surgeonfish, parrotfish, wrasses, jacks and others
- Moray eels

Treatment

There are limited first aid and definitive treatment measures. If the fish was ingested in the previous few hours, vomiting can be induced to remove any remaining fragments. The victim should be fully conscious if it is necessary to induce vomiting. The severely toxic victim may require respiratory support. Physician care is required as soon as possible.

Scombroid Poisoning

Mackerel-like fish of the family Scombridae and a few other species may be the source of scombroid poisoning. All forms of tuna, including albacore, as well as bonito and mackerel are examples of Scombridae fish. Occasionally, nonscombroid fish such as dolphin (mahi-mahi), bluefish, sardine and marlin may be the source of the toxin.

As a result of improper handling of these fish — such as allowing exposure to sun or room temperature for several hours — a toxic histamine-like substance develops. Bacterial action converts histidine (a normal constituent of dark-meat fishes) into a toxin. The reaction is not allergic, but a response to the toxic byproducts. The fish have been typically reported to have a peppery taste, but this may be a result of the chef's attempting to conceal the condition of the fish.

Clinical Features

About 30-60 minutes after ingestion, symptoms of nausea, vomiting, diarrhea and abdominal pain may appear. These symptoms may be followed by headache, palpitations and a generalized rash with itching and blister formation. The symptoms may become very severe, with cardiovascular shock. Infrequently, death has occurred.

Prevention

Fish should be properly refrigerated and not exposed to sunlight or warm temperatures for long periods. Suspect fish should be discarded.

Treatment
An antihistamine may be helpful for scombroid poisoning; plus you should get a consultation with a physician as quickly as possible. Since this is not due to an endogenous release of histamine, glucocorticoids will not change the natural course of the disease.

Parasitism
Raw or lightly pickled marine or freshwater fish of many species are consumed frequently as sushi, sashimi or similar dishes. Both marine and freshwater fish are hosts for several roundworms and tapeworms which may be transmitted to humans. Sushi may be the source of diphyllobothriasis (fish tapeworm infection) or *anisakiasis* (Anisakis roundworm).

Any of the lightly pickled fish of many species also may be the source of anisakiasis. The larvae may be present in many commonly marketed fish, including salmon, mackerel, cod, pollock, herring and sole. Prevent this form of parasitism by eating only fish that have been fully cooked to 140°F / 60°C. Avoid raw, lightly pickled or undercooked fish.

Pufferfish Poisoning
Tetrodotoxin is the culprit responsible for so-called pufferfish poisoning. This poison is not delivered via a sting, however; most cases of Pufferfish Poisoning are caused from intentional ingestion of fish dishes that include pufferfish, blowfish, balloon fish, sunfish, porcupine fish, toadfish, globefish and swellfish (Tetrodontidae).

Pufferfish are considered an Asian delicacy, served in some types of sushi and sashimi, as well as the popular dish known as fugu. This is the leading cause of death in Japan due to food poisoning. Unless the chef is specially trained and licensed to cut the meat in a particular fashion, the dish may contain a large amount of the neurotoxin, found in the organs of these fish or skin.

Clinical Features
Signs and symptoms generally occur from 10 to 45 minutes after ingestion. The illness begins with numbness and tingling around the mouth, salivation, nausea and vomiting. Symptoms may progress to paralysis, loss of consciousness, and respiratory failure, and if untreated, can lead to death. It is said that this toxin can cause a state of suspended animation acting in a uniquely manner at mitochondrial level, which some say might explain the myth of voodoo's zombies.

Treatment
Seek medical treatment as soon as possible. Induce vomiting if the poisoned person is awake and alert and has eaten the fish in less than three hours. Be sure to keep any recumbent vomiting persons on their sides to help keep the airway clear. If paralysis sets in, the injured person may require rescue breathing until you reach a hospital's emergency department.

SEXUALLY TRANSMITTED DISEASES

The traveler who practices high-risk behaviors may encounter a number of sexually transmitted diseases. Currently, 147 countries are reporting HIV/AIDS, and the World Health Organization reported that the number of people living with HIV globally rose to 33 million in 2007, with a drop in new cases to 2.7 million in that year.

Wide availability of antiretroviral therapy has helped keep AIDS deaths comparatively low, at about 40,000 in 2005 in Western Europe and North America. In sub-Saharan Africa, the prevalence varies from 1 to 28 percent. The global death rate is falling slowly (data from www.unaids.org).

Hepatitis B, syphilis, gonorrhea and other sexually transmitted diseases are widespread. Be aware of the risks of these diseases. Treatment is frequently complicated by drug resistance on the part of the organism or by the lack of any effective treatment at all. Prophylaxis is best. Other than abstinence, the most effective prophylactic measure is the use of condoms.

Be aware that equipment used for tattooing, body piercings, ear piercing and other such procedures may not be subject to the same health regulations enforced in the United States. Needles and other instruments should be in single use, disposable, sterile packaging. If there is any question of sterility, the traveler should avoid these activities.

TRAVEL GUIDELINES

Travel on Airlines

Long international trips can result in more-than-usual fatigue. The sudden shift in time zones results in the well-known jet lag. In addition, the noise, low humidity, irritants in the cabin air and physical inactivity all contribute to fatigue. Avoiding alcohol and caffeine and using a sedative for sleep will help to minimize the problem. Plan to rest on arrival day after a shift of multiple time zones.

There is a growing concern that sitting in a cramped airplane seat for long periods of time may result in deep vein thrombosis (DVT, or blood clots) in the legs. These clots could break off and travel to the lungs, resulting in a potentially fatal pulmonary embolism. Current preventive measures are to:

- Avoid sitting still for long periods. During the flight, it may help to move around the aircraft from time to time and do some inflight exercises;
- Keep hydrated by drinking sufficient water and fruit or vegetable juices;
- Individual's with certain pre-existing health issues may want to consider wearing graduated compression stockings for long-haul flights. These need to be fitted to the size of the calves, not the foot size, and they aren't suitable for people with arterial disease. Before travel, discuss this with your doctor.

- Discuss taking aspirin before and after a long-haul flight with your doctor. The effectiveness of aspirin in the prevention of this condition needs more study; more research is needed to confirm how effective it is.

Travel in Motor Vehicles

Infectious disease is not the major cause of disability or loss of life for the traveler — motor vehicle accidents are. A variety of factors contribute to the motor vehicle accident, most of which can be prevented or abated. These factors are well known and similar in all nations, the primary one being the use of seat belts. Familiarize yourself with local traffic laws and patterns before driving. Bear in mind that local observation of traffic laws may be limited.

The risks in a developing nation may be increased because of inaccessible medical care. Remote locations may not have an adequate level of care appropriate to the injuries. There is also the possibility of inadequate screening of blood supplies, inadequate sterilization of instruments and needles in medical facilities.

Prescription Drugs

A traveler going abroad with a pre-existing medical problem should carry a letter from the attending physician, describing the medical condition and any prescription medications, including the generic names of prescribed drugs.

Any medications being carried overseas should be left in their original containers and be clearly labeled. Travelers should check with the foreign embassy of the country they are visiting to make sure any required medications are not considered to be illegal narcotics. (A listing of foreign embassies and consulates in the United States is available on the Department of State's website at http://www.state.gov/s/cpr/rls/dpl/32122.htm. Foreign embassy and consulate contact information can also be found on the Country Specific Information for each country.)

If you wear eyeglasses or contacts take an extra pair with you. Pack medicines and extra eyeglasses in your hand luggage so they will be available in case your checked luggage is lost. To be extra secure, pack a backup supply of medicines and an additional pair of eyeglasses in your checked luggage.

If you have allergies to certain medications, foods, insect bites, or other unique medical problems, consider wearing a "medical alert" bracelet. You may also wish to carry a letter from your physician explaining required treatment. This would be useful, should you become ill.

Enjoy Yourself!

Travel with an open mind and leave your prejudices at home. Travel with curiosity and imagination. Travel relaxed, and — above all — travel patiently. It takes time to understand others, especially where there are barriers of language and customs. Stay flexible and adaptable to all situations, and you'll have a wonderful time!

TRAVEL CHECKLIST

GENERAL NEEDS

Malaria prophylaxis

TRAVELERS DIARRHEA KIT

Pepto-Bismol®
Antibiotic (prescribed)
Loperamide (non-prescription antidiarrheal)
Antidiarrheal (prescribed)
Oral rehydration solution (ORS)

Travel medical kit
General risk avoidance
Insect precautions
Medical assistance abroad
Safe eating and drinking habits
Safe sexual practices
Travel health insurance

VACCINATIONS, IMMUNIZATIONS

ROUTINE

Diphtheria-Tetanus
Measles — Mumps — Rubella Pertussus — Poliomyelitis
Varicella (Chicken Pox)

TRAVEL-SPECIFIC

Cholera
Yellow Fever
Hepatitis A
Hepatitis B
Meningococcal Meningitis
Rabies
Typhoid Fever
Japanese Encephalitis

SURVEILLANCE AND OUTBREAK INFORMATION

Morbidity and Mortality Weekly Report www.cdc.gov/mmwr
Weekly Epidemiological Review www.who.int/wer
Canada Communicable Disease Report www.phac-aspc.gc.ca/publicat/ccdr-rmtc

MEDICAL ASSISTANCE FOR TRAVELERS

International Society of Travel Medicine www.istm.org
US Department of State www.travel.state.gov

INTERACTIVE WEB-BASED SOURCES

Centers for Disease Control and Prevention Travel Information
www.cdc.gov/travel
World Health Organization International Travel www.who.int/ith
Health Canada Travel www.TravelHealth.gc.ca
UK National Travel Health www.fitfortravel.scot.nhs.uk

MALARIA MAPS

For information, see the websites of the CDC or WHO.

BOOKS

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Cook & Zumla, *Manson's Tropical Diseases*, Saunders, 2002

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Eddleston, *Oxford Handbook of Tropical Medicine*, Oxford University Press, 2004

Red Book, *American Academy of Pediatrics Report of the Committee on Infectious Diseases*, Annual Updates

Thompson, *Travel & Routine Immunizations*, Shoreland, 2003

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SECTION II: Diving Disorders That Do Not Require Recompression

DROWNING

A drowning incident involves a lack of oxygen, possible aspiration (water in the lungs) and possibly even full cardiac arrest resulting from immersion. It has been recommended that the term "near-drowning" no longer be used. Every drowning victim should be taken to a medical facility for thorough evaluation, no matter how trivial the episode may seem. In minor cases, medical treatment may be unnecessary.

Divers should be familiar with the problem of drowning and with the techniques of rescue and resuscitation. In-water rescue is a special subject requiring study and practice to gain the necessary expertise. Divers are urged to participate in one of the scuba lifesaving and accident management courses offered by virtually all diver certification agencies.

In potentially dangerous situations — such as in caves and currents — the safety of the rescuers or the group may take precedence over the ideal medical management of such an injury. The rescue effort may need to be abandoned if continuing would pose a significant risk to the safety of the rescuer.

While submerged, a drowning victim eventually dies from a hypoxic cardiac arrest. Drowning occurs in stages as outlined below:

- The victim next fights to stay afloat while hyperventilating, which may result in negative buoyancy.
- Submergence occurs, and reflex breath-holding begins. The urge to breathe becomes stronger and stronger as the victim consumes all the available oxygen from air remaining in the lungs.
- After two to three minutes, the combination of the lack of oxygen and carbon dioxide accumulation causes an uncontrollable urge to breathe; the victim eventually inhales water, though usually very little.
- The individual, although unconscious, begins to swallow water reflexively. Consequently, some victims will have a stomach full of water.
- As oxygen is consumed, carbon dioxide accumulates more; the urge to breathe becomes stronger. The reflex swallowing gives way to a strong, deep breath. When the lungs are then emptied of air, the individual becomes more negatively buoyant.

A complete recovery is possible if:

- the drowning victim is rescued before significant aspiration (inhaling water) occurs; and
- breathing is restored before circulatory arrest occurs, which otherwise results in permanent brain damage.

Treatment of drowning depends on the restoration of breathing, heartbeat and obtaining assistance from qualified medical personnel.

In the event of drowning, immediately assess the airway and breathing. Perform rescue breathing as soon as possible with the non-breathing person, but maybe wait until the unresponsive person has been moved to shallow water or indeed out of the water. It is very hard to carry out effective rescue breaths in deep water. Once the individual has been removed from the water, assess him/her, and if necessary begin CPR immediately. Look for foreign bodies in the airway; divers have been known to bite off the bite tabs on some regulators and aspirate them. The routine use of abdominal thrusts or the Heimlich maneuver for drowning victims is not recommended.

Successful resuscitation of drowning victims in cold water has occurred even after prolonged submersion. Immersion times of more than one hour will make successful resuscitation unlikely. Unless immersion time can be definitively determined, CPR should always be initiated; however, if there is obvious evidence of death such as decomposition, severe trauma (e.g., head or body crushed), or trained medical personnel are available to certify death, stop efforts to resuscitate.

Survival after a prolonged immersion is possible if the water is icy cold (especially for children), even though the diver initially appears to be dead. (For CPR guidelines, see the following section on hypothermia.) Since delayed pulmonary edema, or fluid in the lungs, frequently occurs, all cases of drowning should receive medical evaluation.

THERMAL STRESS

The diver is subject to the effects of temperature as well as to the effects of water pressure. Water has a very high heat capacity and is an excellent conductor of heat. Heat transfer occurs whenever a temperature gradient exists between two objects, and always moves from the object with the higher temperature to the object with the lower temperature. Control of heat production and flow maintains stable body temperature.

Normal body core temperature is generally accepted as 98.6°F / 37°C, but actual temperatures vary in accordance with daily cycles, monthly cycles (for women) and with the individual. Deviations that exceed normal ranges produce hyperthermia or hypothermia.

Hyperthermia

Hyperthermia is a condition of elevated body core temperature. The lower temperature limit of hyperthermia is poorly defined. The U.S. Occupational Safety and Health Administration (OSHA) requires a planned intervention when oral temperature exceeds 99.7°F / 37.6°C.

Research protocols often restrict the upper limit for core temperature to 102°F / 39°C or 104°F / 40°C. Heat stroke can occur when the core temperature exceeds 104°F / 40°C. However, extreme ultramarathon runners have been observed to sustain core temperatures of 108°F / 42°C.

The core temperature response to heat stress is strongly influenced by an individual's state of acclimatization (adaptation to repeated or sustained environmental exposure), the physical-work demands and the relative humidity of the environment.

The heat stress associated with rising relative humidity increases dramatically at higher air temperatures. Body cooling relies not on sweating but on the evaporation of sweat. Evaporation is inhibited by increasing relative humidity.

The U.S. National Weather Service developed a heat index (apparent temperature) scale in 1990 to account for the effect of relative humidity.

Water immersion represents the highest level of relative humidity. Between the loss of evaporative cooling and the huge heat capacity of water, water temperatures that exceed 97°F / 36°C are not well tolerated, particularly if exercise is required. However, since such high-water temperatures are not commonly experienced by recreational divers, most heat insult will occur during surface activities. Heat illness can be divided into five classic categories for purposes of description and management.

Signs & Symptoms

- **Heat edema:** peripheral edema
- **Heat cramps:** muscle cramps and spasm
- **Heat syncope:** temporary loss of consciousness
- **Heat exhaustion:** headache, nausea/vomiting, low blood pressure, dizziness, fatigue and temporary loss of consciousness; mental function is normal; rectal temperature remains below 104°F / 40°C
- **Heat stroke:** pronounced mental status change, severe headache, nausea/vomiting, loss of consciousness and possible cessation of sweating; rectal temperature exceeds 104°F / 40°C

Management of Heat Illness

Action should be taken to remove the heat stress or remove the individual from the stressful environment when signs or symptoms develop. The greater the magnitude of the insult, the more aggressive the efforts to cool.

- Heat edema is easily resolved with rest and elevation of extremities.
- Heat cramps are managed with ice massage, stretching and oral fluids.
- Heat syncope is managed with a resting, supine position, mild elevation of extremities and vital sign monitoring (blood pressure, heart rate, temperature and respiration).
- Heat exhaustion requires vital sign and core temperature monitoring, oral electrolyte-containing fluids (e.g., Gatorade®), rest and cooling. If the patient becomes dizzy or blood pressure drops with standing, intravenous fluids may be required.
- Heat stroke requires urgent cooling, vital signs and core temperature monitoring, intravenous fluids and rest.

Cooling measures may be as simple as a seat in the shade for minor heat insults through to immersion in ice water for victims of heat stroke. Immediate cooling is critical for serious cases. Even though it is uncomfortable, ice water baths for heat stroke victims are documented as safe and effective. If signs and symptoms do not begin to abate after treatment, or if the individual appears to be getting warmer despite management efforts, medical aid is required.

Prevention

Unacceptably high water temperatures are not a common problem for most divers. The more common stressors are exposure to hot surface conditions, particularly when wearing suits designed to protect the diver from cool or cold water (especially drysuits), and the physical work involved in carrying dive equipment on land. Adequate hydration, a source of shade, and the ability to rest and adjust or remove attire as required are the main preventive measures.

Adequate hydration requires continual attention in hot and, more so, in hot and humid environments. The need is increased for divers who experience the diuretic (urine-producing) effects of tight wetsuits and/or immersion. Urine concentration will be influenced by acute changes in dietary intake, activity and thermal status, but passing clear, colorless urine several times per day is at least consistent with adequate hydration. If urine volume is reduced or the color darkens, divers should drink more water and stimulant-free fluids.

Hypothermia

Hypothermia is a condition of reduced body core temperature, defined as a temperature below 95°F / 35°C. Exposure to cold results in heat loss at a rate dependent on protective clothing, the temperature gradient between skin and the environment, the heat capacity of the environment (much greater for water than air), body composition (lean-versus-fat ratio and body mass-to-surface area), and the presence of wind or water movement.

'HELP' position

Water conducts heat 20-27 times faster than air. The cold shock associated with sudden immersion in water colder than 59°F / 15°C (with no thermal protection) can result in an inspiratory gasp response. While primarily observed when the head is above water, this can increase the risk of water inhalation. The stress response will produce extremely rapid breathing and heart rates.

The cold shock response may be accompanied by pain and mental disorientation, possibly leading to fear and panic. Thermal protection by a wetsuit, drysuit or other survival-type suit will dramatically lessen the immediate effects, but heat loss will still occur over time.

Heat production is increased by exercise or shivering, but for individuals with little or no thermal protection, swimming increases the exposed surface area and rate of heat transfer to the water. On average, core temperature can be maintained by swimming activity in water warmer than 75°F / 24°C. The core temperature of unprotected swimmers will generally drop in colder water. An inability to continue swimming (swimming failure) will typically develop more rapidly than expected in cold water.

Persons who are immersed unprotected, but with buoyant support in cold water when there is a chance of rescue, should remain still, holding a position to minimize exposed surface area. Pulling the knees together and up to the chest into the heat-escape-lessening position ("HELP," or rescue position) provides improved protection of the high heat loss areas of the armpits, groin, anterior chest and thighs.

Hypothermia can also occur in relatively warm or even tropical waters as a result of slow body cooling. This may happen in water as warm as 84°-91°F / 29°-33°C if no thermal protection is worn. The person may not be aware of the slow heat drain for some time. The following are the common signs (observable manifestations) and symptoms (subjective or nonobservable manifestations) of hypothermia.

Signs & Symptoms

MILD HYPOTHERMIA (core temperature 95°-90°F / 35°-32°C)

- Increased heart rate
- Impaired coordination
- Uncomfortably cold
- Impaired ability to concentrate
- Shivering
- Introversion/Inattentiveness
- Decreased motor activity
- Fatigue

MODERATE HYPOTHERMIA (core temperature 90°-82°F / 32°-28°C)

- Increasing muscular incoordination
- Stumbling gait
- Slurred speech
- Confusion
- Amnesia
- Shivering slows or stops
- Weakness
- Drowsiness
- Hallucinations

SEVERE HYPOTHERMIA (core temperature below 82°F / 28°C)

- Inability to follow commands
- Decreased heart rate
- Inability to walk
- Loss of consciousness
- Decreased respirations
- Absence of shivering
- Dilated pupils
- Decreased blood pressure
- Appearance of death
- Muscle rigidity

Management of Hypothermia

Hypothermia may be mild, with little risk to the individual, or it may be severe, with death a possibility. A variety of rewarming strategies can be used, depending on the degree of hypothermic injury, the level of consciousness of the victim, the nature of other injuries and the availability of resources and additional medical aid.

The mildly hypothermic individual will be awake, conversing lucidly, complaining of cold and probably shivering. Assuming no other injuries, a mildly hypothermic victim can be rewarmed with a variety of passive or active techniques with minimal risk of complications.

Recognizing that many options, particularly the more aggressive and invasive techniques, will likely not be available in remote settings, rescuers must do what they can to protect victims from further injury.

Remove wet clothing and replace with dry insulating inner and windproof outer layers, including the head, whenever possible. Shivering will provide effective rewarming. The individual who feels comfortable exercising at this point can increase the rewarming rate. Exercise will transiently increase the afterdrop — a continued decline in core temperature after removal of (or from) the cold stress — but this should not be problematic in most cases of mild hypothermia.

The fully alert and cooperative hypothermic individual can have warm liquids to drink. These deliver negligible amounts of heat, but will help to correct the inevitable dehydration and provide a sense of comfort. Most beverages can be used. Avoid alcohol, as it can compromise awareness and contribute to dehydration and inappropriate vasodilatation. Food will augment the individual's energy reserves, but is not a critical immediate need for the well-nourished victim.

The person with moderate hypothermia will be awake, but may be confused, apathetic or uncooperative and may have difficulty speaking. Moderate hypothermia demands more caution since cardiac dysrhythmias should be expected. Gentle handling and active techniques such as heated blankets, forced-air rewarming and heated and humidified breathing gas are all desirable, if available.

Due to compromised physical coordination and the potential to increase afterdrop, physical exercise is not recommended for persons with moderate hypothermia. Afterdrop can increase the risk of physiological collapse sometimes observed during or shortly after rescue from immersion. Gentle handling, including keeping the victim supine (on the back) with heart and head at similar levels and completely at rest will reduce the risk of collapse. Use the most effective alternatives at hand when rewarming. Take care to insulate the injured person from the ground or surroundings (consider using a wetsuit as an insulated mattress), even if the need is not communicated.

A bath in warm water is another good option for the moderately hypothermic individual. You will need to provide physical support, however, throughout the transfer and immersion. The initial immersion temperature should be lukewarm, definitely not more than 105°F / 41°C, to minimize the sensation of burning that the person will likely experience. After immersion, the water temperature can be progressively increased to no more than 113°F / 45°C.

If hot water is not available, augment insulated clothing with chemical packs or electric pads. To avoid burns, these should never be applied directly to the skin.

The severely hypothermic individual may be unconscious, with a slow heart rate and respiration, or may even appear dead, with no detectable heartbeat. Look very carefully for signs of life, such as breathing, movement, or a pulse in the neck (carotid artery). Assess breathing, and later assess the pulse for a period of at least one minute to confirm respiratory arrest or pulseless cardiac arrest requiring CPR.

Death from cold-water immersion usually results from loss of consciousness and subsequent drowning. If drowning preceded the hypothermia, then successful resuscitation is unlikely. If continued breathing or movement is present, then the heart is beating, even if at a slow rate. Spending sufficient time to check for spontaneous pulse is essential. If there is either breathing or heartbeat, external heart massage (chest compression) is not needed. For the unconscious hypothermic individual, the main goals are to maintain adequate blood pressure and respiration and to prevent further heat loss.

Severe hypothermia leaves the individual susceptible to cardiac arrest. Extremely gentle handling — supine position with head and heart at same level, fully supported, no physical activity — and aggressive and often invasive rewarming strategies are required to save victims. Cardiac arrhythmias may result from severe hypothermia or even from rewarming the severely hypothermic individual. Basic life support takes precedence over efforts to rewarm.

If there are no signs of life, begin CPR and make arrangements for emergency transport to the nearest medical facility.

Rewarming of the severely hypothermic victim is almost impossible to accomplish in the field. Protect against further heat loss. If CPR is required, it should be continued, if possible, until medical assistance is obtained. There have been successful resuscitations after prolonged CPR, in part, because of the protective effect of hypothermia. Although injured persons can appear to be clinically dead because of marked depression of the brain and cardiovascular function, full resuscitation with intact neurological recovery is possible, if unusual.

The outlook is poor in adults who have a core temperature below 82°F / 28°C, have been immersed more than 50 minutes, have life-threatening injuries or are more than four hours from definitive medical care.

In the hypothermic individual, discontinue CPR only if:

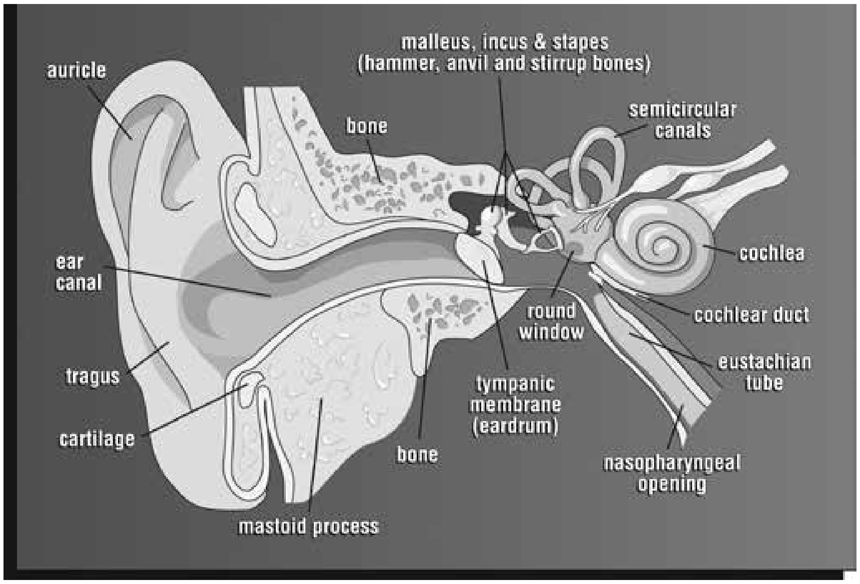
1. The person is successfully resuscitated.
2. Rescuers become too fatigued to continue.
3. The person has completely rewarmed and is still unresponsive to properly applied CPR.
4. A medically trained and qualified individual arrives at the scene, and, after examination, declares the person dead.

In a Cold-Water Immersion Incident

- Determine cause of immersion to reduce risk to the rescue team.
- Handle victim as gently as possible.
- Assess airway, breathing and circulation (be aware of an increased risk of cardiac arrest during handling and removal from the water).
- If CPR required, continue until EMS arrives.
- Give as much oxygen as possible.
- Determine cause for immersion.
- If injury is suspected, support and immobilize neck.
- Arrange transport to a medical facility.
- Prevent further heat loss.
- Rewarm as needed and capacity allows.

Prevention

The prevention of hypothermia requires preparation. The diver must understand the use of protective garments to conserve body heat and control heat loss. Most divers will benefit from wearing thermal protection in water cooler than 80°F / 27°C. Significant thermal stress can be expected in water colder than 75°F / 24°C. Divers should ensure that they have the proper protective equipment and experience to dive safely in cool or cold waters. Unprotected coldwater immersion will produce incapacitation much faster than expected. Readiness and rapid action are required to increase the likelihood for successful outcome for any rescue or self-rescue.



The middle ear is the space behind the eardrum. It is vented to the atmosphere by the auditory (Eustachian) tube, which connects it to the back of the throat. If this tube is blocked, the space behind the eardrum cannot equilibrate with ambient pressure.

If the pressure difference across the eardrum is small, only slight injury (called a squeeze) may result. Symptoms may include a sense of fullness and muffled sound in the affected ear, or there may be frank pain as the eardrum distends.

Large pressure differences can have very serious results — rupture of the eardrum, and/or damage and rupture of a similar smaller membrane covering the round or oval window inside the ear. If an eardrum ruptures, the pain of eardrum distension is typically suddenly relieved. However, if water suddenly enters the middle ear, dizziness and possibly vertigo and severe nausea may result. Fortunately, these symptoms will disappear when the water reaches body temperature, but this means there's a significant ear injury that needs evaluation and care before one can resume diving.

Ear-clearing injuries most commonly occur during descent and can result from going down as little as 6 ft (2 m) with a blocked Eustachian tube or from forceful clearing attempts once the ear is blocked. Injury can be prevented in most cases by applying proper ear-clearing techniques as described in the following pages.

Ear-clearing injuries are rare on ascent because the Eustachian tube normally allows gas to exit safely. Rarely, there is unequal release from the middle ear cavities during ascent, resulting in a relative pressure difference between the ears and unequal stimuli to the vestibular system in the inner ear. This results in a condition called alternobaric vertigo. The diver may experience temporary dizziness and disorientation that clear when the pressure is balanced.

If the diver reaches the surface with unequal pressure between the two middle ear cavities, dizziness and disorientation may persist. There have been instances of increasing pain during ascent, with the eventual perforation of the eardrum and subsequent inner ear damage. In a serious diving injury, dizziness on ascent or shortly after a dive can also be caused by decompression sickness (DCS).

Signs & Symptoms

- Nystagmus *(rapid back-and-forth eye movement)*
- Hearing loss
- Ear pain
- Loss of balance
- Dizziness
- Nausea
- Traumatic eardrum damage with bleeding
- Jaw or neck pain
- Hearing difficulty

Prevention

Cautious, nonforceful, clearing — begun on the surface prior to descending — can help divers avoid injuries. Divers should not use excessive force in attempting to clear the ears. If unable to clear, ascend a few feet until clearing is possible and then resume, making a slower descent, clearing continuously. It is helpful to descend feet-first down a weighted line when possible.

Equalization Techniques

The novice diver should learn equalization techniques from an experienced instructor. There are several recommended techniques, and it is advisable to practice them on land before attempting them in the water. The most common technique is called the Valsalva maneuver and is performed by blocking the nostrils, closing the mouth and bearing down as though attempting to exhale. The pressure in the nose and throat then increases, forcing air up the Eustachian tube into the middle ear. This also equalizes the sinuses.

Use the Frenzel technique by closing the mouth and nose and contracting the muscles of the floor of the mouth. The tongue is elevated and compresses the trapped air, forcing it up the Eustachian tube.

The Edmonds technique is often successful for divers having difficulty with either the Valsalva or Frenzel. Perform this technique by jutting the lower jaw forward so that the lower teeth project well in front of the upper teeth, then completing either the Frenzel or Valsalva maneuver.

Treatment

Serious ear damage should be treated by an ear, nose and throat specialist (ENT specialist or otolaryngologist) in consultation with an experienced diving physician. If serious signs are present, contact a dive medicine physician or DAN immediately. Place the diver on bed rest, with head elevated and advise against coughing, sneezing, attempting forceful bowel movements or using forceful breath-hold maneuvers.

Otitis Externa

Prolonged or frequent immersion may result in an external ear infection, otitis externa (OE), commonly called swimmer's ear. The disease does not necessarily result from bacterial contamination in the water, but is due to the breakdown of the epithelial cells lining the ear canal as a result of frequent exposure to water. The bacteria normally present in the ear canal gain access to the spaces under the epithelium and multiply.

The first symptom is usually itching or a wet feeling in the affected ear which, if not treated, can progress to painful lymph node inflammation. Once OE develops, the only treatment is to stop diving and use antibiotic eardrops and, in severe cases, oral antibiotics.

Prevention is key. Acetic Acid Otic Solution, USP 2 percent, is effective in providing prophylaxis against OE. These solutions are currently prescription medications. Other preparations are available over the counter (OTC). Ask your doctor about similar products.

These OTC solutions usually consist of 95 percent isopropyl alcohol, with anhydrous glycerine. They have generally not been tested in the diving environment, so how well they work is still under scrutiny.

A bottle of ear-drying solution should be a part of your dive bag. Whatever preparation you choose to use, the trick is in the application. Before your first dive in the morning and after your last dive each night, the *U.S. Navy Diving Manual* recommends this procedure:

1. Tilt the head to one side and fill the external ear canal gently.
2. Leave the solution in the ear canal for a full five minutes.
3. Then tilt the head to the other side, allowing the solution to run out.
4. Repeat this procedure in the other ear.

For the best possible results, time the five-minute treatment. If the solution does not remain in the ear a full five minutes, the effectiveness of the procedure is greatly reduced. Remember, this is a prophylactic procedure that should be started before the ear becomes infected; beginning the treatment after an infection occurs is not effective.

One word of warning: Do not put drops in your ear if you have reason to suspect you have a ruptured eardrum. If you do, it may wash bacteria into the middle ear, where an infection requires antibiotics.

CONDITIONS RELATED TO BREATHING GAS UNDERWATER

Nitrogen Narcosis

The acute effects of nitrogen on the diver have been compared to those of alcohol intoxication. Just as alcohol impairs judgment and coordination, breathing nitrogen in air affects the diver with significant impairment at depths of 100 fsw/30 msw. Everyone is affected whether or not they recognize it, although there is some individual variation.

More important than individual variation is the fact that familiarity with the sensation can be confused with a false sense of not being impaired. The effects often go unrecognized as the diver becomes overconfident. This will be true even of the "experienced" diver who may dive beyond 100 fsw/30 msw seemingly without effect.

While experiencing narcosis, most divers are able to perform routine tasks, but they may not be able to handle an emergency. Nitrogen narcosis may play a major role in many diving accidents. All divers are susceptible to nitrogen narcosis.

Signs & Symptoms

- Inappropriate behavior
- Inattentiveness
- Repeating but not obeying hand signals
- Rigid and inflexible thinking
- Stupor
- Impaired consciousness at depth
- Lack of concern for task and own safety
- Tendency to panic rather than to cope constructively

Prevention

Recreational divers breathing air should avoid depths greater than 130 fsw/40 msw. Air dives deeper than this involve unacceptable risks promoted by nitrogen narcosis.

Treatment

Ascend until symptoms clear (using a controlled ascent). Resolution of symptoms should be immediate.

Oxygen Toxicity

Although oxygen is required for human life, it can have toxic effects when breathed at above-normal pressures. The organs affected are the lung and the central nervous system (CNS). Oxygen toxicity involving the lungs (pulmonary oxygen toxicity) results from long (many hours) exposures usually encountered only during recompression treatments or during long decompression using enriched oxygen breathing mixtures and will not be covered in this book.

Recreational divers can encounter oxygen toxicity involving the brain (CNS oxygen toxicity). The diver using regular scuba equipment at reasonable depths will not encounter this problem, but gas density and heavy exertion can cause carbon dioxide retention that makes divers more sensitive to oxygen. The current maximum oxygen partial pressure recommended for diving is 1.4 ATA or, under more restricted circumstances, to 1.6 ATA.

Air will have an oxygen partial pressure of 1.4 and 1.6 ATA at 188 and 220 fsw (61 and 72 msw), respectively. Divers using modified gas mixtures with concentrations of oxygen higher than air are at risk at much shallower depths.

A 32 percent enriched-air nitrox (EAN, or nitrox) mix will have an oxygen partial pressure of 1.4 and 1.6 ATA at 111 and 132 fsw (36 and 43 msw), respectively. A 36 percent nitrox mix will have an oxygen partial pressure of 1.4 and 1.6 ATA at 95 and 114 fsw (31 and 37 msw), respectively. A diver breathing pure oxygen can have convulsions at depths as shallow as 20 fsw/6 msw.

Signs & Symptoms

- Nausea
- Dizziness
- Abnormal vision
- Convulsion
- Ringing ears
- Facial twitching
- Confusion

Convulsions (or seizures) due to oxygen are not harmful per se, if the diver can be prevented from injury while thrashing about or from drowning if underwater. Minimizing the risk is critical since oxygen convulsion may occur without warning.

Prevention

Avoid deep diving, and do not use breathing gases with oxygen concentrations inappropriately high for the depth. Oxygen partial pressures high enough to cause symptoms are unlikely when diving on air within recommended recreational depth/time limits. Problems are more likely to be encountered when breathing elevated oxygen mixtures (EAN) or when using rebreathers.

A maximum oxygen partial pressure of 1.4 ATA has been recommended for open-circuit scuba using nitrogen-oxygen breathing gas mixtures. For scuba divers who adhere to the 1.4 ATA oxygen limit, an oxygen convulsion is unlikely.

Opening the airway: If the diver is not breathing, begin rescue breathing.

Oxygen partial pressures as high as 1.6 ATA following National Oceanic and Atmospheric Administration (NOAA) depth/time limits have been used by some, but it is usually recommended that these higher partial pressures be reserved for situations in which the diver is largely at rest, such as during decompression stops.

For extended diving exposures using rebreathers, the U.S. Navy has a 1.3 ATA limit oxygen partial pressure. Special training is required before diving nitrox or using rebreathers. This must include methods of minimizing the possibility of oxygen toxicity.

If symptoms occur, reduce the oxygen partial pressure immediately by ascending or switching to a breathing gas with a lower oxygen partial pressure. Do not assume that an oxygen convulsion will not occur until the diver has been on a reduced oxygen level for at least five minutes.

Treatment

Early symptoms should be treated by surfacing if possible. Management of an underwater seizure is difficult, and the victim's life is clearly at risk. Like learning cardiopulmonary resuscitation (CPR), practicing the proper handling of an oxygen convulsion helps you maintain this vital skill.

Once the convulsion subsides, if the mouthpiece is secure (or if the diver is wearing a full-face mask) and the diver is still in the water and breathing, then leave everything in place until you can get the diver out of the water. Once on the surface, if the diver is not breathing, remove the mouthpiece and begin rescue breathing, clearing the airway as required.

While the injured diver is in the water, the main goal is to prevent drowning. After the seizure ends, ensure that the diver's airway is open. Once out of the water, be on the lookout for foreign bodies in the airway. During a convulsion, it is possible to bite off parts of the mouthpiece, which can find their way into the trachea. In these cases the diver will begin coughing upon returning to consciousness, or the diver may try to breathe but not get any air into the lungs. Here you need to institute the standard procedures taught in CPR classes to remove a foreign body.

Carbon Dioxide Toxicity

Carbon dioxide (CO_2) buildup in the diver using conventional scuba gear is caused by increased breathing resistance in the circuit, intentional skip-breathing (consciously decreasing breathing rate in an attempt to conserve gas), overexertion or equipment malfunction (especially the nonreturn valve).

Equipment malfunction is more common in divers using rebreathing equipment employing CO_2 scrubbers. The high gas density of compressed air at depths over 100 ft / 30 m can cause normally adequate regulators to perform poorly, leading to CO_2 buildup. Divers working strenuously at depth are at greater risk for CO_2 buildup.

Signs & Symptoms

- Labored or rapid breathing
- Muscle twitching
- Shortness of breath
- Dizziness, nausea
- Slowed responses
- Headache
- Confusion
- Unconsciousness

Prevention

Avoid the causes of CO_2 buildup and do not skip-breathe. If breathlessness occurs, a diver should stop and rest until breathing is normal.
If breathing troubles persist, the diver should surface and rest.

Treatment

Symptoms usually clear quickly after the cause is removed, although a headache may persist for hours. The diver who does not stop and rest during the early symptoms risks unconsciousness at depth. This has no satisfactory management and can lead to embolism or drowning.

Hypoxia

The term hypoxia is used to denote low tissue oxygen levels. Manifestations of hypoxia include rapid heartbeat and breathing, dizziness, euphoria, lightheadedness, confusion, vision impairment, lack of coordination, turning blue (cyanosis), drowsiness, unconsciousness and death.

Reasons for hypoxia include impaired circulation, lung injury (e.g., pneumothorax, water aspiration, cardiorespiratory decompression sickness) or a breathing gas in which the oxygen partial pressure is low.

Symptoms of hypoxia are not usually apparent until the oxygen partial pressure drops to less than 0.15 ATA, or at the surface, 15 percent oxygen. Altitude hypoxia is caused when the oxygen partial pressure is reduced due to low ambient pressure. Hypoxia is the most common cause of rebreather fatalities, due to equipment malfunction or operator error. Hypoxia is treated by administering a breathing gas containing a high percentage of oxygen.

Contaminated Gas Supply

Contaminants can be introduced to a compressed gas supply by inadequate filtration or faulty operation of compressor systems. Breathing gas must meet exceptionally high quality standards for use underwater. The concentration of gas breathed under pressure means that any contaminants are also concentrated. Carbon monoxide (CO), for example, can pose a serious risk to divers. Both odorless and tasteless, CO cannot be immediately perceived. It binds to hemoglobin that would normally carry oxygen, but with a much greater affinity (200 to 250 times greater than oxygen). Once CO is bound, the ability to transport oxygen is restricted for long periods of time. Since the effect is persistent, a small amount in a breathing gas has great impact when it is concentrated under pressure.

Additional contaminants, including carbon dioxide, oil and other volatiles can also pose significant risk. Only some may be perceived during pre-dive checks.

Signs & Symptoms

- Taste or odor to breathing gas
- Headache
- Dizziness
- Nausea
- Hyperventilation or air hunger
- Impaired concentration

Prevention

Breathing gas supplies should be secured from reputable sources. Unusual odor or taste noted during pre-dive checks should prompt replacement of the supply.

Treatment

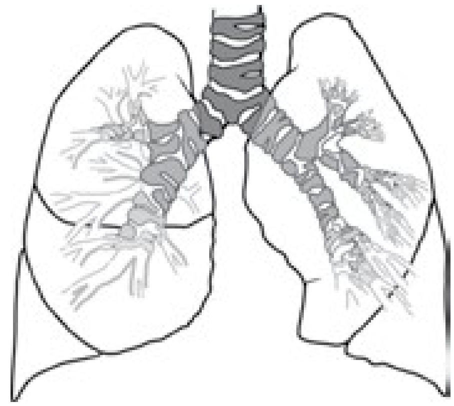
Discontinue use of problem gas immediately, surface and take fresh air and oxygen, if available. If any symptoms or discomfort persist, medical evaluation is required. CO poisoning is most effectively treated by hyperbaric oxygen therapy. Surface oxygen also clears CO from hemoglobin, but at a much slower rate.

LUNG OVERPRESSURE PROBLEMS

Overinflation of the lungs is a common cause of a number of disorders. A local pressure buildup in part of the lung may damage it and allow air to escape into the circulatory system, leading to air embolism.

Air can also escape from the lung into nearby tissues and cause three other disorders:

- Pneumothorax
- Mediastinal emphysema
- Subcutaneous emphysema



These disorders can occur separately or with an air embolism, depending upon the exact nature of the lung injury. The occurrence of any of these disorders means that the lung has been injured, and an air embolism should be suspected.

After a lung overpressure incident divers should not resume diving without consulting a physician knowledgeable in dive medicine.

Pneumothorax

The lungs are not attached directly to the chest wall, but are kept expanded in the chest cavity by negative pressure between the lung and the chest wall. If lung damage allows air to enter the chest cavity and alters the negative pressure that normally keeps the lung expanded, lung collapse can occur.

Signs & Symptoms

- Rapid shallow breathing
- Blue skin, lips, fingernails (cyanosis)
- Shortness of breath
- Pain in chest

Prevention

Breathe normally and ascend slowly.

Treatment

A person with a pneumothorax does not need recompression but does require medical treatment. A physician may need to insert a chest tube, withdraw air from the chest cavity and allow the lung to reinflate. If the pneumothorax is small, breathing 100 percent oxygen may hasten resorption of gas, without the need for a chest tube. A chest tube may be required regardless of the size of the pneumothorax if recompression therapy is required for other reasons — such as decompression illness. Not usually life-threatening (unless it is a tension pneumothorax), this condition does require immediate care at a hospital. The injured person should make no further dives until an evaluation has been conducted by a physician familiar with diving medicine.

Pneumothorax, mediastinal emphysema and subcutaneous emphysema can occur separately or with an air embolism.

Mediastinal Emphysema

Air may escape from a damaged lung into the space between the lungs (mediastinum) which contains the heart and various large blood vessels. This space extends from the diaphragm to the neck.

Signs & Symptoms

- Pain in chest, usually under the breastbone (sternum)
- Shortness of breath
- Faintness
- Difficulty in breathing
- Change in voice

Prevention

Breathe normally and ascend slowly.

Treatment

A physician should examine the diver for other signs of a lung over-pressure accident and observe for 24 hours. Mediastinal emphysema can be hard to see on a plain X-ray. A CT scan may be helpful if available. Unless air embolism or decompression sickness is also present, recompression of the diver is usually not required. Breathing 100 percent oxygen at the surface will hasten resorption of the trapped gas.

Subcutaneous Emphysema

Air escaping from a lung may also be trapped under the skin, usually around the neck.

Signs & Symptoms

- Swelling at base of neck/feeling of fullness
- Change in voice
- Difficulty swallowing
- Crackling sensation when skin is pressed

Prevention

Breathe normally and ascend slowly.

Treatment

This is usually not an emergency. The diver should be examined by a physician and observed for other problems, especially for air embolism. Breathing 100 percent oxygen at the surface will hasten resorption of the trapped gas.

The injured person should make no further dives until an evaluation has been conducted by a physician familiar with diving medicine.

MOTION SICKNESS

A common complaint of divers who spend time on a dive boat traveling to dive sites, motion sickness has affected nearly everyone at least once. The most distressing symptom of nausea is caused by overstimulation of the vestibular balance organs and/or a mismatch between the sensory input of the eyes and the vestibular or inner ear. Closing the eyes or sitting where the rocking motion of the boat is clearly visible helps to prevent the problem. Gazing at the horizon, rather than concentrating on the immediate vicinity, is also useful. Staying away from areas with strong fumes, particularly fuel, is a good idea, too.

Motion sickness itself is not a serious medical problem, but it may set the scene for more serious incidents. Affected individuals can develop an almost desperate inattentiveness. The desire to get into the water quickly to reduce motion sickness can affect the care taken in setting up equipment or attending to a buddy.

Once underwater, vomiting can be a real problem if a diver fouls his or her second stage and/or inhales water. It is not true that vomiting underwater is obligatorily followed by an uncontrollable reflex inhalation, but coughing or choking can occur. Removing a regulator to vomit underwater keeps the regulator from being fouled but must be done carefully. Divers should think carefully before deciding to start a dive when seriously affected.

Mild nausea from motion sickness must also be differentiated from the symptoms, dizziness and nausea; they may signal a more serious injury. This can be difficult at times, as motion sickness can often recur and persist after the diver returns to land.

Signs & Symptoms

- Sweating
- Pallor (paleness)
- Vomiting
- Nausea
- General ill feeling
- Mild headache

Treatment

Persistent or unusually severe nausea needs to be evaluated by a physician, especially if other symptoms are also present. Drugs to treat motion sickness are available, but should be used with caution during diving as most of these drugs cause mild drowsiness and a decrease in mucous secretions. Since both effectiveness and the level of side effects vary between individuals, no single drug is specifically recommended.

Transderm Scopolamine® has been evaluated by the U.S. Navy and has shown to have minimal adverse effects in divers. The Transderm Scop® patch is a prescription medication that contains 1.5 mg of scopolamine.

When it is placed on the skin, the patch will deliver the drug at a constant rate for three days. After that period, the patch should be removed. If you are still in an environment where motion sickness will be a problem, you can use another. Never wear more than one patch at a time, even if you think one is exhausted. There is a risk of too much of the medication entering the bloodstream, causing undesirable side effects.

While on a dive trip, place the patch at least an hour before boarding the boat. Scrub the area behind the ear with an alcohol swab and dry well. Once the patch is placed, it can be left there continuously for three days, even when diving. If the patch falls off or is removed, discard it. If motion sickness is still likely to be a problem, place a new patch immediately. Before placing a new patch, remove the old one. When the patch foil wrapper is opened, do not touch the patch under the peel skin. If some of the medication gets on your finger and you touch your eye, the drug will be then absorbed rapidly.

Side effects may occur, including dry mouth, drowsiness and blurred vision. Less frequently, disorientation, memory disturbances, dizziness and restlessness may occur. Scopolamine should be used with caution in patients with narrow-angle glaucoma, with pyloric obstruction or urinary bladder neck obstruction (e.g., due to prostate enlargement).

Rare side effects include hallucinations, confusion, difficulty urinating, skin rashes and eye pain. These side effects depend on each individual; there is no way to know in advance who will be affected. Thus, before using it to prevent motion sickness, wear the patch on dry land for at least 24 hours to test its effects. Do not consume alcohol while wearing the patch.

If side effects occur, remove the patch. If the patch is worn for more than three days, withdrawal symptoms can occur when it is removed; these symptoms, which generally do not occur until 24 hours after removal, include dizziness, nausea, vomiting, headache and disturbances of equilibrium. These symptoms are also associated with decompression sickness, and they can complicate diagnosis if the patch is removed right after making a deep dive. If you have these symptoms and you wore the patch at any time, tell the examining physician.

Note: Mild motion sickness is often relieved once underwater, but one experiencing severe nausea should exercise caution. In that situation, canceling the dive would be a wise decision.

Insulin-requiring diabetes mellitus (IRDM) has traditionally been considered an absolute contraindication to diving. Persons with IRDM who chose to dive despite medical recommendations to the contrary generally did so by hiding their condition. However, in recent years, there has been a growing shift away from the blanket prohibition position due to antidiscrimination laws and the growing record of diving safely by individuals with diabetes. Those with IRDM can now receive training and dive in several countries.

An international workshop in 2005, jointly sponsored by the Undersea and Hyperbaric Medical Society (UHMS) and DAN, reached agreement that dive candidates who use either dietary control or medication (oral hypoglycemic agents [OHA] and / or insulin) to treat diabetes but who are otherwise qualified to dive may undertake recreational scuba diving, provided the meet certain criteria. This has been ratified by the Recreational Scuba Training Council (RSTC) in the United States.

The criteria are detailed in the full-consensus guidelines. These guidelines consist of 19 points that are divided into three sections:

- selection and surveillance
- scope of diving
- glucose management on the day of diving

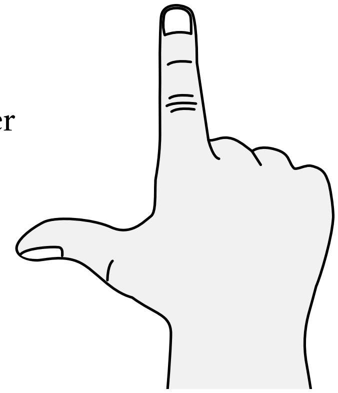
Read a single-page summary of the guidelines on the DAN website. The workshop discussions and complete text of the guidelines appear in the published proceedings.*

The guidelines contain practical recommendations for rescue medications and procedures in case a diver develops hypoglycemic problems underwater. Individuals with diabetes, their buddies and dive leaders should all be aware of the status of the diver or divers, signs and symptoms of hypoglycemia and procedures required in case of a problem.

The diver with diabetes is generally very sensitive to manifestations of hypoglycemia. There are typically early warning signs and symptoms (headache, altered mood and fatigue) and mild to moderate reactions (tremors, accelerating heart rate, neck pain, irritability and extreme fatigue) that will prompt the individual to take corrective action or request assistance. In the remote chance that the problem is not addressed in a timely manner, severe signs that could be observed underwater include decreased awareness or unresponsiveness, unconsciousness or convulsions.

* Pollock NW, Uguccioni DM, Dear GdeL, eds. Diabetes and recreational diving: guidelines for the future. Proceedings of the UHMS/DAN 2005 June 19 Workshop. Durham, NC: Divers Alert Network; 2005.

The suspicion of hypoglycemia can be easily communicated underwater with an “L” signal (for “low”) formed with the extended upright index finger and extended thumb of either hand.



The diver can signal with either hand as a question or as a statement. Before the dive, discuss the signal, its significance and action plans.

Rescue medications include oral glucose carried by the diver and buddy during all dives and parenteral glucagon available at the surface. Parenteral glucagon is an injectable agent that stimulates the liver to release glucose into the bloodstream to counter severe hypoglycemia reactions. If hypoglycemia is noticed underwater, the diver should surface with his or her buddy, establish positive buoyancy, ingest glucose and leave the water.

INJURY & OTHER MEDICAL EMERGENCIES

Dive trips are no different from other travel, and not all emergencies will be dive-related. Trauma, injuries, heart attacks and strokes can and do occur, and their treatments generally do not differ from what would normally be applied.

Knowledge of first aid and being able to rapidly contact trained medical personnel are the mainstays of treatment. Evaluation of the airway and initiating CPR, where required, are almost always the first steps in treating emergencies.

Oxygen is usually a part of the first aid for most of these types of conditions; plus, oxygen delivery is covered in Section IV.

Some diving injuries will, however, require a treatment not usually found at most medical facilities, namely recompression.

For this reason, it is crucial that the need for recompression be assessed in all emergencies involving divers; this is covered fully in Section III. Prompt recompression is likely to be most effective.

MARINE ANIMAL INJURY
Introduction

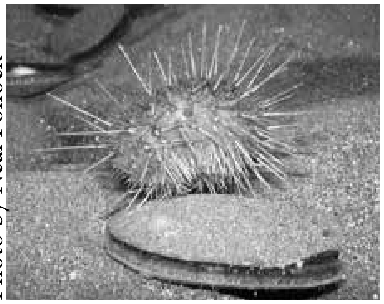


Photo by Neal Pollock

This section describes the initial first aid measures for the management of injury due to an encounter with a marine animal. These measures use ordinary first aid supplies and mostly do not involve the use of prescription drugs or procedures best left to medical professionals.

The sea is filled with creatures that may appear harmless, although some are capable of wounding, poisoning or even killing an unlucky diver. Despite the extreme rarity of serious incidents, the shark is the most well known of marine perils. Far more common are the animals with both defensive and offensive weapons potent enough to cause human injury. The best protection against most injuries is a healthy respect for these animals. When in doubt, keep your distance.

Most marine animal injuries are the result of a chance encounter (such as swimming into a jellyfish) or a defensive maneuver by the animal (a stingray wound, for example). Injury is rarely due to an aggressive action on the animal's part. Marine animals are generally harmless unless deliberately or accidentally threatened or disturbed. The wounds that result, however, share many common characteristics, although they differ in type and severity. These wounds are nearly always contaminated with bacteria, frequently with foreign bodies and occasionally with venom.

Many publications are available to divers to help in identification of marine life. A diver's ability to recognize and identify the commonly encountered animals at a dive site adds to the pleasure of the dive and helps to avoid those animals capable of harm. There are several excellent publications that cover in detail the identification of marine life hazardous to the diver and the management of injury that may follow an encounter.

Following are useful references:

- Auerbach, P.S., *A Medical Guide to Hazardous Marine Life*. 4th edition, Best Publishing Co., 2006.
- Auerbach, P.S. *Medicine for the Outdoors*. 3rd edition, Lyons Press, 1999.
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Divers concerned about injury may lessen the opportunity for an adverse encounter by showing respect for the undersea environment and knowing the damage that humans can do — and have done — to living marine organisms. Most divers are now aware of these problems and are careful in their personal diving techniques to respect the sea and its living creatures. "Look, but don't touch," is the most conservative approach.

In the event of injury, identification of the animal responsible for the injury is helpful. However, symptoms may not appear for hours after the contact, or the animal may not have been seen or recognized at the time of injury. Treatment, then, is frequently based on the presentation of the injury with limited information as to the cause. Careful examination of the characteristics of the wound may indicate the most likely source.

Wounds

Wounds or soft-tissue injuries may be classified as closed or open. A closed wound (contusion) results from blunt trauma to the skin, which produces injuries to the soft tissues beneath the skin surface. Such wounds can be caused by mask squeeze, falls, pinching injuries or the bites of marine animals without well-developed teeth. Stingrays, when hand-fed, frequently produce contusions (which look like world-class "hickies") when they inadvertently sample the diver's arms or legs. However, they are also capable of biting with sufficient force to amputate a fingertip.

Another closed wound is the contact injury resulting from touching an animal capable of releasing a venom, but not capable of deeply penetrating the skin surface (e.g., beyond the epidermis) with its delivery apparatus. Examples are sponges, coelenterates and certain segmented worms.

An open wound is the result of an injury that penetrates the skin surface. It may or may not be accompanied by injury to tissues beneath the skin. Open wounds can be subdivided by the characteristics of the injury.

Lacerations, avulsions and amputations are produced by a sharp instrument such as a fish bite, coral edge or shell. Avulsion occurs when a flap of skin or body part is torn loose partially or is completely amputated.

Abrasions are superficial wounds that occur when the skin is rubbed or scraped over a rough surface so that part of the outer skin layer (the epidermis) is lost. Deeper abrasions may involve the dermis. Abrasions may ooze blood and tissue fluid, and are often covered with debris.

Puncture wounds are stabs from a sharp object such as a tooth, fang, a fish or sea urchin's spine, or a cone shell's radicular tooth ("dart").

Envenomation

Many marine animal injuries are complicated by a venom delivered by the animal either by injection via a spine or fang or contact with some part of the animal. The coelenterates, for example, possess stinging cells (nematocysts) capable of penetrating the human skin for a short distance and delivering venom. Each nematocyst contains a tiny amount of venom, but following an encounter with a large animal, the total number of nematocysts delivered may be several million. Other examples of venomous marine animals are discussed in these pages.

FIRST AID TREATMENT — GENERAL

For any marine animal injury, there are general principles of treatment, determined by the type of injury and the responsible animal. You will find important first aid information here for managing the injury until medical assistance is available.

NOTE: Infection, which can be severe, can occur from any marine injury in which the skin is punctured. If the area becomes painful, red or swollen in the days after the injury, seek medical attention.

Contusions

A small contusion does not require treatment, although the temporary application of an ice pack and gentle compression may minimize swelling and bleeding. A large contusion may result in extensive bleeding beneath the skin, with significant swelling. Apply pressure and ice packs to a large contusion and, if possible, elevate the injured part above heart level. Apply a splint to an injured extremity to prevent motion to decrease bleeding, swelling, and pain. Any time that a compression wrap or splint is applied, be certain that the circulation to the body part beyond the wrap or splint remains intact, as determined by the presence of normal sensation and tissue color.

Abrasions

Abrasions must be cleaned of debris that may be embedded. This is optimally accomplished with adequate supplies of a germicidal soap and clean, preferably disinfected, water. This procedure should be done as soon as possible, after which you should cover the wound lightly with antiseptic ointment underneath a sterile, and preferably nonadherent, dressing.

Puncture Wounds

Puncture wounds may not produce significant external bleeding. However, there can be internal bleeding not visible from outside the body. Occasionally an impaled object remains in a puncture wound. Large impaled objects should not be removed but left in place, stabilized by a bulky dressing. Smaller objects such as sea urchin spines should also be left alone until adequate equipment and facilities are available for removal. If a spine is small and easily extracted from a hand, arm, foot, or leg, this may be done so long as the rescuer is confident that it has not penetrated a blood vessel. Be prepared to apply pressure directly to the wound if there is more than very minor bleeding.

Lacerations, Avulsions, Amputations

Steady, direct pressure at the site and elevation are the most effective means to control bleeding.

These wounds require immediate control of bleeding prior to any other measure. Bleeding is best controlled by direct pressure upon the injury and elevation of the injured part above heart level, if possible.

Although it happens rarely, direct pressure can at times be insufficient, and pressure must be applied to an artery at an accessible point (closer to the heart) on the arm or leg. Tourniquets are not recommended. There are several potential hazards with a tourniquet. It is a last resort when using it is the only way to save the injured person's life at the risk of sacrificing a limb. If a tourniquet must be applied, tighten it until bleeding stops, and do not release it until proper medical care is available. If transport will be prolonged, it is acceptable to loosen the tourniquet briefly for a moment after it has been in place for 20 to 30 minutes, to see if pressure alone — without the tourniquet — will control the bleeding. If brisk, uncontrolled bleeding occurs, be prepared to rapidly apply the tourniquet again.

After the bleeding is controlled, irrigate the wound with sterile water or clean (preferably, disinfected) tap water to remove loose debris.

Follow these guidelines in wound care:

- **Do not** attempt to pick out embedded foreign matter. Cover the wound with a dry, sterile dressing.
- If there are amputated parts, these should be preserved loosely wrapped in a saline-moistened gauze and kept in a cool container.
    - **Do not** warm an amputated part.
    - **Do not** place it in water or directly on ice; **do not** cool it with dry ice or do not allow the part to freeze. Simply wrap it in a moist dressing until it can be delivered to the medical treatment facility.

Envenomation

Most of the symptoms following envenomation are due to the poisonous nature of the venom itself. However, an allergic reaction to a venom may occur, particularly if the individual has had a previous exposure to the same or a similar venom. Occasionally, an allergic reaction occurs in an individual not known to be allergic to the specific venom. Rarely, a very severe, true allergic reaction, termed anaphylaxis, occurs. This is a life-threatening situation — the victim is very short of breath due to swelling in the mouth and throat, and constriction of the lung airways, and has a rapid pulse and low blood pressure. This type of episode usually develops within minutes after the injury, but — rarely — can be delayed for several hours.

The pressure bandage helps prevent or delay venom absorption and reduce its clinical effect.

Anaphylaxis is an emergency that requires immediate medical care. Individuals who know themselves to be at risk for this type of reaction frequently carry epinephrine (e.g., EpiPen® or other auto injectors) in a prepared kit for self-injection. If epinephrine is available, rescuers should help in administering it to the injured person, following the package directions.

Minimize the toxic effects of the venom by prompt treatment. This requires rapid removal of any remaining venom, neutralizing the effect of the venom that cannot be removed, and relieving pain and other symptoms produced by the venom.

Pressure Bandages

Australian authorities advise the application of a pressure (or "pressure-immobilization") bandage applied to extremities that have sustained by stings from sea snakes, the blue-ringed octopus and cone shells. The pressure bandage appears to prevent or delay venom absorption and reduce its clinical effect. For maximum effectiveness, the pressure bandage must be combined with immobilization of the extremity.

In the event of envenomation, place a gauze pad over the wound and wrap the extremity from the tips of the fingers or toes. Use a broad bandage applied tightly as if treating a sprained ankle, but not tight enough to stop circulation. The bandage should cover the entire extremity and be followed by application of a splint for immobilization. The bandage should remain in place until medical care is available. Leave finger or toe tips exposed so that you can see skin and nail color. If the skin or nail beds turn blue or numbness and tingling or loss of feeling occur, the bandage is too tight.

Application of Heat

Because many venoms appear to be sensitive to heat, you may help alleviate pain by applying a hot pack (approximately 113°F / 45°C) or take a hot shower for 30-90 minutes or until pain is relieved. Avoid excessive heat, because it can burn the skin. Always test the heat on an uninjured body part to be certain that it is not scalding. Heat is effective in treating injuries from most spiny creatures, such as echinoderms (e.g., starfish, sea urchins), as well as stings from spined fish (e.g., lionfish, scorpionfish, stonefish), and stingrays.

Application of seawater to a jellyfish sting to rinse away tentacles and nematocysts usually does not worsen it, because application of seawater does not per se stimulate the discharge of nematocysts, which may be released by the application of freshwater, because of its lower salt content.

It has recently been suggested that heat is useful to ease the pain for the stings of certain jellyfish, namely, the Australian man of war jellyfish sting, by mechanism(s) unknown. Hot fresh water is still lower in salt content, so one should be extremely cautious in following this recommendation. It should not be assumed that it is appropriate to generalize this observation to other jellyfish, because it has not been observed or proven, and application of hot (hypotonic, fresh) water might make things worse.

Some lifeguards claim that putting a person under a fresh water shower is helpful for a jellyfish sting. Since hypotonic water usually worsens a sting, the only reason that this might work is because the force of the spray from the shower might supercede the deleterious effect of the hypotonic water. Again, one must be very cautious in using this method.

The application of cold packs (presumably dry, not moist) to jellyfish stings has been recommended as a therapy. Cold hypotonic water is hypotonic first and cold second, so application of ice water or crushed ice directly to the skin could worsen the situation, perhaps dramatically.

Application of a pressure immobilization dressing is not indicated, and may be harmful, for a jellyfish sting.

Contact Wounds

Contact injury most commonly results from an encounter with sponges, coelenterates or a segmented worm, although there are other animals that can produce contact injury.

Sponges

There are about 12 toxic species of sponges that are the source of a poorly understood toxin that may cause a contact dermatitis. Frequently, the diver is unaware of the contact until symptoms develop later, with the appearance of an itching rash. This type of injury is uncomfortable, but not life-threatening. Within the first few hours, the application of vinegar for 30 to 45 minutes to the area of contact may be helpful.

Coelenterates / Cnidaria

This phylum includes thousands of species of aquatic invertebrates and is responsible for more envenomations than any other marine phyla. Close to 9,000 species of coelenterates are known, of which at least 100 are capable of injury to humans. A common factor among animals in this phylum, which include Portuguese man-of-war, fire coral, box jellyfish, true jellyfish and sea anemones, is the presence of nematocysts (stinging capsules).

Of several types of nematocysts, those of the penetrating type usually cause injury. They are needlelike, up to 0.02 inches / 0.5 mm long and discharge venom. The triggering mechanism is initiated by many factors, including physical contact, stimulation by fresh water, or by a chemically mediated mechanism. The identity of the animal frequently can be determined by examination of the nematocysts under a microscope.

The pattern of the coelenterate sting is characteristic for each animal and depends on the morphology of the tentacle and the aggregation of nematocysts.

The sting of the Portuguese man-of-war (*Physalia physalis*) demonstrates single long stripes with blisters. The box jellyfish (*Chironex fleckeri*) pattern consists of multiple long and relatively broad red lines with adherent tentacles in a cross-hatched pattern. The nonmobile species (fire coral, sea anemones and hydroids) produce a pattern related to how they were touched.

Portuguese man-of-war

Sometimes the injured diver develops symptoms immediately after contact and can even identify the responsible animal. Jellyfish and the Portuguese man-of-war are not always easy to locate in the water, but the pattern of the injury and tentacles remaining on the skin can lead to identification. The Portuguese man-of-war is the most common coelenterate causing serious injury in swimmers and divers.

The Portuguese man-of-war is distributed by tides and currents over the surface of the oceans. The specialized fishing tentacles may stretch out 50 feet / 15 meters from the floating sail and are dangerous. They are difficult to see, even in clear water, and may become detached from the main body of the animal in rough seas. Contact with a single tentacle may cause the release of hundreds of thousands of nematocysts, each bearing venom. Frequently, many tentacles and millions of nematocysts are involved in producing injury.

The jellyfish of the Cubozoa class, including the box jellyfish (also known as the sea wasp), contain several individual species that are the most venomous marine animals known and capable of causing major human injury. The most venomous species of the Cubozoa class are restricted to the warm waters of the Indo-Pacific region. The animals are pale in color, transparent and almost invisible. They are able to swim at speeds of 1 knot with — or even against — currents.

Fatalities have occurred in the waters of northern Australia and the Philippines. The Gulf Coast sea wasp (*Chiropsalmus quadrumanus*, a different species than the one found in the Pacific) of the United States is not as toxic, but is dangerous and is known to have caused a fatality. This creature has a body which is boxlike and about 8 inches / 20 cm long. There are 15 tentacles per pedalium (corner appendage attached to the body), and each tentacle is about 10 ft / 3 m in length.

Bristle Worms

Bristle worms are segmented worms found at depths accessible to divers as well as elsewhere in the oceans. The appendages on each segment of the worm are tipped with bristles, which are a form of armament. These detach easily on contact with the skin, producing pain for several hours. The larger worms can also cause injury by biting.

General Effects

Sponges

An itching rash may develop within a few hours after contact with a sponge and is similar to the rash of contact with other mildly toxic marine animals. It is safe to assume that a diver who has handled a sponge and develops a rash on the hands has been exposed to a toxic species. The reactions are usually mild and subside in a few days with little or no treatment, but they can become quite severe, with pain and blistering.

Coelenterates

Box jellyfish *

The reaction to coelenterate envenomation may range from mild stinging from fire coral, lasting only minutes, all the way to death, which can occur within six to seven minutes of contact with a box jellyfish. If the animal was not identified at the time of contact, the geographic location of the dive, the character of the wound and the systemic reaction may identify the culprit. Coelenterate venoms are complex mixtures of proteins and carbohydrates and share common characteristics as well as species-specific effects. Allergic reactions are possible, and may be severe or life threatening.

Reactions to the venoms from hydroids, sea anemones and coral are usually mild, self-limited and require little, if any, treatment. But a few sea anemones are capable of producing a severe, even fatal, injury.

The larvae of the thimble jellyfish (e.g., *Linuche unguiculata*), among others, produce an itchy, red rash with blisters or bumps generally on skin areas covered by bathing suits. Erroneously believed caused by "sea lice," this is known as "sea bather's eruption."

The severe reactions to marine animal injuries, some possibly life-threatening, are usually the result of envenomation by Portuguese man-of-war or a member of the Cubozoa class. If the injured diver is in Indo-Pacific waters, it is important to identify the animal, if possible, because of the availability of an antivenom to the Australian box jellyfish (*Chironex fleckeri*). The local effects of *C. fleckeri* envenomation are multiple, interlacing whiplash lines with a "frosted," "beaded" or "ladder" pattern and transverse wheals (welts). After seven to 10 days there is necrosis (local tissue death) and ulceration. The skin lesions require months to heal. The clinical

* Photo courtesy OAR/National Undersea Research Program (NURP); University of Connecticut

features are excruciating pain, followed by confusion, unconsciousness and, rarely, death due to respiratory failure. If death occurs, it is usually in the first 10 minutes, and survival is likely if death does not occur during the first hour after injury. The cardiovascular effects include an initial rise in blood pressure followed by hypotensive / hypertensive oscillations, shock, muscle spasm, and muscular and breathing paralysis.

Clinical features of the other Cubozoa and the Physalia injuries are similar and range from mild itching to a severe systemic reaction, where intensity increases with time. The skin shows an injury pattern consistent with the tentacle contact, with an immediate stinging sensation with a rapid increase in pain and accompanied by numbness and tingling.

The major risk after contact is drowning if the individual, due to the pain and confusion, is unable to maintain buoyancy in the water. Within a few hours, contact points show blistering, swelling and discoloration, followed during the next days by skin ulcers and possible secondary infection.

Bristle Worms

The bristle worm contact produces an immediate reaction: a sensation of burning, followed by a red rash that itches intensely and has local swelling.

Prevention

Over-the-counter preparations such as Safe Sea® jellyfish-safe protective lotion, may help in preventing stings from sea life. Available from local scuba retailers, the lotion, in a preparation with or without sunscreen, prevents stings from jellyfish, sea nettles, stinging coral and sea anemones, according to its manufacturer. It is applied before entering the water. The length of time an application lasts in the water may vary depending upon water conditions.

FIRST AID TREATMENT — CONTACT INJURY

Sponges

Following known contact with a sponge that has produced symptoms, the skin should be gently dried and foreign material such as spicules (minute, spiky bodies that support sponge tissue) removed with adhesive tape. Follow that with a vinegar soak that can be repeated several times a day. After initial treatment, a moisturizing lotion or mild over-the-counter steroid cream can help in relieving symptoms during the period required for healing. If the reaction is severe, potent topical or systemic steroids may be prescribed by a physician.

Coelenterates

The first step in managing a severe coelenterate injury is to prevent drowning and use resuscitative measures if needed. Anticipate an allergic reaction and treat appropriately.

After the diver has been rescued, the tentacles must be removed from the skin without triggering the release of more nematocysts. Use gloves ("double glove" if possible if wearing thin surgical gloves) to handle the tentacles, and irrigate the area with large amounts of sea water. Freshwater irrigation may cause the nematocysts to discharge, causing more pain to the injured diver. Researchers in Australia have suggested that applying topical isopropyl ("rubbing") alcohol may cause nematocysts to discharge, but many observers note that it is an effective field treatment that improves, rather than worsens, the situation.

For stings from box jellyfish, apply a dilute vinegar solution (3 to 5 percent acetic acid) to disable the stinging capsules. Do not rub the area or apply the pressure-immobilization technique. Prompt medical attention is needed, so that antivenom can be administered if it is necessary and available.

If the injury occurs in the Indo-Pacific area, identification of the animal is important. As noted on the previous page, there is an antivenom available for the box jellyfish (Commonwealth Serum Laboratory, Australia — CSL Limited: www.CSL.com.au). Trained lifesavers have administered this product successfully nearly a hundred times in the field.

Bristle Worms

Remove visible bristles with tweezers or forceps, followed by an application of adhesive tape to the dry skin to remove the remaining bristles. Flushing the area afterwards with dilute vinegar, ammonia or isopropyl alcohol may be beneficial.

Puncture Wounds

Spines

Puncture wounds are frequently due to an encounter with an animal equipped with a spine. Adapted by animals for various purposes, spines are generally used for protection, although animals frequently use specialized spines for tasks like locomotion and gathering prey. Spines may be concealed or highlighted, slashing or penetrating and venomous or non-venomous. Some are fragile and needlelike, while others are large and strong, with recurved teeth.

Animals in several phyla possess spines that are alike in the principle of operation, but that differ in location, size, potency of venom and degree of hazard to the diver. Both invertebrate and vertebrate animals have spines, and an examination of the characteristics and functions of spines found in each group is useful.

Echinoderms

Sea urchins and sea stars are members of the 6,000 species of echinoderms, approximately 80 of which are venomous to man. They are worldwide in distribution. Sea urchins are nocturnal animals that seek shelter during daylight in coral reefs and niches. Starfish are active during daylight hours, although they are commonly seen during night dives.

Echinoderms, which are radially symmetrical animals, usually have five arms or radii and a more or less rigid skeleton embedded in the body wall.

There are two known venomous starfish: the *Acanthaster planci* (crown of thorns), found in the Indo-Pacific and Red Sea, and *Acanthaster elissi*, found in the eastern Pacific. The outer surface of the body of both is covered by large, sharp spines, calcareous structures that may break off upon penetration and are then difficult to remove from the wound. Glands in the animal's skin produce a venom which causes a severe inflammatory response consisting of redness and swelling; it is associated with severe pain, vomiting, numbness and, rarely, paralysis.

There are many hazardous sea urchin species; all produce similar symptoms. Sea urchins are equipped with spines that vary greatly among species: In some, they are long, hollow, slender and needle sharp. The sharpness permits them to penetrate easily and then break because of their brittleness. Many spines contain a calcium carbonate core and cause injury by mechanical skin penetration. The embedded spine is frequently visible, or in some cases it may have withdrawn and left behind pigment, producing a characteristic "tattooing" at the site.

Penetration by the spine can result in an immediate burning sensation, followed quickly by redness, swelling and aching. The wound is complicated by deposition of calcareous foreign bodies and a reaction to toxic venom. More serious symptoms of numbness and paralysis have been reported, and infection is common.

The spines are of three types: straight hollow, straight solid and pedicellariae used for grasping. The pedicellariae have a three-pronged "fang" at the end that surrounds a venom gland. The pedicellariae seize any organic material they encounter and inject the venom.

The sea urchins with pedicellariae capable of delivering the most potent stings belong to the Toxopneustidae family. Found in the Indo-Pacific region, they possess short, thick spines and deliver a venom.

First Aid Treatment — Echinoderms

Spine fragments must be removed to prevent a granulomatous (infected, chronically inflamed) reaction from occurring many months later. Remove long spines along their vertical axis, using care not to break them. Do not break up the spines under the skin to leave them in place; they may not be absorbed. A local anesthetic can be infiltrated by qualified medical people to relieve pain. A bath of hot water for 30 to 60 minutes or more sometimes relieves pain. No other field remedy has a verifiable benefit.

Stingrays (Order Rajiformes)

Stingray injuries are fairly common in most warm and tropical U.S. waters. These injuries can be serious. There are estimates of more than 1,500 injuries per year in the United States from these animals. With one exception, stingrays are marine.

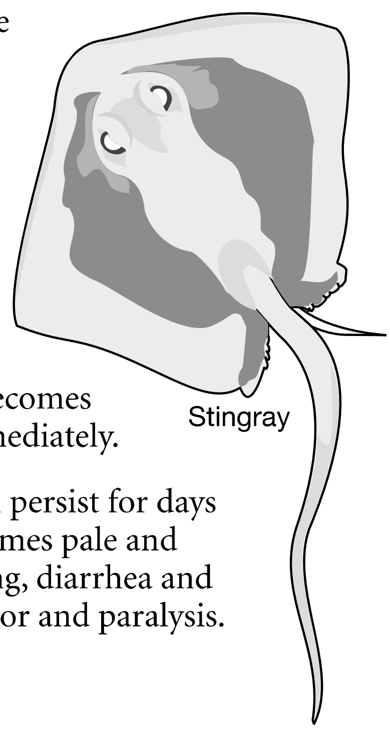
Their favorite habitats are sandy areas, shoals or river mouths in shallow water. They lie on top of the sand or partially burrowed with only the eyes, gill slits and caudal appendage ("tail") visible. The stinging spine is part of the tail and situated near the base. The spine is made of a hard cartilaginous material and has sharp, recurved teeth along either side. There are deep grooves on the underside of the spine, where the venom glands are located. The spine is covered by an integumentary sheath, which protects the stinging organ.

Most injuries occur when a person steps on an unsuspecting stingray lying in the sand; this can result in a defensive response by the animal.

The injury begins as a puncture wound when the spine penetrates the skin. It then becomes a jagged laceration as the spine is withdrawn, and the recurved teeth inflict further injury while venom is injected into the wound.

The sheath remains behind in fragments so that the wound contains:

- a foreign body (the sheath)
- venom
- some seriously damaged tissue
- inevitably, bacterial contamination.



Stingray

The result is a complicated injury that may require extensive treatment and prolonged healing time. Infection is a high probability in any marine puncture wound. If the affected area becomes painful, swollen or red, seek medical attention immediately.

Clinical features of the injury include pain that can persist for days and a bleeding laceration in an area that soon becomes pale and swollen. The venom may cause nausea and vomiting, diarrhea and appetite loss. There may be muscular cramps, tremor and paralysis.

The heart and blood vessels are affected, depending on the amount of venom injected. A small dose may cause a slowing of heart rate and a fall in blood pressure. A large dose can cause a disturbance in heartbeat and coronary circulation and can even produce respiratory depression. Fatalities have occurred when the stingray spine perforated the heart, chest cavity or abdominal cavity.

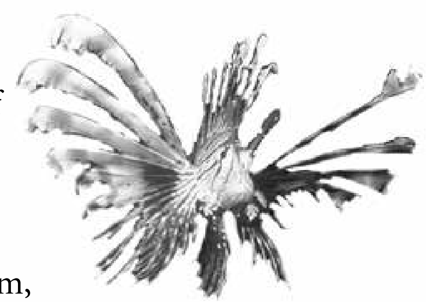
The venomous stingray species are numerous. Members of the Dasyatidae are probably the most common, with representatives around the world. Other species capable of harm include the spotted eagle ray, Aetobatis narinari; the California bat ray, *Myliobatis californicus*; the cow-nosed ray, *Rhinoptera bonasus*; and the Urolophidae, or round stingrays.

First Aid Treatment — Stingrays

Irrigate the wound to remove venom, and attempt to extract the spine and integument, a membrane or sheath covering the spine. If possible, remove all traces of the sheath. However, if the spine has penetrated in a location where it may be occluding severe bleeding, such as deeply into the abdomen, chest or neck, leave it in place until you reach a medical facility. If an arm or leg is injured, immerse the area in hot water at 113°F / 45°C for 30 to 90 minutes or until the pain is relieved. This maneuver may be insufficient to relieve pain, so that pain medications and/or local anesthetic injection by a medical professional is necessary. Monitor the pulse and respirations, and provide resuscitation as needed.

Fish Stings

There are many fish species with spines capable of injecting a venom. The spines may be concealed, as in stonefish, or highlighted, as in lionfish as a warning to predators.



Lionfish

This ability is nearly always a protective mechanism, and not as likely to affect divers as fishermen, who handle the fish by net or line.

Ratfish

The ratfish (*Hydrolagus colliei*) are cartilaginous fish that prefer cold water; they are found from the surface down to 9,843 ft / 3,000 m. They have two dorsal fins, the second of which has a venomous, sharp spine at the anterior edge that curves rearward; it is raised only when the animal is threatened. Although it is difficult for a diver to touch a ratfish underwater, they move away before the opportunity arises. These animals can inflict a painful wound if the spine penetrates tissue. There is immediate pain increasing in intensity, then gradually decreasing; the pain can persist for days. The area around the wound becomes numb and cyanotic, with the appearance of a severe inflammation.

II

Catfish

Catfish are a large group of species — most of which are freshwater — with a few marine species. There is a single, strong, needle-sharp spine located in front of the dorsal and pectoral fins. The spine is covered by an integumentary sheath that contains the venom glands. A few species have recurved teeth along the spine. These teeth can lacerate a wound, enhancing venom absorption and increasing the likelihood of infection. Two common species in the United States are the "sea catfish" (*Galeichthys felis*) and the freshwater Carolina madtom (*Noturus furiosus*). The gafftopsail catfish (*Bagre marinus*) inhabits the east coast of the Americas from New England to Brazil.

Weeverfish

The weeverfish are small, attractive but aggressive marine fish with a well-developed venom apparatus. They may be a real danger to a diver. The weevers bury themselves in soft sand until they dart out rapidly to strike. They have a series of dorsal spines with venom glands, producing a venom that affects the nervous system and the blood cells.

The pain from a sting is instant and rapidly worsens to excruciating levels. If not treated, the pain will subside in about 24 hours, although full recovery may take several days to months. There have been very severe reactions reported, including death. Two European species include the greater weeverfish (*Trachinus draco*) and the lesser weeverfish (*T. vipera*).

Scorpionfish/Stonefish

Scorpionfish

Scorpionfish (family Scorpaenidae) and stonefish (family Synancejidae) are found worldwide in tropical and temperate areas. The family Scorpaenidae can be divided into scorpionfish (Scorpaena) and lionfish, also known as zebra or turkeyfish (Pterois).

The most deadly punctures comes from the stonefish, or devilfish (*Synanceia horrida*), of the Indo-Pacific. Both scorpionfish and stonefish are shallow-water dwellers and may be found on sandy bottoms, rocks or coral reefs. Their protective camouflage coloring makes them extremely difficult to see. Accidental encounters are common with scorpionfish.

The zebrafish are beautiful, ornate coral reef fish usually found in shallow water hovering over a crevice or resting on a fixed object. They are fearless, and handling one of these fish can result in an extremely painful experience. Marine aquarium hobbyists are occasionally stung by such animals kept in home aquariums.

The spines of these groups differ somewhat, but all deliver venom. The stonefish is perhaps the most dangerous, as its spines are very strong. The symptoms of a sting are quite similar for all species. Identification of the responsible fish may not be possible, but there is no great variety in symptomatology regardless of the species responsible. There is immediate pain, with increasing intensity and a dusky, blue-colored wound that remains the same for several hours and then begins to improve if the sting is minor. If the sting is severe, the situation can continue to worsen up to a severity necessitating amputation of a portion of a foot.

There is an antivenom available for stonefish stings from Commonwealth Serum Laboratories (CSL Limited) in Australia (www.csl.com.au).

Toadfish

The numerous species of toadfish (family Batrachoididae) are small bottom fish that inhabit most of the warm-water coastal areas of the world. The fish from the genus Thalassophryne are the venomous ones, while the rest are generally harmless.

Toadfish have broad, depressed heads and large mouths. They have two dorsal fin spines with venom glands and another spine located in the gill cover. Anglers are the frequent victims of a sting when they attempt to remove a hooked fish from their line. The pain is similar to that of the scorpionfish and develops rapidly, with intense pain followed by swelling, redness and heat. There are no recorded fatalities, and the symptoms subside within a few days.

Surgeonfish

Family Acanthuridae contains both surgeonfish and tangs and have spines that resemble scalpels near the tail. If the fish is threatened, it extends the spine and lashes out with its tail. Contact with the spine can produce a deep, painful laceration. There may be a venom associated with this spine.

Other Species

There are other fish with venomous spines capable of producing wounds in divers. These include the gurnards (family Dactylopteridae); sea robins (family Triglidae); dragonets (family Callionymidae); rabbitfish (family Siganidae); scats (family Scatophagidae); stargazers (family Uranoscopidae); and leatherbacks (family Carangidae).

FIRST AID TREATMENT — FISH LACERATIONS, STINGS

The wounds produced by the various species of animals with venomous spines have common features. The wounds are frequently lacerations and puncture wounds, containing venom, foreign material (e.g., dirt or sand), and contaminated with bacteria. The basic principles of wound care apply to these injuries after the injured diver has been initially evaluated and stabilized. It is important to relieve pain as promptly as possible and to cleanse the wound of all foreign material using sterile technique if available.

Irrigation of the wound may remove venom as well as portions of the integumentary sheath (layer of skin or membrane covering or enclosing the spine), slime, sand, etc. If any foreign material remains, healing will be delayed or may not occur. Many of these venoms respond to heat therapy, and a hot soak at a temperature not to exceed 113°F / 45°C should be initiated for 30 to 90 minutes.

The care of these wounds can be summarized as follows:

- Resuscitate as needed.
- Rest affected area in a position of comfort.
- Immerse the wound in hot water to tolerance (115°F / 45°C) for 30 to 90 minutes or until pain is relieved and does not recur.
- Use local anesthetic, if needed for pain relief.
- Remove foreign body.
- Apply general wound care, including antibiotics if needed.
- Systemic analgesics or narcotics are rarely needed.
- Do not use ligatures, tourniquets or pressure bandages.
- Seek medical attention

Some of these wounds will be severe either due to the size of the animal (stingray) or the potency of the venom (stonefish). The stingray wound may require surgical exploration and surgical removal of foreign material and damaged tissue. The stonefish injury may require an antivenom, which itself may be hazardous.

To avoid infection, keep the wound clean. Victims of these injuries should be treated at a local medical facility, the sophistication of which will depend on the location of the diving area. Divers Alert Network can frequently advise concerning immediate care of these injuries and refer to appropriate medical centers. DAN Members, of course, can be evacuated at no cost.

Blue-Ringed Octopus

The blue-ringed octopus (*Hapalochaena maculosa* and *Hapalochlaena lunulata*) is found around countries and islands of the Indo-Pacific area. These animals are small (0.4-3.5 oz / 10-100 gm weight; 0.8-8 in / 2-20 cm length) and attractively colored with yellowish-brown rings on the tentacles and striations on the body. When alarmed, the rings turn a striking iridescent blue. They are frequently found in tidal pools and shallows around reefs.

Clinical Features

Most bites from the blue-ringed octopus have minor effects. The bite may be painless and unnoticed at first. However, in some cases a 0.4 inch / 1.0 cm blanched area may develop with swelling, with an occasional blood blister. There may be a clear, yellowish or bloody discharge from the wound.

There have been cases in which, within minutes, a rapid, painless paralysis progresses, beginning with numbness and tingling sensations around the mouth, neck and head. Other symptoms include nausea, vomiting and shortness of breath, with rapid, shallow respirations. The injured person may also experience disturbances in vision, with paralysis of eye movement and fixed, dilated pupils.

As paralysis progresses, speech and swallowing may become difficult, with generalized weakness and incoordination, and, finally, complete paralysis lasting four to 12 hours. The victim may be conscious, but unable to respond.

First Aid Treatment — Blue-Ringed Octopus

If the bite is on an extremity, immobilize the limb and apply a pressure bandage.

Prompt medical attention is required, but cardiopulmonary resuscitation is rarely required. Be prepared to support the victim's breathing. The venom of the blue-ringed octopus is tetrodotoxin, the same paralytic toxin found in pufferfish. Seek medical treatment as soon as possible.

Cone Shells

Cone shells (family Conidae) are collectors' favorites. These univalve mollusks are up to 4 inches / 10 cm in length and have a proboscis extendable from the narrow end, which can reach around to the rear of the animal's shell. The proboscis carries one to 20 venomous radular teeth, which can be extended to pierce the skin or a thin diveskin.


Cone shell

The animals inhabit shallows, reefs, ponds and rubble, burying themselves in sand with siphon exposed. The fish-eating cones are the dangerous ones; their venom consists of two or more substances that produce neuromuscular interference with sustained contraction. These substances also can have major effects on skeletal muscular activity.

Clinical Features

The venom produces inflammation, swelling and, often, severe pain. If present, pain is aggravated by salt water; the area becomes pale, bluish in color and numb. The general symptoms are numbness and tingling that can ascend from the bite to the entire body in about 10 minutes, especially in the areas around the mouth and lips.

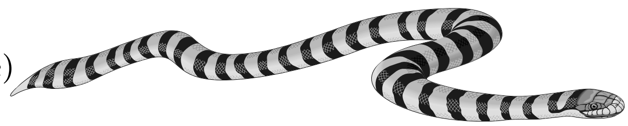
Skeletal muscle involvement spreads from the site. It usually starts as a mild weakness and may progress to a point where the injured diver's limb is completely limp and no voluntary movement is possible; this is known as flaccid paralysis. Swallowing and speech become difficult. There is visual impairment: double vision, blurred vision, paralyzed voluntary muscles and paralyzed pupillary reactions developing within 10-30 minutes. Respiratory paralysis may dominate, with shallow, rapid breathing, cyanosis, apnea and coma, followed by death.

First Aid Treatment — Cone Shells

If paralysis is not present, keep the patient at rest and reassure him. If the bite is on an extremity, it should be immobilized and a pressure bandage applied. Seek immediate medical assistance.

If the injured person experiences paralysis, provide cardiopulmonary resuscitation as needed. The individual may be conscious, but unable to communicate. Breathing support — mouth-to-mouth or other artificial ventilation — may be required until medical help is available.

Sea Snakes


Sea snake

Sea snakes (family Hydrophiidae) are reptiles found only in the tropical and temperate waters of the Indo-Pacific, usually in coastal waters, but sometimes far at sea. Sea snakes do not occur in the North or South Atlantic or in the Caribbean. There are approximately 50 species and all are venomous, although only a few species have been implicated in serious human envenomations or fatalities. Sea snakes may be aggressive at times, especially if handled or threatened. They are characterized by a flat paddle-shaped tail not seen on any land snake.

The venom is more toxic than cobra venom, but less is delivered; only about a quarter of the bites become symptomatic. The snakes have a delivery apparatus developed for small prey and not very hazardous to humans. In most species, the fangs are short, easily dislodged from their sockets, and not able to penetrate a wetsuit. The venom is a heat-stable, non-enzymatic protein that blocks neuromuscular transmission.

Clinical Features

The puncture wound will usually show from one to four marks, although as many as 20 are possible. There may be fangs embedded in the wound or wetsuit. For the individual who is bitten, there may be a symptom-free interval of 10 minutes to several hours. If generalized symptoms do not appear in six to eight hours, significant poisoning has likely not occurred.

The initial symptoms may be euphoria and anxiety, with restlessness, thirst, nausea and vomiting. More severe symptoms may develop and extend centrally from the bit. These may include painful muscle spasms and ascending paralysis, leading to respiratory failure and death.

First Aid Treatment — Sea Snake

Australian authorities recommend pressure bandages around the bite, but do not recommend application of a tourniquet. Immobilize the bitten body part and do not allow exertion. Do not attempt incision and drainage of the area to remove venom.

Be prepared to begin cardiopulmonary resuscitation. A nonspecific antivenom is available (Commonwealth Serum Laboratory, Australia — website: www.csl.com.au), but should be restricted for use by physicians.

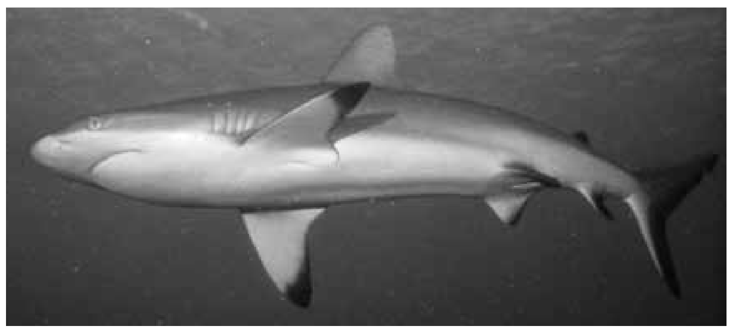
LACERATIONS, AVULSIONS, AMPUTATIONS

Some puncture wounds described may also have the characteristics of a laceration. There are a few marine animals capable of causing a major laceration, including sharp coral edges and predatory reef fish.

Coral lacerations may appear to be clean, but may become inflamed, swollen and tender within a few hours. The coral can discharge nematocysts directly into the wound, allowing venom to be injected, accompanied by bacterial and coral fragment contamination; a foreign-body reaction to the nematocysts and coral fragments occurs. Bacterial contamination may lead to abscess formation.

The shark is probably the most impressive of marine animals capable of harm to humans. Shark attack is a genuine but very unlikely danger — most divers consider themselves fortunate to even see a shark.

The very few encounters that result in injury usually occur after a shark perceives a threat, is molested in some way, or is enticed by some object on the diver (fish on a stringer, for example).



One typical attack pattern begins with a bump or brush contact with the prey by the shark; this produces an abrasion that can be extensive. If the shark continues with the attack, it will bite from a horizontal or slightly

UNPROVEN — AND POSSIBLY HARMFUL — FOLK REMEDIES

Marine biotoxicology is in its infancy, and there is little funding for research. The treatments for marine animal injury, therefore, are largely based on experience and anecdotal reference. Most of the treatments in use have supporters and detractors who engage in heated debate concerning efficacy. Much remains to be done to discover reliable treatments based on sound research.

There are many therapies, unproven, possibly harmful, or even dangerous, and not recommended, advocated from time to time.

Some examples of these unproved, possibly harmful actions include:

- Urinating on the injury site
- Incision of fish sting and snake bite wounds
- Applying oil or gasoline to an injury
- Applications of oxidizing agents, strong alkalis or acidic substances

upward position, with the head back and the upper teeth projecting forward. This can produce a major injury. The wound is characterized by a crescent-shaped rim with separate incisions from each tooth on the rim. There are usually tooth fragments in the wound and a crushing injury with tissues torn from the body and severe hemorrhage.

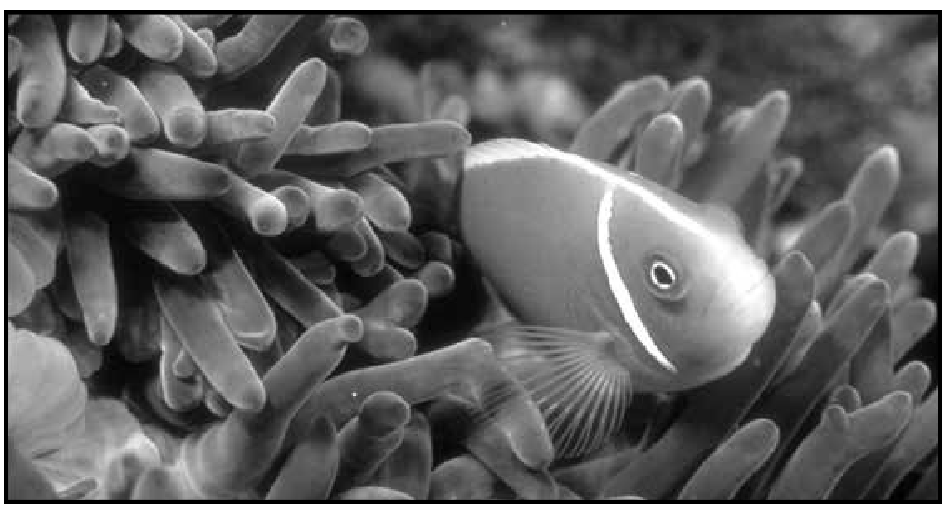
If the shark did not complete the bite, there may be only bruising and abrasive injury with teeth marks. Usually there is a single bite. Amputations and extensive body wounds are common; massive bleeding and shock are major immediate complications.

First Aid Treatment: Shark Attack and Major Lacerations

Remove the injured person from the water and immediately begin measures to control bleeding. This is best accomplished by direct pressure over the bleeding vessels; firm pressure on an artery generally will quickly stop bleeding.

When direct pressure is not successful in controlling the bleeding, apply a tourniquet between the wound and the heart; it must be tight enough to stop arterial blood flow. Use a tourniquet on extremities only. Once , a tourniquet applied, do not release it until definitive therapy is available or bleeding is felt to be controlled by pressure techniques alone.

The injured person should be placed in a head-down/legs elevated position to combat shock and kept warm, even in a warm climate. Medical assistance must be obtained for intravenous fluid resuscitation as quickly as possible. The requirements may be massive, and fluid administration should begin before hospital transfer if possible. Do not give anything by mouth.



The clownfish, or anemone fish (family Pomacentridae; subfamily Amphiprionae), inhabits the anemone surrounded by its stinging cells.

PREVENTION OF MARINE ANIMAL INJURIES

- Avoid contact with the animal: this sounds simple, but it may not be if you have poor buoyancy control and/or are experiencing conditions of poor visibility, currents, confined areas or other environmental limitations.
- Do not attempt to handle, tease, feed or annoy any marine animal. Do not explore a crevice with your hand; that can promote a reaction by a concealed animal defending itself.
- Strive to develop excellent buoyancy control and remain aware of what surrounds you.
- Do not allow a current to force you against a fixed object; it may be covered with marine animals.
- Wear protective clothing.
- Make an effort to find out which animals you may encounter in your dive and learn about their characteristics and habitats before you begin the dive. This will help you enjoy your dive more and prevent possible injury from the animals you encounter.

SECTION III: DISORDERS THAT REQUIRE RECOMPRESSION

Careful observation and common sense are both needed to respond appropriately to a suspected case of decompression illness (DCI).

If you suspect DCI, steps to follow include answering these questions:

- Is something seriously wrong with the individual?
- How rapidly is the condition changing?
- How should the injured person be stabilized on site?
- What help is needed, and where it should be obtained?

An individual with shoulder pain that is unchanged over several hours is obviously in a less critical condition than someone who surfaces unconscious.

RECOGNIZING DECOMPRESSION ILLNESS

Decompression illness (DCI) is a term that includes **arterial gas embolism (AGE)** and **decompression sickness (DCS)**. These two diseases are described separately below because their presumed causes are different. From a practical standpoint, however, distinguishing them from one another based on the diver's signs and symptoms may be impossible. The initial treatment and stabilization are the same for both conditions.

Arterial Gas Embolism (AGE)

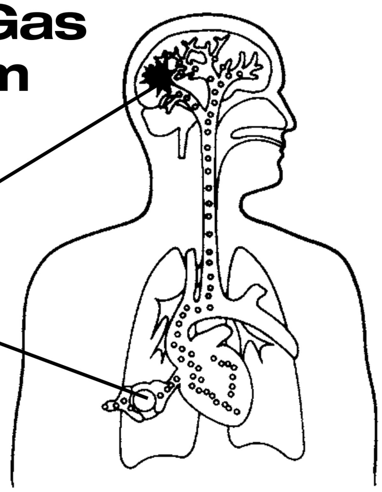
If a diver ascends without exhaling, air trapped in the lungs expands and may rupture lung tissue, releasing gas bubbles into the arterial circulation. Bubbles are then carried to body tissues, including vital organs such as the heart and brain. When lodged in small arteries, bubbles may interrupt circulation; they may damage the lining of vessels and impair flow even if they pass through without being trapped. This is air embolism, or arterial gas embolism. When AGE affects the brain, it is called a cerebral arterial gas embolism (CAGE).

This condition can occur when, in some cases, divers may have made a panic ascent, or held their breath during ascent. However, air embolism can occur even if ascent appeared normal. Some lung conditions (such as asthma) can cause gas-trapping during ascent, and subsequent AGE.

The effects of reduced circulation to the brain are critical, often leading to unconsciousness and paralysis; they require immediate treatment.

The most dramatic sign of air embolism is the diver who loses consciousness within 10 minutes of surfacing. In these cases, a true medical emergency exists, and rapid evacuation to a treatment facility is paramount.

Arterial Gas Embolism



Some cases of AGE occur in divers who surface awake and have minimal symptoms of neurological dysfunction.

If the diver experiences only symptoms such as tingling, numbness, weakness, difficulty in thinking, then there is time for a more thorough evaluation to rule out other causes.

Signs & Symptoms of AGE

- Paralysis or weakness
- Convulsions
- Dizziness
- Visual blurring
- Personality change
- Bloody froth from mouth or nose (sign of possible pulmonary barotrauma)
- Unconsciousness
- Cessation of breathing
- Chest pain
- Disorientation
- Death

Note: Symptoms and signs usually appear during or immediately after surfacing and may resemble a stroke.

Prevention

Relax and breathe normally during ascent. Lung conditions such as asthma, infections, cysts, tumors, scar tissue from surgery or obstructive lung disease may predispose to air embolism. If you have any of these conditions, then you should be evaluated by a dive physician.

Treatment — Call DAN!

The early management of air embolism and decompression sickness is the same and is covered in the Immediate Care section that follows. Although a diver with an air embolism requires urgent recompression for definitive treatment, patient stabilization and early medical management at the nearest medical facility may be appropriate before transportation to a more distant chamber.

Oxygen first aid may be highly effective and is strongly recommended for AGE. Signs of air embolism and serious DCS often disappear after initial oxygen breathing, but they may reappear later. Because of the possibility of delayed recurrence, always contact DAN or a dive physician, even if the symptoms and signs seem to have resolved. Recompression therapy for an air embolism can be effective even if delayed, although a cure may be more likely with early treatment.

Decompression Sickness (DCS)

Decompression sickness (also called the bends, or caisson disease) is the result of decompression following exposure to increased pressure. During a dive, the body tissues absorb nitrogen from the breathing gas in proportion to the surrounding pressure. As long as the diver remains at pressure, the gas presents no problem. When pressure is decreased (such as on ascent), the nitrogen can come out of solution and form bubbles in the tissues and bloodstream. In order to minimize the likelihood of DCS, it is always wise to stay away from the very edge of dive computer / table limits and to use those devices conservatively.

Bubbles forming in or near joints are the presumed cause of the joint pain of a classical "bend." More serious manifestations such as paralysis can be caused by bubbles in the spinal cord or brain.

Who gets decompression sickness? There is great individual variation. Some divers can develop decompression sickness even when other divers making the same dive remain symptom-free. These variations are caused by myriad factors, most unknown. Evaluation of a diver for symptoms of DCS, therefore, must be made on an individual basis. The fact that other divers making the same dive are unaffected is no reason to discount the possibility of decompression sickness (or other injury).

Signs & Symptoms of DCS

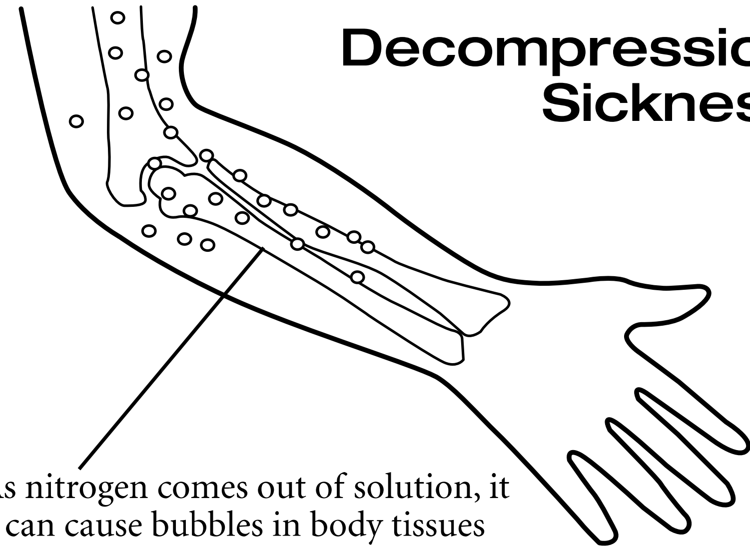
- Pain in joints and/or muscles, arms, legs or torso
- Numbness, tingling
- Dizziness, inability to maintain balance while walking or standing
- Coughing spasms
- Unusual fatigue
- Paralysis, weakness
- Collapse or unconsciousness
- Shortness of breath
- Skin itch or rash

Note: Signs and symptoms usually appear within 24 hours after surfacing; but in severe cases, symptoms may appear before surfacing or immediately afterwards. Delayed occurrence of symptoms is rare, but it does occur, especially if diving is followed by altitude exposure.

Prevention

Recreational divers should dive conservatively, whether they are using dive tables or computers. When using tables, one conservative principle is to select the table depth equal to or greater than the actual depth in order to confer a greater degree of safety. This practice is highly recommended for all divers, especially when diving in cold water or under strenuous conditions such as swimming against a current.

Divers should preferably avoid approaching maximum allowable bottom time, especially when diving deeper than 100 ft / 30 m.
Employing conservative diving practices such as leaving at least 10 minutes of no-stop time on the computer or table will help reduce risk. Using



As nitrogen comes out of solution, it can cause bubbles in body tissues

enriched-air nitrox (EAN) as the breathing mix with an air protocol on the computer or dive tables is also a good way to reduce risk.

For those using tables or computers, the most important risk factors for DCS are dive depth and bottom time. However, other factors include exertion during the dive, rapid ascent, repetitive diving, cold water and diving deeper than 80 ft / 24 m.

Hard exercise immediately after a dive or exposure to altitude or flying after a dive may also increase the risk of DCS. There are also undoubtedly diver-related risk factors. Although it is recognized that some divers seem to be more likely than others to develop DCS, the exact reasons are not yet understood.

Breathing Surface Oxygen

Immediate breathing of high concentrations of oxygen is a highly effective measure in relieving the signs and symptoms of decompression sickness. Use it whenever it is available. The injured person should breathe 100 percent oxygen as long as supplies last or up to a maximum of 12 hours or until medical evaluation. It may be continued for a longer period at the discretion of a physician.

Although oxygen first aid may reduce symptoms substantially, the treatment plan should not be changed even if improvement occurs. In cases with complete relief, consult DAN or a dive physician to determine whether recompression or other follow-up is appropriate.

Recompression treatment for all forms of DCS can be effective, particularly when performed early. Although successful treatment has occurred many days after symptom onset, early therapy is more effective.

FLYING AFTER DIVING

2002 Consensus Guidelines for Flying After Recreational Diving

The following guidelines are the consensus of attendees at the 2002 Flying After Diving Workshop. They apply to air dives followed by flights at cabin altitudes of 2,000 to 8,000 ft (610 to 2,438 m) for divers who do not have symptoms of decompression sickness (DCS).

The suggested preflight surface intervals do not guarantee avoidance of DCS. Longer surface intervals will reduce DCS risk further.

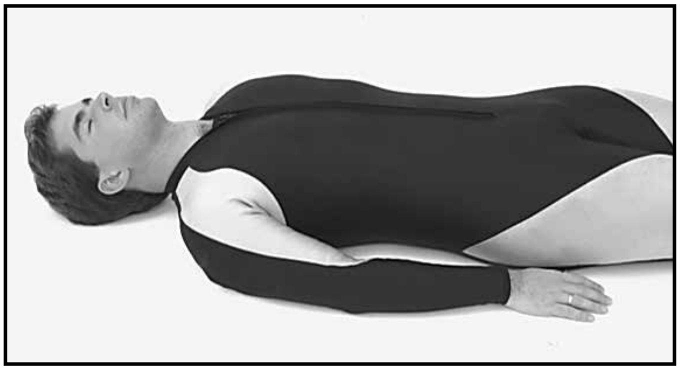
- For a single no-decompression stop dive, a minimum preflight surface interval of 12 hours is suggested.
- For multiple dives per day or multiple days of diving, a minimum preflight surface interval of 18 hours is suggested.
- For dives requiring decompression stops, there is little evidence on which to base a recommendation; therefore, a preflight surface interval longer than 18 hours appears prudent.*

Treatment — Call DAN!

Decompression sickness or air embolism generally requires recompression treatment.

However, the injured diver should usually be stabilized and receive prompt medical treatment at the nearest medical facility before transport to a recompression chamber. If there is no nearby medical or recompression facility, consult with a diving physician or call DAN.

** Sheffield PJ, Vann RD (eds). DAN Flying After Diving Workshop Proceedings. Durham, NC: Divers Alert Network, 2004.*



If cardiorespiratory resuscitation is required, put the injured diver in the supine position. If vomiting occurs in this position, quickly turn the diver on his side to help clear the airway before resuming resuscitation.

CARE OF THE DIVER WITH DECOMPRESSION ILLNESS

Initial Evaluation at the Dive Site

Suspect decompression illness if any of the signs or symptoms previously described occur within 24 hours of surfacing from a dive. The initial state of the affected diver determines the order and urgency of the actions.

Severe

Symptoms are severe and appear rapidly and within an hour of surfacing. Unconsciousness may occur. Symptoms may be progressing, and the diver is obviously ill. The diver may be profoundly dizzy, have trouble breathing or have a significant change in level of consciousness. Obvious neurological injury is present if the injured person shows signs of altered consciousness, abnormal gait or weakness.

These divers are notably very sick, and a true medical emergency exists. Monitor airway and breathing and, if necessary (e.g., if the diver is unconscious), consider CPR and take immediate action to have the diver evacuated. Check for foreign bodies in the airway. If ventilatory or cardiac resuscitation is required, put the injured diver in the supine position (lying on the back). If vomiting occurs in this position, quickly turn the diver on his side in order to facilitate clearing the airway before resuming resuscitation.

Even if CPR is successful and the diver regains consciousness, 100 percent oxygen should be provided and continued until the diver arrives at a medical facility.

The lateral recumbent, or recovery, position places the person on the side with head supported at a low angle and the upper leg bent at the knee to prevent the body from moving forward. If vomiting occurs in this position, gravity assists in keeping the airway clear.

If trained healthcare personnel are available,

and appropriate intravenous administration equipment are available, then an intravenous (IV) infusion using isotonic fluids (crystalloid: normal saline, Lactated Ringers solution, Normosol-R® or a colloid, e.g., a starch solution) without dextrose should be administered. If dehydration is suspected and there is no contraindication to rapid fluid administration (such as heart failure, pulmonary edema or cardiorespiratory DCS, or the "chokes"), an initial rapid infusion of 1 liter of a saline solution as described above should be administered as quickly as possible to begin correction of dehydration and hemoconcentration. Once this is accomplished, the rate of administration should be reduced to a rate appropriate to maintain adequate cardiac output as judged by heart rate, blood pressure and urine output.

Additional fluid boluses may be required, but should only be given by trained healthcare personnel capable of weighing the need for further fluid against possible complications such as pulmonary edema. Divers with spinal cord decompression sickness may be unable to urinate and require bladder catheterization. Large fluid boluses are not recommended for divers with AGE alone (without DCS) or patients with cardiorespiratory DCS or pulmonary edema of any cause.

If trained personnel are available, a urinary catheter should be placed in all unconscious divers and in those who cannot urinate.

After stabilization and arrangements for evacuation are made, contact DAN for the nearest available chamber. DAN medical experts can get in touch with the receiving facility to assist in diagnosis and, if necessary, treatment. Do this even if the diver appears to be improving while using oxygen.

Milder cases, in which manifestations are stable and not life-threatening should be treated with oxygen: Continue with oxygen until the injured person is evaluated medically. Individuals who are alert and not nauseated or vomiting can receive fluids by mouth.

Unless the pain is severe, do not attempt to treat the pain with analgesics until advised to do so by medical personnel. If the diver is not allergic or intolerant to it, acetaminophen or a simple nonsteroidal anti-inflammatory analgesic (e.g., ibuprofen — Advil®, Motrin®) may be used if the pain is severe. Contact DAN or the nearest medical facility for advice on transport, even if symptoms improve or are relieved with oxygen. Emergency air transport may not be necessary in such cases.

While awaiting evacuation, take as detailed a history as possible and try to evaluate and record the diver's neurological status. This information will be useful to those at the receiving medical facility. If air evacuation is used, cabin pressure should be maintained at the highest level (i.e., lowest altitude equivalent) consistent with aircraft safety.

Dive History

If possible, obtain and document the following information:

- For 48 hours preceding the injury, a description of all dives: depths/times, ascent rates, intervals between dives, breathing gases, problems or symptoms
- Symptom onset times and progression, relative to surfacing from last dive
- Description of all first aid measures (including times and method of oxygen delivery) and effect on symptoms since accident
- The results of the on-site neurological examination (described below)
- Description of all joint or other musculoskeletal pain including: location, intensity, changes with movement or weight-bearing
- Description and distribution of any rashes
- Description of any traumatic injuries before, during or after the dive

ON-SITE NEUROLOGICAL EXAMINATION

Information regarding the injured diver's neurological status will be useful to medical personnel in not only deciding the initial course of treatment but also in the effectiveness of treatment. Examination of an injured diver's central nervous system soon after an accident may provide valuable information to the physician responsible for treatment.

The On-Site Neuro Exam is easy to learn and can be done by individuals with no medical experience. Perform as much of the examination as possible, but do not let it interfere with evacuation to a medical treatment facility.

Examination of an injured diver's central nervous system soon after an accident may provide valuable information to the physician responsible for treatment.

The On-Site Neuro Exam is easy to learn and can be performed by individuals with no medical experience.

While it is best to participate in a training course specific to performing neurological assessments, the examination can be done while reading from this manual. **Perform the following steps in order; record the time and results.**

SYMPTOMS

For each symptom, record the locations and time of onset. Symptoms may come and go. Therefore, ask the diver to report periodically.

- Does the diver have any pain anywhere?
- How severe is it? Rate it 0-10: "0" = no pain; "10" = worst pain ever.
- Does it change with movement at the nearest joint?
- Is there any numbness or tingling?
- Is there any vertigo (spinning), dizziness, nausea or vomiting?
- Are there any changes in vision?
- Does the diver have nausea and/or vomiting?
- Is the diver able to urinate?

MENTAL FUNCTION

Consciousness

- Is the diver alert?
- Does the diver respond to commands, only to pain or is he/she unresponsive?

Orientation

- Is the diver oriented to person, place and time?
- Ask: What is your name? Where are you? What time is it?

CRANIAL NERVES

Eyes

- Can the diver move eyes in all directions?
- Any eye twitching (nystagmus)

Face

- Have diver close eyes and smile: Is the face symmetrical?

Hearing

- Is the diver's hearing approximately equal in both ears?
- Can the diver hear your finger and thumb rubbing together at a distance greater than 1 foot while in a quiet place?

Sensation on the face

- Is there any area where light touch or pin prick cannot be felt? Record the location.

MOTOR FUNCTION

- Get the diver to push against you to assess strength in as many muscle groups as you can.
- Check shoulders, biceps and triceps, grip strength.
- Are these all normal, weak or no movement?
- Check flexion and extension of the hips, knees and ankle.
- Are these all normal, weak or no movement?

SENSORY FUNCTION

- Are there any areas where light touch cannot be felt on the body? Record the location.
- Any areas where pin prick cannot be felt? Record the location.

COORDINATION AND BALANCE

- Can the diver walk normally; walks but wobbly; falls over? Check this only on a stable platform.
- Can the diver follow, using one index finger, from his/her nose to your index finger held out in midair? What happens if you move your finger and repeat?

OTHER INFORMATION

- **Record time test performed** .... a.m./p.m.

The diver's condition may prevent the performance of one or more of these tests. Record any omitted test and the reason.

If any of the tests are not normal, suspect injury to the central nervous system.

The tests should be repeated at 60-minute intervals while awaiting assistance to determine whether any change occurs. Report the results to the emergency medical personnel responding to the call. Good diving safety habits would include practicing this examination on normal divers to become proficient in the test.

III At the Medical Treatment Facility

(Information for Medical Personnel)

The following section is aimed at medical personnel: *If, in the course of your rescue or that of a friend, you find yourself at a facility that has not had much experience with divers — do ask — then they may find this part of the guide helpful.*

If an individual has made a dive within the past 24 hours and has joint or muscle pain, skin rashes, hearing or vestibular problems, abnormalities of consciousness or higher mental function, personality changes, cerebellar abnormalities, disorders of sensation or muscle strength or problems emptying the bladder, consider decompression illness in your differential diagnosis.

The definitive treatment for decompression illness is recompression. Initial stabilization should first be accomplished for the Emergency and Urgent patient (see previous section), and 100 percent oxygen should be delivered until definitive recompression can be accomplished.

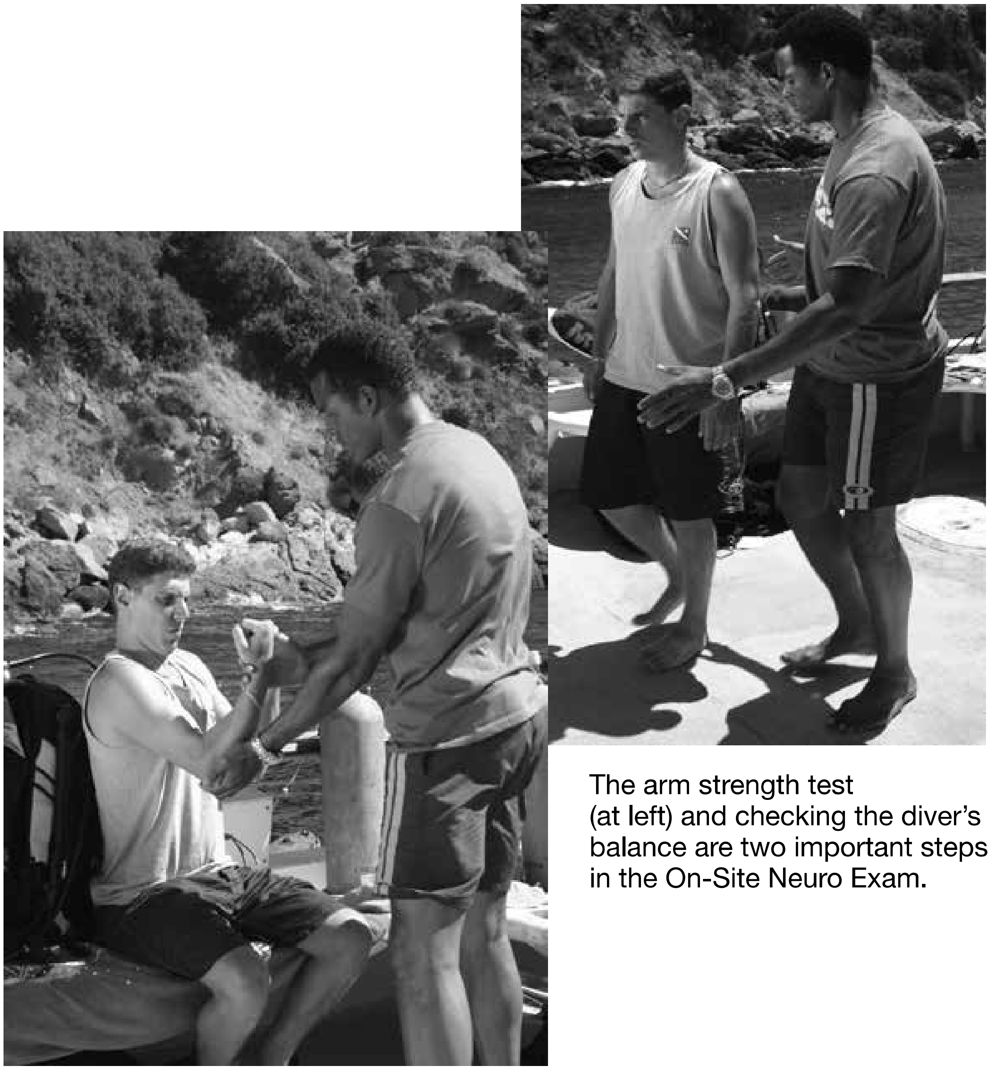
The injured diver should be kept hydrated using an isotonic solution not containing dextrose. If the diver is unconscious or unable to void, then a urinary catheter should be inserted.

If you suspect a diving accident and are unfamiliar with dive medicine, obtain help from a local medical expert or call DAN at +1-919-684-9111 for assistance in deciding whether recompression is needed, where the closest recompression facility is, and in arranging to transport the patient to the treatment facility.

Before consulting with dive medical experts, obtain the following useful information.

- For 48 hours preceding the injury, gather a description of all dives: depths/times, ascent rates, intervals between dives, breathing gases, problems or symptoms. List symptom onset times and progression occurring after surfacing from last dive.
- Describe all first aid measures (including times and method of 100 percent oxygen delivery) and effect on symptoms since the accident.
- A complete neurological exam should include: higher mental function; cerebellar function (finger-nose, gait and tandem gait or ability to walk barefoot heel-toe on a hard floor); strength of all major muscle groups; sensation (e.g., pin prick, light touch, and temperature), proprioception (reception of a stimulus) and coordination.
- Examining of auditory and vestibular function should include presence of hearing or balance deficits, tinnitus, nystagmus and appearance of tympanic membranes.

- Description of all joint or other musculoskeletal pain should include: location, intensity, changes with movement or weight-bearing.
- Note the description and distribution of any rashes. Describe any traumatic injuries before, during or after the dive.



Sara Shoemaker Lind Photos

The arm strength test (at left) and checking the diver's balance are two important steps in the On-Site Neuro Exam.

In-Water Recompression Treatment

What is it? In-water recompression is defined as re-entering the water to a depth of 15 ft / 4.5 m while breathing a high concentration of oxygen (usually 100 percent).

Do it only if you have training. This treatment should never be attempted unless it can be performed by trained, experienced individuals who have all of the proper equipment available.

The Australian system for oxygen treatment in the water may be appropriate for very remote calm-water locations until evacuation can be accomplished.* The system requires advanced planning, immediate access to extensive, essential equipment, a large oxygen supply, and individuals trained in the technique for support of the diver's needs during treatment.

Before embarking on any dive trip, inquire about the emergency support facilities that are available and whether in-water recompression would be used. If so, find out the levels of training of the individuals who would perform this technique.

In-water recompression treatment performed improperly or without extensive training and experience can end with the diver being forced to the surface in cold water, or with an inadequate air supply.

Other problems can include panic, seasickness, difficulty in communications, hypothermia from prolonged exposure to water, hyperoxic convulsions and drowning. In addition, incomplete treatment and further nitrogen uptake by the diver often occurs. Because of all these risks, in-water recompression is an option that is used only when diving in remote areas.

** Edmonds C., Lowry C., Pennefather J. & Walker, R., Diving and Subaquatic Medicine: 4th Ed. Appendix C2, Arnold, London UK; 2002.*

SECTION IV:
Principles of First Aid

CPR/Basic Life Support

Students receiving instruction in oxygen use will have completed training in CPR by a national agency and follow emergency cardiac care guidelines such as those published by the American Heart Association (www.americanheart.org).

Learning CPR procedures is not difficult, but does require training and practice with qualified instructors. This manual is not intended as a resource for learning basic life support, but it is important to review the steps of CPR. Recheck your CPR basic manual for further details.

In the unconscious victim it is common to find obstruction of the upper airway by a foreign body or the tongue. The drowning victim may have a damaged oxygen delivery system and requires massive oxygen supplementation. This section emphasizes the use of oxygen in the event of diving injury and drowning, but it does not approach the many other indications for oxygen treatment.

Oxygen First Aid

Oxygen first aid is one of the most important measures taken at the scene of the accident for the victim of an underwater diving injury before definitive medical care becomes available.

Supplemental oxygen is a valuable adjunct in CPR, in drowning, and in serious accident or injury that impairs the body's ability to transport oxygen to the tissues. The presence of gas bubbles can produce obstruction in blood vessels, thus an interruption of blood supply and cause a cascade of cellular effects.

Decompression illness (DCI) — pulmonary overpressure injury that results in arterial gas embolism (AGE) and decompression sickness (DCS) — are the most important indications for the use of oxygen. Breathing 100 percent oxygen will create a significant gradient from normal tissue to the tissues where the blood flow has been blocked. This may be just enough to prevent or delay permanent injury.

High concentrations of inhaled oxygen are helpful in several ways. DCI is due to the formation of bubbles composed of nitrogen or air. By breathing 100 percent oxygen, a pressure gradient is created between the bubble and the tissues; the bubble becomes smaller and is eventually reabsorbed at a faster rate than if breathing air. The goal is to provide 100 percent oxygen in order to speed nitrogen elimination and get good oxygen supply to hypoxic areas.

The goal of oxygen first aid in pressure-related diving injuries is to provide 100 percent oxygen in order to speed nitrogen elimination and get good oxygen supply to hypoxic areas.

The injured diver should be transported to the nearest medical facility, and a physician knowledgeable in dive medicine should be consulted. Oxygen first aid must **NOT** be considered a substitute for recompression treatment, if this type of treatment is indicated. (See the following pages for guidelines in providing surface oxygen).

DAN has developed a special course in the use of oxygen in diving injuries. This course is taught by DAN-certified instructors throughout the world. See the DAN website for a listing of current DAN instructors or contact DAN.

DAN advises that oxygen and people trained to use oxygen should be available on all dive boats and at all dive sites. The diver should be a prepared diver with CPR, rescue, and oxygen skills and insist that oxygen be available at the dive site or on any boat that will be used for diving.

DCI may involve the central nervous system and can cause cessation of breathing due to damage to the control centers. In this situation, rescue breathing and oxygen administration are essential to prevent death.

The use of oxygen in the early stages following a diving injury may reduce or totally relieve the symptoms within a short time. If this happens, however, the emergency is not over. Oxygen first aid should be continued; if stopped, symptoms may return.

Responding to the Injured Diver

This section does not replace formal training in Diver Rescue, CPR or Oxygen First Aid. Before attempting any of the following skills, you should complete a formal course of instruction to gain the knowledge and skills necessary to assist an injured diver.

Managing an Injured Diver on the Surface

- Ensure safety of yourself and the injured diver.
- Establish positive buoyancy for yourself and the injured diver.
  - Remove weight belts.
  - Inflate buoyancy control devices as appropriate.
- Assess diver's responsiveness. Ask: "Are you all right?"
- If the diver is responsive, assist the diver with the problem and bring him/her to the shore or the boat.
- If the diver is unresponsive, alert someone on shore or the boat.
- Contact the local emergency medical services (EMS).
- If close to shore or boat, tow the unresponsive diver to the closest stable site for out-of-water management and begin basic life support. Provide one breath every five seconds.
- Otherwise, open the injured diver's airway.
  - Remove the injured diver's regulator or snorkel and mask, if necessary.
  - Support the diver's head, and avoid submerging the diver's face.
- Assess breathing by looking, listening and feeling for 5 to 10 seconds.
  - Look for movement of the chest.
  - Listen for breathing.
  - Feel breathing against your cheek.
- If the injured diver is not breathing, provide two rescue breaths, and
  - Maintain an open airway, using the head-tilt, chin-lift method.
  - Use an oronasal resuscitation mask or pinch the injured diver's nose to make a seal.
  - Give two normal breaths (one second in duration) enough to make the chest rise.
  - Watch the chest rise and fall.
  - Prevent water and other debris from entering the airway.
  - If the first breath is ineffective, check and reposition the airway, and reattempt ventilations.
- Remove the diver's equipment.
- Remove the diver from the water.
- Reassess the diver's condition. If still not breathing, deliver two rescue breaths and begin CPR.

IV

Performing cardiopulmonary resuscitation (CPR) in the water is not recommended because:

1. It is not feasible to perform adequately.
2. It delays the start of more definitive treatment on land.

Managing the Injured Diver on the Shore or Boat

- Ensure safety of yourself and the injured diver.
  - Use medical gloves and other personal protection equipment.
  - Use an oronasal or other resuscitation mask.
- Assess diver's responsiveness.
  - Grasp the diver's shoulder.
  - Ask: "Are you all right?"
- If the diver is responsive:
  - Continue to monitor and evaluate the diver's airway and breathing.
  - Provide high concentrations of oxygen.
  - Seek further medical assistance and advice.
- If the diver is unresponsive, send someone for help and activate local EMS.
- Open the diver's airway with the head-tilt, chin-lift maneuver.
  - Place one hand on the diver's forehead, and gently tilt the head back.
  - With the other hand, lift the chin with two or three fingers.
- Assess breathing by looking, listening and feeling for 5 to 10 seconds.
  - Look for movement of the chest.
  - Listen for breathing.
  - Feel breathing against your cheek.
- If the diver is breathing:
  - Place the diver in the recovery position to help protect the airway.
  - Continue to monitor and evaluate the diver's airway and breathing.
  - Provide high concentrations of oxygen.
  - Seek further medical assistance and advice.
- If the diver is not breathing, provide two rescue breaths.
  - Maintain an open airway with the head-tilt, chin-lift method.
  - Use an oronasal resuscitation mask or pinch the injured diver's nose to make a seal.
  - Give two normal breaths (one second in duration), enough to make the chest rise.
  - Watch the chest rise and fall.
  - If the first breath is ineffective, check and reposition the airway and reattempt ventilations.
  - Allow the diver's chest to fall before providing a second breath.
  - If available, provide supplemental oxygen.

- If the diver is not breathing, begin CPR.
  - Locate the lower sternum (breastbone).
  - Place the heel of one hand with the other hand on top of the first.
  - Perform 30 compressions at a rate of 100 per minute.
  - Combine compressions and rescue breathing at a ratio of 30:2.
  - If available, provide supplemental oxygen.
- Continue CPR until circulation and breathing resume or help arrives.

Additional details regarding CPR protocols for one or two rescuers and other first aid procedures are available through hands-on training courses. Contact your local dive center for information on training opportunities.

Providing Emergency Oxygen First Aid

Providing emergency oxygen first aid for an injured diver is one of the most important measures that can be taken prior to professional medical care and hyperbaric treatment.

Because respiratory arrest, cardiac arrest, drowning and scuba diving injuries interrupt or impair the body's ability to supply oxygen to the body's tissue, it's important to provide the highest concentration of oxygen possible. The injured diver's medical status helps determine which delivery method will provide the highest concentration of oxygen.

Note: DAN recommends that you seek formal training in the use of oxygen prior to use. Oxygen is a prescription drug in many countries, and improper handling and maintenance of oxygen equipment can cause serious injury, including death, to both the injured diver and rescuer.

To determine the oxygen delivery device that will provide the highest concentrations of oxygen, determine whether the diver is breathing or not, and select the delivery device with the highest concentration of oxygen available.

Breathing Injured Diver

- Demand inhalator valve with oronasal mask;

- Nonrebreather mask with a minimum 15 liter per minute (Lpm) oxygen flow rate; or

- Other oxygen delivery devices capable of providing high concentrations of oxygen, such as closed-circuit oxygen rebreathers.

The demand inhalator valve is far more effective than the nonrebreather mask in both conserving oxygen supplies and delivering a high inspired fraction to the patient. Closed-circuit oxygen rebreathers are even more effective at conserving oxygen supplies. These devices can be of great value to support remote diving activity when long delays to reach definitive medical aid are expected.

Nonbreathing Injured Diver

- Oronasal resuscitation mask (DAN mask) with a minimum 15 Lpm oxygen flow rate.

Trained medical professionals may consider:

- Flow-restricted oxygen-powered ventilator (FROPV).
- Bag-valve mask.

Once the oxygen delivery device is chosen, follow this quick review of the steps to using one of the following oxygen delivery devices. [**Note:** The use of supplemental oxygen should always take place within the context of Basic Life Support (BLS) and techniques such as rescue breathing and CPR. This section is not a substitute for formal training in oxygen first aid.]

Demand Inhalator Valve Procedures

1. Deploy the oxygen unit and open the cylinder valve.
2. Ask the diver to breathe normally from the demand inhalator valve and mask.
3. Check for leaks around the face.
4. Monitor the injured diver and oxygen pressure gauge.

Nonrebreather Mask Procedures

1. Deploy the oxygen unit and nonrebreather mask.
2. Set constant-flow control to 15 Lpm.

3. Inflate the mask's reservoir bag.
4. Ask the diver to breathe normally from mask.
5. Check for leaks around the face.
6. Monitor the injured diver and oxygen pressure gauge.

Oronasal (DAN) Mask Procedures

1. Deploy the oxygen unit and the oronasal mask.
2. Attach oxygen tubing to mask and oxygen regulator.
3. Set constant-flow control to 15 Lpm.
4. Provide CPR as indicated.

Notes on the Use of Oxygen

- Have enough oxygen supply for transport from the farthest dive site to the nearest EMS contact.
- Oxygen first aid should not be considered a substitute for definitive care by a trained healthcare provider.
- Do not overlook the priority of airway and breathing monitoring when providing emergency oxygen.

Oxygen Equipment Warnings

- Extinguish all open flame and smoking materials.
- Turn oxygen cylinder valves slowly.
- Do not allow the use of any oil or grease to come in contact with oxygen or oxygen equipment.
- Do not expose oxygen cylinder to high temperatures.

Positioning of the Injured Diver

Positioning of the diver is also important to facilitate CPR and the provision of oxygen first aid. Depending on the condition of the injured diver, place the diver in the appropriate position.

- Injured divers who are responsive (who are communicating) may be placed in either of these positions:
  - Recovery position (on side, usually the left, with head supported)
  - Semirecumbent position (comfortably reclining)
- Unresponsive breathing injured divers should be placed in the recovery position (on either side with the head supported) to help maintain an open airway and reduce the likelihood of the aspiration of vomitus in the lungs.
- Unresponsive nonbreathing injured divers should be placed in the supine position (on the back) in order for the rescuer to be able to perform CPR/rescue breathing.

Notes on Positioning

- The diver should be in a stable, comfortable position, without pressure on the chest that could impair breathing.
- Avoid crossing the arms or legs in a manner that might restrict circulation.
- Avoid movement of the diver without stabilization if a head, neck or spinal injury is suspected.
- A head-down position is not recommended unless it is required to treat low blood pressure.

SUMMARY

General Principles of Accident Management are:

Airway and Breathing

- First priority always goes to the airway.
- Every diver with suspected DCS or AGE should receive oxygen.
- Every unresponsive person should be assumed to have respiratory insufficiency and needs:
  - (a) Protection of airway.
  - (b) Careful monitoring to determine whether assisted ventilation is required.

ACRONYMS

ACLS – advanced cardiac life support
AED – automated external defibrillator
AGE – arterial gas embolism
AIDS – acquired immune deficiency syndrome
ATA – atmospheres absolute
BCD – buoyancy compensation device
BLS – basic life support
CAGE – cerebral arterial gas embolism (also called air embolism)
CDC – Centers for Disease Control and Prevention (U.S.)
CNS – central nervous system
CPR – cardiopulmonary resuscitation
DAN – Divers Alert Network
DCI – decompression illness
DCS – decompression sickness
DEET – N,N-diethyl-meta-toluamide
DVT – deep vein thrombosis
EAN – enriched-air nitrox
EMS – emergency medical services
ENT – ear, nose and throat
FROPV – flow-restricted oxygen-powered ventilator
fsw – feet of sea water
GMT – Greenwich Mean Time
HAV – hepatitis A virus
HELP – heat escape lessening position
HIV – human immunodeficiency virus
IRDM – insulin-requiring diabetes mellitus
Lpm – liters per minute
msw – meters of sea water
NOAA – National Oceanic and Atmospheric Administration (U.S.)
OE – otitis externa
OHA – oral hypoglycemic agents
ORS – oral rehydrating solution
OSHA – Occupational Safety and Health Administration
OTC – over-the-counter
PFSI – preflight surface interval
PPD – (purified protein derivative) tuberculin skin test
TB – tuberculosis
TD – travelers diarrhea
UBA – underwater breathing apparatus
UHMS – Undersea and Hyperbaric Medical Society
WHO – World Health Organization

GLOSSARY

Afterdrop
A transient decline in core temperature, often occurring after removal from cold stress.

Alternobaric Vertigo
An extreme dizziness and disorientation resulting from unequal pressure in the two middle ears, typically during ascent.

Antihistamine
Drugs that may be part of some "over-the-counter" medicines for allergies and colds. Some antihistamines cause drowsiness.

Arterial Gas Embolism
Air in the arterial circulation. In divers this may be caused by a sudden reduction in ambient pressure, such as a rapid ascent without exhalation, causing over-pressurization of the lung and pulmonary barotrauma. The most common target organ is the brain, and the usual signs and symptoms include the rapid (<15 minutes) onset of weakness, numbness, confusion or alteration in consciousness after reaching the surface.

Barotrauma
A condition caused by a change in ambient pressure in a gas-filled space. When gas is trapped in a closed space within the body, the gas will be compressed if the depth increases and will expand if the depth decreases. Barotrauma injuries of descent include ear squeeze, tympanic membrane rupture or sinus squeeze. Injuries of ascent include pulmonary barotrauma, which can result in air embolism, pneumothorax or pneumomediastinum.

Carbon Dioxide
A waste gas produced by the metabolism of oxygen in the body.

Carbon Monoxide
A highly poisonous, odorless, tasteless and colorless gas formed when carbon material burns with restricted access to oxygen. It is toxic by inhalation since it competes with oxygen in binding with the hemoglobin, thereby resulting in diminished availability of oxygen in tissues.

Cardiac Arrest
The inability of the heart to generate effective circulation. It is confirmed by the absence of the carotid pulse in an unconscious nonbreathing person.

Conjunctival Suffusion
Redness of the membrane covering the eye.

Cyanosis
A bluish discoloration of the skin and mucous membranes due to deficient oxygenation of the blood.

Decompression Illness (DCI)
The broad term that encompasses both DCS and AGE. DCI is commonly used to describe any systemic disease caused by a reduction in ambient pressure. It is used because the signs and symptoms of DCS and AGE can be similar.

Decompression Sickness (DCS)
A syndrome caused by bubbles of inert gas forming in the tissues and

bloodstream during or after an ascent from a compressed-gas dive. The symptoms may include itching, rash, joint pain, muscle aches or sensory changes such as numbness and tingling. More serious symptoms include muscle weakness, paralysis or disorders of higher cerebral function, including memory and personality changes.

Dehydration
Depletion of body water. Mild dehydration may go unnoticed. More severe dehydration can cause dizziness, rapid heartbeat and low blood pressure (hypotension).

Enriched-Air Nitrox (EAN)
A nitrogen / oxygen breathing gas mixture containing more than 21 percent oxygen, usually made by mixing air and oxygen. Also known as oxygen-enriched air.

Hyperthermia
A condition of elevated body core temperature.

Hypoglycemia
A condition of low blood sugar.

Hypothermia
A condition of reduced body core temperature (below 95°F / 35°C).

Hypoxia
Inadequate oxygen supply to the body tissues.

Initial Assessment
Assessment of the airway and breathing in an ill or injured person.

Lpm
Liters per minute. A measurement of a flow rate of gas or liquid.

Mediastinum
The space within the chest located between the lungs; it contains the heart, major blood vessels, trachea and esophagus.

Mediastinal Emphysema (Pneumomediastinum)
Air within the tissues between the two lungs, e.g. surrounding the heart (not within the heart or blood vessels). This is usually the result of pulmonary barotrauma, but can occur as a result of perforation of the esophagus, stomach or intestine.

Myalgia
Muscle pain.

No-Decompression Dive or No-Stop Dive
A dive where direct ascent to the surface at 30-60 fsw (9-18 meters of sea water) per minute is allowed at any time during the dive without a decompression stop.

Nystagmus
Spontaneous, rapid, rhythmic movement of the eyes occurring on fixation or on ocular movement.

Oxygen
A colorless, odorless, tasteless gas essential to life making up approximately 21 percent of air.

IV

Oxygen Toxicity
The term describing the syndrome caused by breathing of oxygen at greater-than-normal atmospheric pressure. Oxygen toxicity primarily affects the central nervous system (CNS) and the lungs. Pulmonary oxygen toxicity is caused by inflammation of the lung tissue itself, resulting in shortness of breath, cough and a reduced ability to perform exercise.

Parenteral
Introduced in a manner other than through the digestive tract, as with parenteral glucagon, an injectable agent which stimulates the liver to release glucose into the bloodstream to counter severe hypoglycemia reactions.

Pulmonary Edema
An accumulation of fluid in the lungs.

Pulmonary Overexpansion
Abnormal distension of the lungs. In divers, pulmonary overexpansion can cause rupture of alveoli and penetration of gas into various surrounding spaces, causing mediastinal emphysema, pneumothorax or arterial gas embolism.

Rapid Ascent
An ascent rate fast enough to put a diver at increased risk of decompression illness, usually at rates in excess of 60 fsw / 18 msw per minute.

Recovery Position
First aid technique for a patient who is unconscious or injured but breathing. The person is placed lying on the side; this helps keep the airway clear if the injured person begins to vomit.

Respiratory Arrest
Cessation of breathing.

Sign
Any medical or trauma condition that can be observed and described.

Supine
Lying flat on back, with face upward.

Symptom
Any nonobservable condition described by the patient.

CARDIOPULMONARY RESUSCITATION (One-Rescuer Adult CPR)

Remember S-A-F-E

Stop;
Assess scene;
Find and secure oxygen, first aid kit and automated external defibrillator (AED) unit; and use
Exposure protection (gloves and mask).

Assess Responsiveness

If no response, call for help — call local emergency medical services (EMS) number, get AED or send second rescuer to do this.

Open AIRWAY

Use the head-tilt, chin-lift method for all.

Assess BREATHING

Look, listen and feel for normal breathing for 10 seconds. If not breathing, give two breaths that make chest rise*.

* In its 2008 statement regarding CPR guidelines, the American Heart Association (AHA) encourages lay providers to administer chest compressions without ventilations. If a bystander was previously trained in CPR and is confident in his or her ability to provide rescue breaths with a minimal interruption in chest compressions, then the bystander should provide conventional CPR using a 30:2 compression-to-ventilation ratio.

Respiratory arrest may result from diving incidents involving loss of consciousness. Such cases demand effective artificial resuscitation. While hands-only CPR is deemed to be effective for general use, DAN Education does not plan to change any DAN courses to remove compression/ventilation protocols.

Do Not Assess Circulation

Do not check for signs of circulation. After delivering two rescue breaths, immediately begin chest compressions. If the subject moves, then stop.

Assume that a person who has stopped breathing is also in full cardiac arrest. The only exceptions to this are when caring for children or if you are a professional rescuer.

Chest Compressions

- Give cycles of 30 COMPRESSIONS and *TWO BREATHS until AED arrives, professional rescuers take over or victim starts to move.
- Push hard and fast (100/min) and release completely.
- Depress sternum 1.5 to 2 inches (4 to 5 cm).
- Minimize interruptions in compressions.

AED/Defibrillator ARRIVES

- Turn on AED and apply pads according to directions.
- Deliver shock if directed, resume CPR for 5 cycles.
- Continue CPR until circulation and breathing resume or help arrives.

YOUR BEACON OF SAFETY FOR OVER 30 YEARS.

DAN is a nonprofit organization that receives most of its funding from memberships and tax-deductible donations. DAN provides expert information and advice to the diving public, promotes and supports diving research and maintains a 24-hour emergency telephone line for dive injuries.

All DAN Members receive *Alert Diver*, DAN's member magazine, as well as coverage under the DAN *TravelAssist* plan, which provides free emergency evacuation assistance and a number of important hospital preadmission and legal services. Emergency evacuation assistance is a benefit for all DAN Members and their dependents during any travel at least 50 miles / 80 km from home.

The *TravelAssist* center numbers are listed inside and on your DAN Member card and must be called first in order to activate the services.

Dive accident insurance packages are available to DAN Members. For complete coverage and pricing information, explore DAN.org.

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VOLUME 5

Diving Medicine & Recompression Chamber Operations

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18	Recompression Chamber Operation
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U.S. NAVY DIVING MANUAL

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CHAPTER 17

Diagnosis and Treatment of Decompression Sickness and Arterial Gas Embolism

17-1 INTRODUCTION

17-1.1 **Purpose.** This chapter describes the diagnosis and treatment of diving disorders with recompression therapy and/or hyperbaric oxygen therapy. Recompression therapy is indicated for treating DCS, AGE, and several other disorders unless the diver is critically ill or has experienced a drowning episode. In those cases where diagnosis or treatment are not clear, direct the patient to the highest level of medical care available and contact the Diving Medical Officers at NEDU or NDSTC for guidance. The recompression procedures described in this chapter are designed to handle most situations that will be encountered operationally. They are applicable to both surface-supplied and open and closed circuit SCUBA diving as well as recompression chamber operations, whether breathing air, nitrogen-oxygen, helium-oxygen, or 100 percent oxygen. Treatment of decompression sickness during saturation dives is covered separately in Chapter 13 of this manual. Periodic evaluation of U.S. Navy recompression treatment procedures has shown they are effective in relieving symptoms over 90 percent of the time when used as published.

17-1.2 **Scope.** The procedures outlined in this chapter are to be performed only by trained personnel. Because these procedures are used to treat disorders ranging from mild pain to life-threatening disorders, the degree of medical expertise necessary to carry out proper treatment will vary. Certain procedures, such as starting intravenous (IV) fluid lines and inserting chest tubes, require special training and must not be attempted by untrained individuals. Treatment tables can be initiated without consulting a Dive Medical Officer (DMO), however a DMO should always be contacted at the earliest possible opportunity. A DMO must be contacted prior to releasing the treated individual.

17-2 MANNING REQUIREMENTS

17-2.1 **Recompression Chamber Team.** A recompression chamber team is assembled in two situations; where a recompression chamber is part of a diving operation, and where a recompression chamber is maintained as an area response requirement. This section applies to both situations. The designation “Chamber Supervisor” may be interchanged with “Diving Supervisor” where a recompression chamber is part of an operation. During a complex recompression treatment, the minimum manning and emergency manning levels specified in Table 17-1 may not be adequate to keep up with the surge of activity required at various points during the treatment and additional personnel should be obtained as soon as possible. A second team may be required to relieve the initial team during prolonged treatments.

Table 17-1. *Minimum Manning Levels for Recompression Treatments.*

Minimum Manning Levels for Recompression Treatments			
	Minimum	**Ideal**	**Emergency**
Diving Officer		1	
Master Diver		1	
Chamber Supervisor	1(a)	1	1(a)
Diving Medical Officer		1 (b)	
Inside Tender/DMT	1(b,c,d)	1(c,d)	1(b,c,d)
Log Keeper		1	
Outside Tender	1	1	
Total	3	7	2

Notes:

(a) The Chamber Supervisor and outside tender must perform the essential tasks of all other positions while keeping patient care a priority. The Chamber Supervisor must attempt to obtain additional personnel as soon as possible.

(b) If the patient has symptoms of serious DCS or AGE where Basic Life Support (BLS) or advanced medical support may be required (e.g., airway management, or thoracic needle decompression), a Diving Medical Technician (DMT) or DMO should accompany the patient inside the chamber in addition to the inside tender. However, recompression treatment must not be delayed while awaiting the arrival of a DMO or DMT.

(c) The best qualified person available should provide specialized medical care to a patient in the chamber. The best qualified person may be a non-diving surgeon, respiratory therapist, Independent Duty Corpsman (IDC), etc. Since these are emergency exposures, no special medical or physical prerequisites exist. A qualified Inside Tender is required inside the chamber at all times.

(d) Locking in /out personnel. Inside tenders and additional personnel may be locked in and out during the course of a treatment. Chamber periods should be kept within no-decompression limits if possible. However, decompression may be accomplished in the outerlock utilizing the air decompression schedules in Table 9-9. Once an inside tender exceeds exceptional exposure limits of the applicable schedule they are committed to the entire treatment table.

17-2.2 **Diving Officer.** The Diving Officer is responsible to the Commanding Officer for the safe conduct of recompression chamber operations and for presenting recommended changes to treatment protocols to the Commanding Officer. The Diving Officer is responsible for complying with reporting requirements as listed in Chapter 5 and additional duties as defined in the command dive bill.

17-2.3 **Master Diver.** The Master Diver is the most qualified person to supervise recompression treatments. The Master Diver is trained in diagnosing and treating diving injuries and illnesses and is responsible to the Commanding Officer, via the Diving Officer, for the safe conduct of all phases of chamber operations.

The Master Diver provides direct oversight of the Chamber Supervisor and technical expertise. If circumstances warrant, the Master Diver shall relieve the Chamber Supervisor and assume control of the treatment.

17-2.4 **Chamber Supervisor.** The Chamber Supervisor is responsible for execution of treatment protocols, emergency procedures, and supervision of the chamber team. If the Chamber Supervisor determines the reason for postdive symptoms is firmly established to be due to causes other than decompression sickness or arterial gas embolism (e.g. injury, sprain, poorly fitting equipment), then recompression is not necessary. If the Chamber Supervisor cannot rule out the need for recompression then the Chamber Supervisor must commence treatment. Additionally, the Chamber Supervisor is responsible for:

- Communicating with personnel inside the chamber.
- Adhering to the minimum manning levels for conducting recompression treatment (Table 17-1).
- Ensuring every member of the chamber team is thoroughly familiar with all recompression procedures.
- Ensuring a Diving Medical Officer is contacted at the earliest opportunity during treatment and before release of any patient from the treatment facility.
- Ensuring details related to the assessment and treatment of the patient (e.g. condition prior to treatment, time and depth of complete relief, patient vital signs) are thoroughly documented in the recompression chamber log IAW section 5-5 and the command dive bill.
- Tracking bottom time and the decompression profiles of personnel locking in and out of the chamber.
- Ensuring the decompression profiles of persons locking in and out of the chamber are logged in the chamber log.

17-2.5 **Diving Medical Officer.** The Diving Medical Officer recommends the proper course of treatment, consults with other medical personnel, and prescribes medications and treatment adjuncts. The Diving Medical Officer is the only team member who can modify recompression treatment tables, with concurrence of the Commanding Officer or Officer-in-Charge.

The DMO typically locks in and out of the chamber as the patient's condition dictates (e.g., to administer advanced procedures, perform differential diagnosis, or to verify complete relief of symptoms), and does not commit to the entire treatment unless absolutely necessary. Once committed to remain in the chamber, the DMO's effectiveness in directing the treatment is greatly diminished and consultation with other medical personnel becomes more difficult.

Recompression treatment for diving related disorders may be initiated without consulting a DMO, however, a DMO shall be consulted as early as possible, and should be consulted before committing a patient to a Treatment Table 4 or 7. The DMO may be on scene or in communication with the Chamber Supervisor.

17-2.5.1 **Prescribing and Modifying Treatments.** Because all possible outcomes cannot be anticipated, additional medical expertise should be sought immediately in all cases of decompression sickness or arterial gas embolism that do not show substantial improvement on standard treatment tables. Deviation from these protocols shall be made only with the recommendation of a Diving Medical Officer (DMO).

Not all Medical Officers are DMOs. The DMO shall be a graduate of the Diving Medical Officer course taught at the Naval Diving and Salvage Training Center (NDSTC) and have a subspecialty code of 16U0 (Basic Undersea Medical Officer) or 16U1 (Residency in Undersea Medicine trained Undersea Medical Officer). Medical Officers who complete only the nine-week diving medicine course at NDSTC do not receive DMO subspecialty codes, but are considered to have the same privileges as DMOs, with the exception that they are not granted the privilege of modifying treatment protocols. Only DMOs with subspecialty codes 16U0 or 16U1 may modify the treatment protocols as warranted by the patient's condition with the concurrence of the Commanding Officer or Officer in Charge. Other physicians may assist and advise treatment and care of diving casualties but may not modify recompression procedures.

17-2.6 **Inside Tender/DMT.** When conducting a recompression treatment, at least one qualified tender shall be inside the chamber at all times. The inside tender should be a Diving Medical Technician (DMT) if available, however, any qualified diver or non-diving medical personnel may qualify and perform as an inside tender as stated below.

Diving Medical Technicians receive special training in hyperbaric medicine and medical care and operate under the medical license and supervision of a DMO. DMTs are trained to administer medical treatment adjuncts, handle emergencies that may arise during treatment, and instruct members of the diving team in first aid procedures.

Non-diving medical personnel (e.g., U.S. Naval Reserve Corpsmen, and nursing personnel) may qualify as an Inside Tender via the Military Diver Inside Tender PQS (NAVEDTRA 43910). Non-diving medical personnel must obtain a current diving physical exam, conform to Navy physical standards, and pass the diver candidate pressure test.

The inside tender shall be familiar with all treatment procedures and the signs, symptoms, and treatment of all diving-related disorders.

During the early phases of treatment, the inside tender must monitor the patient periodically for signs of relief of symptoms. Observation of the patient, to include performance of repeat neurological exams, is the principal method of diagnosing the patient's illness and the depth and time of their relief helps determine which treatment table is used.

The inside tender is also responsible for:

- Releasing the door latches (dogs) after a seal is made.
- Communicating with outside personnel.
- Providing first aid as required by the patient.
- Monitoring the patients vital signs.
- Administering treatment gas to the patient at treatment depth.
- Monitoring the patient for signs of oxygen toxicity. (CNS and Pulmonary)
- Ensuring that sound attenuators for ear protection are worn during compression and ventilation portions of recompression treatments.
- Ensuring that the patient is lying down and positioned to permit free blood circulation to all extremities.

17-2.7 **Outside Tender.** The outside tender is responsible for preparing the chamber system for use and securing from use IAW the system operating procedures and the chamber pre and post dive checklists. The chamber operator pressurizes and ventilates the chamber at the required rates as specified by the Chamber Supervisor. The outside tender operates the chamber medical lock, maintains the chamber at the required depth, and monitors chamber internal environmental readings, treatment gas bank, and air supply manifold pressures.

17-2.8 **Emergency Consultation.** Modern communications allow access to medical expertise from even the most remote areas. Emergency consultation is available 24 hours a day with:

Primary:

Navy Experimental Diving Unit (NEDU)

Commercial (850) 230-3100, DSN 436-4351

Secondary:

Navy Diving Salvage and Training Center (NDSTC)

Commercial (850) 234-4651, DSN 436-4651

17-3 ARTERIAL GAS EMBOLISM

Arterial gas embolism is caused by entry of gas bubbles into the arterial circulation as a result of pulmonary over inflation syndrome (POIS). Gas embolism can manifest during any dive where compressed gas is breathed under pressure, even during a brief, shallow dive, or one made in a swimming pool. The onset of symptoms is usually sudden and dramatic, often occurring within minutes after arrival on the surface or even before reaching the surface. For this reason, all persons surfacing from a dive where a compressed gas was breathed, shall remain under the direct observation of the Dive Supervisor for 10 minutes after surfacing. Because the supply of blood to the central nervous system is almost always compromised, arterial gas embolism may result in death or permanent neurological damage unless treated appropriately.

17-3.1 **Diagnosis of Arterial Gas Embolism.** As a basic rule, any diver who has obtained a breath of compressed gas from any source at any depth, whether from diving apparatus or from a diving bell, and who surfaces unconscious, loses consciousness, or has any obvious neurological symptoms within 10 minutes of reaching the surface, must be assumed to be suffering from arterial gas embolism. Recompression treatment shall be started immediately after airway, breathing, and circulation (ABCs) have been assessed. If the diver is pulseless and not breathing establishment of ABCs is a HIGHER PRIORITY THAN RECOMPRESSION. A diver who surfaces unconscious and recovers when exposed to fresh air shall receive a neurological evaluation to rule out arterial gas embolism. Victims of near-drowning incidents who have no neurological symptoms should ALWAYS be carefully evaluated by a DMO, if available, for pulmonary aspiration, or referred to a higher level of medical care.

The symptoms of AGE may be masked by environmental factors or by other less significant symptoms. A chilled diver may not be concerned with numbness in an arm, which may actually be the sign of CNS involvement. Pain from any source may divert attention from other symptoms. The natural anxiety that accompanies an emergency situation, such as the failure of the diver's air supply, might mask a state of confusion caused by an arterial gas embolism to the brain.

If pain is the only symptom, arterial gas embolism is unlikely and decompression sickness or one of the other pulmonary overinflation syndromes, or trauma, should be considered.

17-3.1.1 **Symptoms of AGE.** The signs and symptoms of AGE may include near immediate onset of altered consciousness, dizziness, paralysis or weakness in the extremities, large areas of abnormal sensation (paresthesias), vision abnormalities, convulsions or personality changes. During ascent, the diver may have noticed a sensation similar to that of a blow to the chest. The victim may become unconscious without warning and may stop breathing. Additional symptoms of AGE include:

- Extreme fatigue
- Difficulty in thinking
- Vertigo
- Nausea and/or vomiting
- Hearing abnormalities
- Bloody sputum
- Loss of control of bodily functions
- Tremors
- Loss of coordination
- Numbness

Symptoms of subcutaneous / mediastinal emphysema, pneumothorax and/or pneumopericardium may also be present (see paragraph 3-8). In all cases of arterial gas embolism, the possible presence of these associated conditions should not be overlooked.

17-3.2 **Treating Arterial Gas Embolism.** Arterial gas embolism is treated in accordance with Figure 17-1 with initial compression to 60 fsw. If symptoms are improved within the first oxygen breathing period, then treatment is continued using Treatment Table 6. If symptoms are unchanged or worsen, assess the patient upon descent and compress to depth of relief (or significant improvement), not to exceed 165 fsw and follow Figure 17-1.

17-3.3 **Resuscitation of a Pulseless Diver.** The following are intended as guidelines. On scene personnel must make management decisions considering all known factors. Immediate CPR and application of an Automated External Defibrillator (AED) is indicated for a diver with no pulse or respirations (cardiopulmonary arrest). Access to advanced cardiac life support (ACLS) is a higher priority than recompression. ACLS, which requires special medical training and equipment, is not always available. Although not a substitute for the full range of interventions of ACLS, use of an Automated External Defibrillator (AED) can deliver life-saving shocks when a shockable heart rhythm is detected. CPR, patient monitoring, and drug administration may be performed at depth, but electrical therapy (defibrillation or cardioversion) must be performed on the surface.

CPR must begin immediately and an AED should be placed on the victim as soon as possible. All efforts should be made to immediately transport the patient to the highest level of medical care available while continuing basic life support measures (BLS) measures. If the pulseless diver regains vital signs continue, or begin, transport to the nearest critical care facility prior to recompression.

Effective rescue breathing, excellent chest compressions, and immediate evacuation to a medical facility is the most viable treatment for drowning victims. Delays in access to a critical care facility will most likely will result in an unfavorable outcome for the victim.

A pulseless diver should not be recompressed unless there is no possibility of evacuation. Unless ABCs are restored the diver will likely die, even if adequate CPR is performed, with or without recompression.

CAUTION **Defibrillation is not currently authorized at depth.**

CAUTION **If the tender is outside of no-decompression limits, take appropriate steps to manage the tender's decompression obligation.**

17-3.3.1 **Evacuation not feasible.** If an AED is not available and evacuation is not an option, recompress the patient to 60 feet, continue BLS measures, and contact a UMO. If an AED becomes available, surface the chamber at 30fpm and apply the AED. If the diver regains pulse, continue with recompression and monitor the patient closely.

CAUTION: **If tenders are outside of no-decompression limits, take appropriate steps to manage the tender's decompression obligation. If the pulseless diver does not regain a pulse with application of an AED, continue resuscitation efforts until the diver recovers, the rescuers are unable to continue CPR, or a physician pronounces the patient dead. Avoid recompressing a pulseless diver who has failed to regain vital signs after use of an AED.**

17-4 DECOMPRESSION SICKNESS

While a history of diving (or altitude exposure) is necessary for the diagnosis of decompression sickness to be made, the depth and duration of the dive are useful only in establishing if required decompression was missed. Decompression sickness can occur in divers well within no-decompression limits or in divers who have carefully followed decompression tables. Any decompression sickness that occurs must be treated by recompression.

For purposes of deciding the appropriate treatment, symptoms of decompression sickness are generally divided into two categories, Type I and Type II. Because the treatment of Type I and Type II symptoms may be different, it is important to distinguish between these two types of decompression sickness. The diver may exhibit certain signs that only trained observers will identify as decompression sickness. Some of the symptoms or signs will be so pronounced that there will be little doubt as to the cause. Others may be subtle and some of the more important signs could be overlooked in a cursory examination. Type I and Type II symptoms may or may not be present at the same time.

17-4.1 **Diagnosis of Decompression Sickness.** Decompression sickness symptoms usually occur shortly following the dive or other pressure exposure. If the controlled decompression during ascent has been shortened or omitted, the diver could be suffering from decompression sickness before reaching the surface. In analyzing several thousand air dives in a database set up by the U.S. Navy for developing decompression models, the time of onset of symptoms after surfacing was as follows:

- 42 percent occurred within 1 hour.
- 60 percent occurred within 3 hours.
- 83 percent occurred within 8 hours.
- 98 percent occurred within 24 hours.

Appendix 5A contains a set of guidelines for performing a neurological examination and an examination checklist to assist trained personnel in evaluating decompression sickness cases.

17-4.2 **Symptoms of Type I Decompression Sickness.** Type I decompression sickness includes joint pain (musculoskeletal or pain-only symptoms) and symptoms involving the skin (cutaneous symptoms), or swelling and pain in lymph nodes.

17-4.2.1 **Musculoskeletal Pain-Only Symptoms.** The most common symptom of decompression sickness is joint pain. Other types of pain may occur which do not involve joints. The pain may be mild or excruciating. The most common sites of joint pain are the shoulder, elbow, wrist, hand, knee, and ankle. The characteristic pain of Type I decompression sickness usually begins gradually, is slight when first noticed and may be difficult to localize. It may be located in a joint or muscle, may increase in intensity, and is usually described as a deep, dull ache. The pain may or may not be increased by movement of the affected joint, and the limb may be held preferentially in certain positions to reduce the intensity (so-called guarding). The hallmark of Type I pain is its dull, aching quality and confinement to particular areas. It is always present at rest and is usually unaffected by movement.

Any pain occurring in the abdominal and thoracic areas, including the hips, should be considered as symptoms arising from spinal cord involvement and treated as Type II decompression sickness. The following symptoms may indicate spinal cord involvement:

- Pain localized to joints between the ribs and spinal column or joints between the ribs and sternum.

Table 17-2. ***Rules for Recompression Treatment.***

ALWAYS:

1. Follow the treatment tables accurately, unless modified by a Diving Medical Officer with concurrence of the Commanding Officer or Officer-in-Charge (OIC).
2. Have a qualified tender in the chamber at all times during treatment.
3. Maintain the normal descent and ascent rates as much as possible.
4. Examine the patient thoroughly at depth of relief or treatment depth.
5. Treat an unconscious patient for arterial gas embolism or serious decompression sickness unless the possibility of such a condition can be ruled out without question.
6. Use air treatment tables only if oxygen is unavailable.
7. Be alert for warning signs of oxygen toxicity if oxygen is used.
8. In the event of an oxygen convulsion, remove the oxygen mask and keep the patient from self-harm. Do not force the mouth open during a convulsion.
9. Maintain oxygen usage within the time and depth limitations prescribed by the treatment table.
10. Check the patient's condition and vital signs periodically. Check frequently if the patient's condition is changing rapidly or the vital signs are unstable.
11. Observe patient after treatment for recurrence of symptoms. Observe 2 hours for pain-only symptoms, 6 hours for serious symptoms. Do not release patient without consulting a DMO.
12. Maintain accurate timekeeping and recording.
13. Maintain a well-stocked Primary and Secondary Emergency Kit.

NEVER:

1. Permit any shortening or other alteration of the tables, except under the direction of a Diving Medical Officer.
2. Wait for a bag resuscitator. Use mouth-to-mouth resuscitation with a barrier device immediately if breathing ceases.
3. Interrupt chest compressions for longer than 10 seconds.
4. Permit the use of 100 percent oxygen below 60 feet in cases of DCS or AGE.
5. Fail to treat doubtful cases.
6. Allow personnel in the chamber to assume a cramped position that might interfere with complete blood circulation.

- A shooting-type pain that radiates from the back around the body (radicular or girdle pain).
- A vague, aching pain in the chest or abdomen (visceral pain).

17-4.2.1.1 ***Differentiating Between Type I Pain and Injury.*** The most difficult differentiation is between the pain of Type I decompression sickness and the pain resulting from trauma or other injury such as a muscle strain or bruise. If there is any doubt as to the cause of the pain, assume the diver is suffering from decompression sickness and treat accordingly. Frequently, pain may mask other more significant symptoms. Pain should not be treated with drugs in an effort to make the patient more comfortable. The pain may be the only way to localize the problem and monitor the progress of treatment.

17-4.2.2 **Cutaneous (Skin) Symptoms.** The most common skin manifestation of decompression sickness is itching. Itching by itself is generally transient and does not require recompression. Faint skin rashes may be present in conjunction with itching. These rashes also are transient and do not require recompression. Mottling or marbling of the skin, known as cutis marmorata (marbling), may precede a symptom of serious decompression sickness and shall be treated by recompression as Type II decompression sickness. This condition starts as intense itching, progresses to redness, and then gives way to a patchy, dark-bluish discoloration of the skin. The skin may feel thickened. In some cases the rash may be raised.

17-4.2.3 **Lymphatic Symptoms.** Lymphatic obstruction may occur, creating localized pain in involved lymph nodes and swelling of the tissues drained by these nodes. Recompression may provide prompt relief from pain. The swelling, however, may take longer to resolve completely and may still be present at the completion of treatment.

17-4.3 **Treatment of Type I Decompression Sickness.** Type I Decompression Sickness is treated in accordance with Figure 17-2. If a full neurological exam is not completed before initial recompression, treat as Type II DCS.

Symptoms of musculoskeletal pain that have shown absolutely no change after the second oxygen breathing period at 60 feet may be due to orthopedic injury rather than decompression sickness. If, after reviewing the patient's history, the Diving Medical Officer feels that the pain can be related to specific orthopedic trauma or injury, a Treatment Table 5 may be completed. If a Diving Medical Officer is not consulted, Treatment Table 6 shall be used.

17-4.4 **Symptoms of Type II Decompression Sickness.** In the early stages, symptoms of Type II decompression sickness may not be obvious and the stricken diver may consider them inconsequential. The diver may feel fatigued or weak and attribute the condition to overexertion. Even as weakness becomes more severe the diver may not seek treatment until walking, hearing, or urinating becomes difficult. Initial denial of DCS is common. For this reason, symptoms must be recognized during the post-dive period and treated before they become too severe. Type II, or serious, symptoms are divided into three categories: neurological, inner ear (staggers), and cardiopulmonary (chokes). Type I symptoms may or may not be present at the same time.

17-4.4.1 **Neurological Symptoms.** These symptoms may be the result of involvement of any level of the nervous system. Numbness, paresthesias (a tingling, pricking, creeping, "pins and needles," or "electric" sensation on the skin), decreased sensation to touch, muscle weakness, paralysis, mental status changes, or motor performance alterations are the most common symptoms. Disturbances of higher brain function may result in personality changes, amnesia, bizarre behavior, lightheadedness, lack of coordination, and tremors. Lower spinal cord involvement can cause disruption of urinary function. Some of these signs may be subtle and can be overlooked or dismissed by the stricken diver as being of no consequence.

The occurrence of any neurological symptom after a dive is abnormal and should be considered a symptom of Type II decompression sickness or arterial gas embolism, unless another specific cause can be found. Normal fatigue is not uncommon after long dives and, by itself, is not usually treated as decompression sickness. If the fatigue is unusually severe, a complete neurological examination is indicated to ensure there is no other neurological involvement.

17-4.4.2 **Inner Ear Symptoms ("Staggers").** The symptoms of inner ear decompression sickness include: tinnitus (ringing in the ears), hearing loss, vertigo, dizziness, nausea, and vomiting. Inner ear decompression sickness has occurred most often in helium-oxygen diving and during decompression when the diver switched from breathing helium-oxygen to air. Inner ear decompression sickness should be differentiated from inner ear barotrauma, since the treatments are different. The "Staggers" has been used as another name for inner ear decompression sickness because of the afflicted diver's difficulty in walking due to vestibular system dysfunction. However, symptoms of imbalance may also be due to neurological decompression sickness involving the cerebellum. Typically, rapid involuntary eye movement (nystagmus) is not present in cerebellar decompression sickness.

17-4.4.3 **Cardiopulmonary Symptoms ("Chokes").** If profuse intravascular bubbling occurs, symptoms of chokes may develop due to congestion of the lung circulation. Chokes may start as chest pain aggravated by inspiration and/or as an irritating cough. Increased breathing rate is usually observed. Symptoms of increasing lung congestion may progress to complete circulatory collapse, loss of consciousness, and death if recompression is not instituted immediately. Careful examination for signs of pneumothorax should be performed on patients presenting with shortness of breath. Recompression is not indicated for pneumothorax if no other signs of DCS or AGE are present.

17-4.4.4 **Differentiating Between Type II DCS and AGE.** Many of the symptoms of Type II decompression sickness are the same as those of arterial gas embolism, although the time course is generally different. (AGE usually occurs within 10 minutes of surfacing.) Since the initial treatment of these two conditions is the same and since subsequent treatment conditions are based on the response of the patient to treatment, treatment should not be delayed unnecessarily in order to make the diagnosis.

17-4.5 **Treatment of Type II Decompression Sickness.** Type II Decompression Sickness is treated with initial compression to 60 fsw in accordance with Figure 17-1. If symptoms are improved within the first oxygen breathing period, then treatment is continued on a Treatment Table 6. If severe symptoms (e.g. paralysis, major weakness, memory loss, altered consciousness) are unchanged or worsen within the first 20 minutes at 60 fsw, assess the patient during descent and compress to depth of relief (or significant improvement), not to exceed to 165 fsw. Treat on Treatment Table 6A. To limit recurrence, severe Type II symptoms warrant full extensions at 60 fsw even if symptoms resolve during the first oxygen breathing period.

17-4.6 **Decompression Sickness in the Water.** In rare instances, decompression sickness may develop in the water while the diver is undergoing decompression. The predominant symptom will usually be joint pain, but more serious manifestations such as numbness, weakness, hearing loss, and vertigo may also occur. Decompression sickness is most likely to appear at the shallow decompression stops just prior to surfacing. Some cases, however, have occurred during ascent to the first stop or shortly thereafter. Treatment of decompression sickness in the water will vary depending on the type of diving equipment in use. Specific guidelines are given in Chapter 9 for air dives, Chapter 12 for surface-supplied helium-oxygen dives, and Chapter 15 for EC-UBA dives.

17-4.7 **Symptomatic Omitted Decompression.** If a diver has had an uncontrolled ascent and has any symptoms, he should be compressed immediately in a recompression chamber to 60 fsw. Conduct a rapid assessment of the patient and treat accordingly. Treatment Table 5 is not an appropriate treatment for symptomatic omitted decompression. If the diver surfaced from 50 fsw or shallower, compress to 60 fsw and begin Treatment Table 6. If the diver surfaced from a greater depth, compress to 60 fsw or the depth where the symptoms are significantly improved, not to exceed 165 fsw, and begin Treatment Table 6A. Consultation with a Diving Medical Officer should be obtained as soon as possible. For uncontrolled ascent deeper than 165 feet, the diving supervisor may elect to use Treatment Table 8 at the depth of relief, not to exceed 225 fsw.

Treatment of symptomatic divers who have surfaced unexpectedly is difficult when no recompression chamber is on the dive station. Immediate transportation, while receiving 100% surface oxygen, to a recompression facility is indicated; if this is impossible, the guidelines in paragraph 17-5.4 may be useful.

17-4.8 **Altitude Decompression Sickness.** Decompression sickness may also occur with exposure to subatmospheric pressures (altitude exposure), as in an altitude chamber or sudden loss of cabin pressure in an aircraft. Aviators exposed to altitude may experience symptoms of decompression sickness similar to those experienced by divers. The only major difference is that symptoms of spinal cord involvement are less common and symptoms of brain involvement are more frequent in altitude decompression sickness than hyperbaric decompression sickness. Simple pain, however, still accounts for the majority of symptoms.

17-4.8.1 **Joint Pain Treatment.** If only joint pain was present but resolved before reaching one ata from altitude, then the individual may be treated with two hours of 100 percent oxygen breathing at the surface followed by 24 hours of observation.

17-4.8.2 **Other Symptoms and Persistent Symptoms.** For other symptoms or if joint pain symptoms are present after return to one ata, the stricken individual should be transferred to a recompression facility and treated on the appropriate treatment table, even if the symptoms resolve while in transport. Individuals should be kept on 100 percent oxygen during transfer to the recompression facility.

17-5 RECOMPRESSION TREATMENT FOR DIVING DISORDERS

17-5.1 Primary Objectives. Table 17-1 gives the basic rules that shall be followed for all recompression treatments. The primary objectives of recompression treatment are:

- Compress gas bubbles to a small volume, thus relieving local pressure and restarting blood flow.
- Allow sufficient time for bubble resorption.
- Increase blood oxygen content and thus oxygen delivery to injured tissues.

17-5.2 Guidance on Recompression Treatment. Certain facets of recompression treatment have been mentioned previously, but are so important that they cannot be stressed too strongly:

- Treat promptly and adequately.
- The effectiveness of treatment decreases as the length of time between the onset of symptoms and the treatment increases.
- Do not ignore seemingly minor symptoms. They can quickly become major symptoms.
- Follow the selected treatment table unless changes are recommended by a Diving Medical Officer.
- If multiple symptoms occur, treat for the most serious condition.

17-5.3 Recompression Treatment When Chamber Is Available. Oxygen treatment tables are significantly more effective than air treatment tables. Air treatment tables shall only be used after oxygen system failure or intolerable patient oxygen toxicity problems with DMO recommendation. Treatment Table 4 can be used with or without oxygen but should always be used with oxygen if it is available.

17-5.3.1 **Recompression Treatment With Oxygen.** Use Oxygen Treatment Table 5, 6, 6A, 4, or 7, according to the flowcharts in Figure 17-1, Figure 17-2 and Figure 17-3. The descent rate for all these tables is 20 feet per minute. Upon reaching a treatment depth of 60 fsw or shallower place the patient on oxygen. For treatment depths deeper than 60 fsw, use treatment gas if available.

17-5.3.2 **Recompression Treatments When Oxygen Is Not Available.** Air Treatment Tables 1A, 2A, and 3 (Figures 17-11, 17-12, and 17-13) are provided for use only as a last resort when oxygen is not available. Use Air Treatment Table 1A if pain is relieved at a depth less than 66 feet. If pain is relieved at a depth greater than 66 feet, use Treatment Table 2A. Treatment Table 3 is used for treatment of serious symptoms where oxygen cannot be used. Use Treatment Table 3 if symptoms are relieved within 30 minutes at 165 feet. If symptoms are not relieved in less than 30 minutes at 165 feet, use Treatment Table 4.

17-5.4 Recompression Treatment When No Recompression Chamber is Available. The Diving Supervisor has two alternatives for recompression treatment when the diving facility is not equipped with a recompression chamber. First and foremost, the patient with suspected DCS or AGE should be administered 100% oxygen during transport, if available. If recompression of the patient is not immediately necessary, the diver may be transported to the nearest appropriate recompression chamber or the Diving Supervisor may elect to complete in-water recompression.

17-5.4.1 **Transporting the Patient.** In certain instances, some delay may be unavoidable while the patient is transported to a recompression chamber. While moving the patient to a recompression chamber, the patient should be kept supine (lying horizontally). Do not put the patient head-down. Additionally, the patient should be kept warm and monitored continuously for signs of obstructed (blocked) airway, cessation of breathing, cardiac arrest, or shock. Always keep in mind that a number of conditions may exist at the same time. For example, the victim may be suffering from both decompression sickness and hypothermia.

17-5.4.1.1 ***Medical Treatment During Transport.*** Always have the patient breathe 100 percent oxygen during transport, if available. If symptoms of decompression sickness or arterial gas embolism are relieved or improve after breathing 100 percent oxygen, the patient should still be recompressed as if the original symptom(s) were still present. Always ensure the patient is adequately hydrated. Give fluids by mouth if the patient is alert and able to tolerate them. Otherwise, an IV should be inserted and intravenous fluids should be started before transport. If the patient must be transported, initial arrangements should have been made well in advance of the actual diving operations. These arrangements, which would include an alert notification to the recompression chamber and determination of the most effective means of transportation, should be posted on the Job Site Emergency Assistant Checklist for instant referral.

17-5.4.1.2 ***Transport by Unpressurized Aircraft.*** If the patient is moved by helicopter or other unpressurized aircraft, the aircraft should be flown as low as safely possible, preferably less than 1,000 feet. Exposure to altitude results in an additional reduction in external pressure and possible additional symptom severity or other complications. If available, always use aircraft that can be pressurized to one atmosphere. If available, transport using the Emergency Evacuation Hyperbaric Stretcher should be considered.

17-5.4.1.3 ***Communications with Chamber.*** Call ahead to ensure that the chamber will be ready and that qualified medical personnel will be standing by. If two-way communications can be established, consult with the doctor as the patient is being transported.

17-5.4.2 **In-Water Recompression.** Recompression in the water should be considered an option of last resort, to be used only when no recompression facility is on site, symptoms are significant and there is no prospect of reaching a recompression facility within a reasonable timeframe (12–24 hours). In an emergency, an uncertified chamber may be used if, in the opinion of a qualified Chamber Supervisor (DSWS Watchstation 305), it is safe to operate. In divers with severe Type II symptoms, or symptoms of arterial gas embolism (e.g., unconsciousness, paralysis, vertigo, respiratory distress (chokes), shock, etc.), the risk of increased harm to the diver from in-water recompression probably outweighs any anticipated benefit. Generally, these individuals should not be recompressed in the water, but should be kept at the surface on 100 percent oxygen, if available, and evacuated to a recompression facility regardless of the delay. The stricken diver should begin breathing 100 percent oxygen immediately (if it is available). Continue breathing oxygen at the surface for 30 minutes before committing to recompress in the water. If symptoms stabilize, improve, or relief on 100 percent oxygen is noted, do not attempt in-water recompression unless symptoms reappear with their original intensity or worsen when oxygen is discontinued. Continue breathing 100 percent oxygen as long as supplies last, up to a maximum time of 12 hours. The patient may be given air breaks as necessary. If surface oxygen proves ineffective after 30 minutes, begin in-water recompression. To avoid hypothermia, it is important to consider water temperature when performing in-water recompression.

17-5.4.2.1 ***In-Water Recompression Using Air.*** In-water recompression using air is always less preferable than in-water recompression using oxygen.

- Follow Air Treatment Table 1A as closely as possible.
- Use either a full face mask or, preferably, a surface-supplied helmet UBA.
- Never recompress a diver in the water using a SCUBA with a mouth piece unless it is the only breathing source available.
- Maintain constant communication.
- Keep at least one diver with the patient at all times.
- Plan carefully for shifting UBAs or cylinders.
- Have an ample number of tenders topside.
- If the depth is too shallow for full treatment according to Air Treatment Table 1A:
  - Recompress the patient to the maximum available depth.
  - Remain at maximum depth for 30 minutes.
  - Decompress according to Air Treatment Table 1A. Do not use stops shorter than those of Air Treatment Table 1A.

17-5.4.2.2 ***In-Water Recompression Using Oxygen.*** If 100 percent oxygen is available to the diver using an oxygen rebreather, an ORCA, or other device, the following in-water recompression procedure should be used instead of Air Treatment Table 1A:

- Put the stricken diver on the UBA and have the diver purge the apparatus at least three times with oxygen.
- Descend to a depth of 30 feet with a standby diver.
- Remain at 30 feet, at rest, for 60 minutes for Type I symptoms and 90 minutes for Type II symptoms. Ascend to 20 feet even if symptoms are still present.
- Decompress to the surface by taking 60-minute stops at 20 feet and 10 feet.
- After surfacing, continue breathing 100 percent oxygen for an additional 3 hours.
- If symptoms persist or recur on the surface, arrange for transport to a recompression facility regardless of the delay.

17-5.4.2.3 ***Symptoms After In-Water Recompression.*** The occurrence of Type II symptoms after in-water recompression is an ominous sign and could progress to severe, debilitating decompression sickness. It should be considered life-threatening. Operational considerations and remoteness of the dive site will dictate the speed with which the diver can be evacuated to a recompression facility.

17-6 TREATMENT TABLES

17-6.1 Air Treatment Tables. Air Treatment Tables 1A, 2A, and 3 (Figures 17-11, 17-12, and 17-13) are provided for use only as a last resort when oxygen is not available. Oxygen treatment tables are significantly more effective than air treatment tables and shall be used whenever possible.

17-6.2 Treatment Table 5. Treatment Table 5, Figure 17-4, may be used for the following:

- Type I DCS (except for cutis marmorata) symptoms when a complete neurological examination has revealed no other abnormality. After arrival at 60 fsw a neurological exam shall be performed to ensure that no overt neurological symptoms (e.g., weakness, numbness, loss of coordination) are present. If any abnormalities are found, the stricken diver should be treated using Treatment Table 6.
- Asymptomatic omitted decompression
- Treatment of resolved symptoms following in-water recompression
- Follow-up treatments for residual symptoms
- Carbon monoxide poisoning
- Gas gangrene

17-6.3 **Treatment Table 6.** Treatment Table 6, Figure 17-5, is used for the following:

- Arterial gas embolism
- Type II DCS symptoms
- Type I DCS symptoms where relief is not complete within 10 minutes at 60 feet or where pain is severe and immediate recompression must be instituted before a neurological examination can be performed
- Cutis marmorata
- Severe carbon monoxide poisoning, cyanide poisoning, or smoke inhalation
- Asymptomatic omitted decompression
- Symptomatic uncontrolled ascent
- Recurrence of symptoms shallower than 60 fsw

17-6.4 **Treatment Table 6A.** Treatment Table 6A, Figure 17-6, is used to treat arterial gas embolism or decompression symptoms when severe symptoms remain unchanged or worsen within the first 20 minutes at 60 fsw. The patient is compressed to depth of relief (or significant improvement), not to exceed 165 fsw. Once at the depth of relief, begin treatment gas (N_2O_2, HeO_2) if available. Consult with a Diving Medical Officer at the earliest opportunity. If the severity of the patient's condition warrants, the Diving Medical Officer may recommend conversion to a Treatment Table 4.

NOTE **If deterioration or recurrence of symptoms is noted during ascent to 60 feet, treat as a recurrence of symptoms (Figure 17-3).**

17-6.5 **Treatment Table 4.** Treatment Table 4, Figure 17-7, is used when it is determined that the patient would receive additional benefit at depth of significant relief, not to exceed 165 fsw. The time at depth shall be between 30 to 120 minutes, based on the patient's response. If a shift from Treatment Table 6A to Treatment Table 4 is contemplated, a Diving Medical Officer should be consulted before the shift is made.

If oxygen is available, the patient should begin oxygen breathing periods immediately upon arrival at the 60-foot stop. Breathing periods of 25 minutes on oxygen, interrupted by 5 minutes of air, are recommended because each cycle lasts 30 minutes. This simplifies timekeeping. Immediately upon arrival at 60 feet, a minimum of four oxygen breathing periods (for a total time of 2 hours) should be administered. After that, oxygen breathing should be administered to suit the patient's individual needs and operational conditions. Both the patient and tender must breathe oxygen for at least 4 hours (eight 25-minute oxygen, 5-minute air periods), beginning no later than 2 hours before ascent from 30 feet is begun. These oxygen-breathing periods may be divided up as convenient, but at least 2 hours' worth of oxygen breathing periods should be completed at 30 feet.

NOTE **If deterioration or recurrence of symptoms is noted during ascent to 60**

feet, treat as a recurrence of symptoms (Figure 17-3).

17-6.6 **Treatment Table 7.** Treatment Table 7, Figure 17-8, is an extension at 60 feet of Treatment Table 6, 6A, or 4 (or any other nonstandard treatment table). This means that considerable treatment has already been administered. Treatment Table 7 is considered a heroic measure for treating non-responding severe gas embolism or life-threatening decompression sickness and is not designed to treat all residual symptoms that do not improve at 60 feet and should never be used to treat residual pain. Treatment Table 7 should be used only when loss of life may result if the currently prescribed decompression from 60 feet is undertaken. Committing a patient to a Treatment Table 7 involves isolating the patient and having to minister to his medical needs in the recompression chamber for 48 hours or longer. Experienced diving medical personnel shall be on scene.

A Diving Medical Officer should be consulted before shifting to a Treatment Table 7 and careful consideration shall be given to life support capability of the recompression facility. Because it is difficult to judge whether a particular patient's condition warrants Treatment Table 7, additional consultation may be obtained from either NEDU or NDSTC.

When using Treatment Table 7, a minimum of 12 hours should be spent at 60 feet, including time spent at 60 feet from Treatment Table 4, 6, or 6A. Severe Type II decompression sickness and/or arterial gas embolism cases may continue to deteriorate significantly over the first several hours. This should not be cause for premature changes in depth. Do not begin decompression from 60 feet for at least 12 hours. At completion of the 12-hour stay, the decision must be made whether to decompress or spend additional time at 60 feet. If no improvement was noted during the first 12 hours, benefit from additional time at 60 feet is unlikely and decompression should be started. If the patient is improving but significant residual symptoms remain (e.g., limb paralysis, abnormal or absent respiration), additional time at 60 feet may be warranted. While the actual time that can be spent at 60 feet is unlimited, the actual additional amount of time beyond 12 hours that should be spent can only be determined by a Diving Medical Officer (in consultation with on-site supervisory personnel), based on the patient's response to therapy and operational factors. When the patient has progressed to the point of consciousness, can breathe independently, and can move all extremities, decompression can be started and maintained as long as improvement continues. Solid evidence of continued benefit should be established for stays longer than 18 hours at 60 feet. Regardless of the duration at the recompression deeper than 60 feet, at least 12 hours must be spent at 60 feet and then Treatment Table 7 followed to the surface. Additional recompression below 60 feet in these cases should not be undertaken unless adequate life support capability is available.

17-6.6.1 **Decompression.** Decompression on Treatment Table 7 is begun with an upward excursion at time zero from 60 to 58 feet. Subsequent 2-foot upward excursions are made at time intervals listed as appropriate to the rate of decompression:

Table 17-3. Decompression

Depth	Ascent Rate	Time Interval
58-40 feet	3 ft/hr	40 min
40-20 feet	2 ft/hr	60 min
20-4 feet	1 ft/hr	120 min

The travel time between stops is considered as part of the time interval for the next shallower stop. The time intervals shown above begin when ascent to the next shallower stop has begun.

17-6.6.2 **Tenders.** When using Treatment Table 7, tenders breathe chamber atmosphere throughout treatment and decompression.

17-6.6.3 **Preventing Inadvertent Early Surfacing.** Upon arrival at 4 feet, decompression should be stopped for 4 hours. At the end of 4 hours, decompress to the surface at 1 foot per minute. This procedure prevents inadvertent early surfacing.

17-6.6.4 **Oxygen Breathing.** On a Treatment Table 7, patients should begin oxygen breathing periods as soon as possible at 60 feet. Oxygen breathing periods of 25 minutes on 100 percent oxygen, followed by 5 minutes breathing chamber atmosphere, should be used. Normally, four oxygen breathing periods are alternated with 2 hours of continuous air breathing. In conscious patients, this cycle should be continued until a minimum of eight oxygen breathing periods have been administered (previous 100 percent oxygen breathing periods may be counted against these eight periods). Beyond that, oxygen breathing periods should be continued as recommended by the Diving Medical Officer, as long as improvement is noted and the oxygen is tolerated by the patient. If oxygen breathing causes significant pain on inspiration, it should be discontinued unless it is felt that significant benefit from oxygen breathing is being obtained. In unconscious patients, oxygen breathing should be stopped after a maximum of 24 oxygen breathing periods have been administered. The actual number and length of oxygen breathing periods should be adjusted by the Diving Medical Officer to suit the individual patient's clinical condition and development of pulmonary oxygen toxicity.

17-6.6.5 **Sleeping, Resting, and Eating.** At least two tenders should be available when using Treatment Table 7, and three may be necessary for severely ill patients. Not all tenders are required to be in the chamber, and they may be locked in and out as required following appropriate decompression tables. The patient may sleep anytime except when breathing oxygen deeper than 30 feet. While asleep, the patient's pulse, respiration, and blood pressure should be monitored and recorded at intervals appropriate to the patient's condition. Food may be taken at any time and fluid intake should be maintained.

17-6.6.6 **Ancillary Care.** Patients on Treatment Table 7 requiring intravenous fluid and/or drug therapy should have these administered in accordance with paragraph 17-12 and associated subparagraphs.

17-6.6.7 **Life Support.** Before committing to a Treatment Table 7, the life-support considerations in paragraph 17-7 must be addressed. Do not commit to a Treatment Table 7 if the internal chamber temperature cannot be maintained at 85°F (29°C) or less.

17-6.7 **Treatment Table 8.** Treatment Table 8, Figure 17-9, is an adaptation of Royal Navy Treatment Table 65 mainly for treating deep uncontrolled ascents (see Chapter 13) when more than 60 minutes of decompression have been missed. Compress symptomatic patient to depth of relief not to exceed 225 fsw. Initiate Treatment Table 8 from depth of relief. The schedule for Treatment Table 8 from 60 fsw is the same as Treatment Table 7. The guidelines for sleeping and eating are the same as Treatment Table 7.

17-6.8 **Treatment Table 9.** Treatment Table 9, Figure 17-10, is a hyperbaric oxygen treatment table providing 90 minutes of oxygen breathing at 45 feet. This table is used only on the recommendation of a Diving Medical Officer cognizant of the patient's medical condition. Treatment Table 9 is used for the following:

1. Residual symptoms remaining after initial treatment of AGE/DCS
2. Selected cases of carbon monoxide or cyanide poisoning
3. Smoke inhalation

This table may also be recommended by the cognizant Diving Medical Officer when initially treating a severely injured patient whose medical condition precludes long absences from definitive medical care.

17-7 RECOMPRESSION TREATMENT FOR NON-DIVING DISORDERS

In addition to individuals suffering from diving-related disorders, U.S. Navy recompression chambers are also permitted to conduct emergent hyperbaric oxygen (HBO_2) therapy to treat individuals suffering from cyanide poisoning, carbon monoxide poisoning, gas gangrene, smoke inhalation, necrotizing soft-tissue infections, or arterial gas embolism arising from surgery, diagnostic procedures, or thoracic trauma. If the chamber is to be used for treatment of non-diving related medical conditions other than those listed above, authorization from BUMED Code M95 shall be obtained before treatment begins (BUMEDINST 6320.38 series.) Any treatment of a non-diving related medical condition shall be done under the cognizance of a Diving Medical Officer.

The guidelines given in Table 17-4 for conducting HBO_2 therapy are taken from the Undersea and Hyperbaric Medical Society's Hyperbaric Oxygen (HBO_2) Therapy Committee Report-2014: Approved Indications for Hyperbaric Oxygen Therapy. For each condition, the guidelines prescribe the recommended Treatment Table, the frequency of treatment, and the minimum and maximum number of treatments.

Table 17-4. Guidelines for Conducting Hyperbaric Oxygen Therapy.

Indication	Treatment Table	Minimum # Treatments	Maximum # Treatments
Carbon Monoxide Poisoning, acute	Treatment Table 5 or Table 6 as recommended by the DMO	1-3	3
Gas Gangrene (Clostridial Myonecrosis)	Treatment Table 5	3 times in 24 hours 2 times per day for the next 2-5 days	10
Crush Injury, Compartment Syndrome, and other Acute Traumatic Ischemia	Treatment Table 9	2 times per day for 2-7 days	14
Central Retinal Artery Occlusion	Treatment Table 6	2 times daily to clinical plateau (typically < 1 week) plus 3 days	3 days after clinical plateau
Diabetic Foot Ulcer	Treatment Table 9	Daily for 3-4 weeks, based on healing response	30
Healing of Other Problem Wounds	Treatment Table 9	Daily for 3-4 weeks, based on healing response	60
Severe Anemia	Treatment Table 5 or Table 9 as recommended by DMO	3-4 times per day until blood replacement by transfusion or regrowth	variable, guided by clinical response
Intracranial Abscess	Treatment Table 9	1-2 times daily for up to 3 weeks	20
Necrotizing Soft Tissue Infection	Treatment Table 9	2 times daily until stabilization	30
Refractory Osteomyelitis	Treatment Table 5 or Table 9 as recommended by DMO	20-40 treatments	40
Delayed Radiation Injury, Soft Tissue Necrosis, Bony Necrosis	Treatment Table 9	For radiation injury: 30-60 treatments For prophylaxis: 20 treatments before surgery in radiated field; 10 sessions after surgery	60
Compromised Grafts and Flaps	Treatment Table 9	2 times daily up to 30 treatments	20
Acute Thermal Burn Injury	Treatment Table 9	2 times daily up to 30 treatments	30
Idiopathic Sudden Sensori-neural Hearing Loss	Treatment Table 9	10-20 treatments	20

17-8 RECOMPRESSION CHAMBER LIFE-SUPPORT CONSIDERATIONS

The short treatment tables (Oxygen Treatment Tables 5, 6, 6A, 9; Air Treatment Tables 1A and 2A) can be accomplished easily without significant strain on either the recompression chamber facility or support crew. The long treatment tables (Tables 3, 4, 7, and 8) will require long periods of decompression and may tax both personnel and hardware severely.

17-8.1 **Oxygen Control.** All treatment schedules listed in this chapter are usually performed with a chamber atmosphere of air. To accomplish safe decompression, the oxygen percentage should not be allowed to fall below 19 percent. Oxygen may be added to the chamber by ventilating with air or by bleeding in oxygen from an oxygen breathing system. If a portable oxygen analyzer is available, it can be used to determine the adequacy of ventilation and/or addition of oxygen. If no oxygen analyzer is available, ventilation of the chamber in accordance with paragraph 17-8.4 will ensure adequate oxygenation. Chamber oxygen percentages as high as 25 percent are permitted. If the chamber is equipped with a life-support system so that ventilation is not required and an oxygen analyzer is available, the oxygen level should be maintained between 19 percent and 25 percent. If chamber oxygen goes above 25 percent, ventilation with air should be used to bring the oxygen percentage down.

17-8.2 **Carbon Dioxide Control.** Ventilation of the chamber in accordance with paragraph 17-8.4 will ensure that carbon dioxide produced metabolically does not cause the chamber carbon dioxide level to exceed 1.5 percent SEV (11.4 mmHg).

17-8.2.1 **Carbon Dioxide Monitoring.** Chamber carbon dioxide should be monitored with electronic carbon dioxide monitors. Monitors generally read CO_2 percentage once chamber air has been exhausted to the surface. The CO_2 percent reading at the surface 1 ata must be corrected for depth. To keep chamber CO_2 below 1.5 percent SEV (11.4 mmHg), the surface CO_2 monitor values should remain below 0.78 percent with chamber depth at 30 feet, 0.53 percent with chamber depth at 60 feet, and 0.25 percent with the chamber at 165 feet. If the CO_2 analyzer is within the chamber, no correction to the CO_2 readings is necessary.

17-8.2.2 **Carbon Dioxide Scrubbing.** If the chamber is equipped with a carbon dioxide scrubber, the absorbent should be changed when the partial pressure of carbon dioxide in the chamber reaches 1.5 percent SEV (11.4 mmHg). If absorbent cannot be changed, supplemental chamber ventilation will be required to maintain chamber CO_2 at acceptable levels. With multiple or working chamber occupants, supplemental ventilation may be necessary to maintain chamber CO_2 at acceptable levels.

17-8.2.3 **Carbon Dioxide Absorbent.** CO_2 absorbent in an opened but resealed bucket may be used until the expiration date on the bucket is reached. Pre-packed, double-bagged canisters shall be labeled with the expiration date from the absorbent bucket. Expired CO_2 absorbent shall not be used in any recompression chamber.

17-8.3 **Temperature Control.** Internal chamber temperature should be maintained at a level comfortable to the occupants whenever possible. Cooling can usually be accomplished by chamber ventilation. If the chamber is equipped with a heater/chiller unit, temperature control can usually be maintained for chamber occupant comfort under any external environmental conditions. Usually, recompression chambers will become hot and must be cooled continuously. Chambers should always be shaded from direct sunlight. The maximum durations for chamber occupants will depend on the internal chamber temperature as listed in Table 17-5. Never commit to a treatment table that will expose the chamber occupants to greater temperature/time combinations than listed in Table 17-5 unless qualified medical personnel who can evaluate the trade-off between the projected heat stress and the anticipated treatment benefit are consulted. A chamber temperature below 85°F (29°C) is always desirable, no matter which treatment table is used.

For patients with brain or spinal cord damage, the current evidence recommends aggressive treatment of elevated body temperature. When treating victims of AGE or severe neurological DCS, hot environments that elevate body temperature above normal should be avoided, whenever possible. Patient temperature should be a routinely monitored vital sign.

Table 17-5. *Maximum Permissible Recompression Chamber Exposure Times at Various Internal Chamber Temperatures.*

Internal Temperature	Maximum Tolerance Time	Permissible Treatment Tables
Over 104°F (40°C)	Intolerable	No treatments
95–104°F (34.4–40°C)	2 hours	Table 5, 9
85–94°F (29–34.4°C)	6 hours	Tables 5, 6, 6A, 1A, 9
Under 85°F (29°C)	Unlimited	All treatments

NOTE:
Internal chamber temperature can be kept considerably below ambient by venting or by using an installed chiller unit. Internal chamber temperature can be measured using electronic, bimetallic, alcohol, or liquid crystal thermometers. Never use a mercury thermometer in or around hyperbaric chambers. Since chamber ventilation will produce temperature swings during ventilation, the above limits should be used as averages when controlling temperature by ventilation. Always shade chamber from direct sunlight.

17-8.3.1 **Patient Hydration.** Always ensure patients are adequately hydrated. Fully conscious patients may be given fluid by mouth to maintain adequate hydration. One to two liters of water, juice, or non-carbonated drink, over the course of a Treatment Table 5 or 6, is usually sufficient. Patients with Type II symptoms, or symptoms of arterial gas embolism, should be considered for IV fluids. Stuporous or unconscious patients should always be given IV fluids, using large-gauge plastic catheters. If trained personnel are present, an IV should be started as soon as possible and kept dripping at a rate of 75 to 100 cc/hour, using isotonic fluids (Lactated Ringer's Solution, Normal Saline) until specific instructions regarding the rate and type of fluid administration are given by qualified medical personnel. Avoid solutions containing glucose (Dextrose) if brain or spinal cord injury is present. Intravenously administered glucose may worsen the outcome. In some cases, the bladder may be paralyzed. The victim's ability to void shall be assessed as soon as possible. If the patient cannot empty a full bladder, a urinary catheter shall be inserted as soon as possible by trained personnel. Always inflate catheter balloons with liquid, not air. Adequate fluid is being given when urine output is at least 0.5cc/kg/hr. Thirst is an unreliable indicator of the water intake to compensate for heavy sweating. A useful indicator of proper hydration is a clear colorless urine.

17-8.4 **Chamber Ventilation.** Ventilation is the usual means of controlling oxygen level, carbon dioxide level, and temperature. Ventilation using air is required for chambers without carbon dioxide scrubbers and atmospheric analysis. A ventilation rate of two acfm for each resting occupant, and four acfm for each active occupant, should be used. These procedures are designed to assure that the effective concentration of carbon dioxide will not exceed 1.5 percent sev (11.4 mmHg) and that, when oxygen is being used, the percentage of oxygen in the chamber will not exceed 25 percent.

17-8.5 **Access to Chamber Occupants.** Recompression treatments usually require access to occupants for passing in items such as food, water, and drugs and passing out such items as urine, excrement, and trash. Never attempt a treatment longer than a Treatment Table 6 unless there is access to inside occupants. When doing a Treatment Table 4, 7, or 8, a double-lock chamber is mandatory because additional personnel may have to be locked in and out during treatment.

17-8.6 **Inside Tender Oxygen Breathing.** During treatments, all chamber occupants may breathe 100 percent oxygen at depths of 45 feet or shallower without locking in additional personnel. Tenders should not fasten the oxygen masks to their heads, but should hold them on their faces. When deeper than 45 feet, at least one chamber occupant must breathe air. Tender oxygen breathing requirements are specified in the figure for each Treatment Table.

17-8.7 **Tending Frequency.** Normally, tenders should allow a surface interval of at least 18 hours between consecutive treatments on Treatment Tables 1A, 2A, 3, 5, 6, and 6A, and at least 48 hours between consecutive treatments on Tables 4, 7, and 8. If necessary, however, tenders may repeat Treatment Tables 5, 6, or 6A within this 18-hour surface interval if oxygen is breathed at 30 feet and shallower as outlined in Table 17-7. Minimum surface intervals for Treatment Tables 1A, 2A, 3, 4, 7, and 8 shall be strictly observed.

17-8.8 **Equalizing During Descent.** Descent rates may have to be decreased as necessary to allow the patient to equalize; however, it is vital to attain treatment depth in a timely manner for a suspected arterial gas embolism patient.

17-8.9 **Use of High Oxygen Mixes.** High oxygen N_2O_2/HeO_2 mixtures may be used to treat patients when recompression deeper than 60 fsw is required. These mixtures offer significant therapeutic advantages over air. Select a treatment gas that will produce a ppO_2 between 1.5 and 3.0 ata at the treatment depth. The standardized gas mixtures shown in Table 17-6 are suitable over the depth range of 61-225 fsw.

Decompression sickness following helium dives can be treated with either nitrogen or helium mixtures. For recompression deeper than 165 fsw, helium mixtures are preferred to avoid narcosis. The situation is less clear for treatment of decompression sickness following air or nitrogen-oxygen dives. Experimental studies have shown both benefit and harm with helium treatment. Until more experience is obtained, high oxygen mixtures with nitrogen as the diluent gas are preferred if available. High oxygen mixtures may also be substituted for 100% oxygen at 60 fsw and shallower on Treatment Tables 4, 7, and 8 if the patient is unable to tolerate 100% oxygen.

***Table 17-6.** High Oxygen Treatment Gas Mixtures.*

Depth (fsw)	Mix (HeO_2 or N_2O_2)	ppO_2
0-60	100%	1.00-2.82
61-165	50/50	1.42-3.00
166-225	64/36 (HeO_2 only)	2.17-2.81

17-8.10 **Oxygen Toxicity During Treatment.** Acute CNS oxygen toxicity may develop on any oxygen treatment table.

During prolonged treatments on Treatment Tables 4, 7, or 8, and with repeated Treatment Table 6, pulmonary oxygen toxicity may also develop.

17-8.10.1 **Central Nervous System Oxygen Toxicity.** When employing the oxygen treatment tables, tenders must be particularly alert for the early symptoms of CNS oxygen toxicity. The symptoms can be remembered readily by using the mnemonic VENTID-C (Vision, Ears, Nausea, Twitching\Tingling, Irritability, Dizziness, Convulsions). Unfortunately, a convulsion may occur without early warning signs or before the patient can be taken off oxygen in response to the first sign of CNS oxygen toxicity. CNS oxygen toxicity is unlikely in resting individuals at chamber depths of 50 feet or shallower and very unlikely at 30 feet or shallower, regardless of the level of activity. However, patients with severe Type II decompression sickness or arterial gas embolism symptoms may be abnormally sensitive to CNS oxygen toxicity. Convulsions unrelated to oxygen toxicity may also occur and may be impossible to distinguish from oxygen seizures.

17-8.10.1.1 ***Procedures in the Event of CNS Oxygen Toxicity.*** At the first sign of CNS oxygen toxicity, the patient should be removed from oxygen and allowed to breathe chamber air. Fifteen minutes after all symptoms have subsided, resume oxygen breathing. For Treatment Tables 5, 6, 6A resume treatment at the point of interruption. For Treatment Tables 4, 7 and 8 no compensatory lengthening of the table is required. If symptoms of CNS oxygen toxicity develop again or if the first symptom is a convulsion, take the follow action:

CAUTION **Inserting an airway device or bite block is not recommended while the patient is convulsing; it is not only difficult, but may cause harm if attempted.**

For Treatment Tables 5, 6, and 6A:

- Remove the mask.

- After all symptoms have completely subsided, decompress 10 feet at a rate of 1 fsw/min. For a convulsion, begin travel when the patient is fully relaxed and breathing normally.

- Resume oxygen breathing at the shallower depth at the point of interruption.

- If another oxygen symptom occurs after ascending 10 fsw, contact a Diving Medical Officer to recommend appropriate modifications to the treatment schedule.

For Treatment Tables 4, 7, and 8:

- Remove the mask.

- Consult with a Diving Medical Officer before administering further oxygen breathing. No compensatory lengthening of the table is required for interruption in oxygen breathing.

17-8.10.2 **Pulmonary Oxygen Toxicity.** Pulmonary oxygen toxicity is unlikely to develop on single Treatment Tables 5, 6, or 6A. On Treatment Tables 4, 7, or 8 or with repeated Treatment Tables 5, 6, or 6A (especially with extensions) prolonged exposure to oxygen may result in end-inspiratory discomfort, progressing to substernal burning and severe pain on inspiration. If a patient who is responding well to treatment complains of substernal burning, discontinue use of oxygen and consult with a DMO. However, if a significant neurological deficit remains and improvement is continuing (or if deterioration occurs when oxygen breathing is interrupted), oxygen breathing should be continued as long as considered beneficial or until pain limits inspiration. If oxygen breathing must be continued beyond the period of substernal burning, or if the 2-hour air breaks on Treatment Tables 4, 7, or 8 cannot be used because of deterioration upon the discontinuance of oxygen, the oxygen breathing periods should be changed to 20 minutes on oxygen, followed by 10 minutes breathing chamber air or alternative treatment gas mixtures with a lower percentage of oxygen should be considered. The Diving Medical Officer may tailor the above guidelines to suit individual patient response to treatment.

17-8.11 **Loss of Oxygen During Treatment.** Loss of oxygen breathing capability during oxygen treatments is a rare occurrence. However, should it occur, the following actions should be taken:

If repair can be completed within 15 minutes:

- Maintain depth until repair is completed.

- After O_2 is restored, resume treatment at point of interruption.

If repair can be completed after 15 minutes but before 2 hours:

- Maintain depth until repair is completed.

- After O_2 is restored: If original table was Table 5, 6, or 6A, complete treatment with maximum number of O_2 extensions.

17-8.11.1 **Compensation.** If Table 4, 7, or 8 is being used, no compensation in decompression is needed if oxygen is lost. If decompression must be stopped because of worsening symptoms in the affected diver, then stop decompression. When oxygen is restored, continue treatment from where it was stopped.

17-8.11.2 **Switching to Air Treatment Table.** If O_2 breathing cannot be restored in 2 hours switch to the comparable air treatment table at current depth for decompression if 60 fsw or shallower. Rate of ascent must not exceed 1 fpm between stops. If symptoms worsen and an increase in treatment depth deeper than 60 feet is needed, use Treatment Table 4.

17-8.12 **Treatment at Altitude.** Before starting recompression therapy, zero the chamber depth gauges to adjust for altitude. Then use the depths as specified in the treatment table. There is no need to "Cross Correct" the treatment table depths. Divers serving as inside tenders during hyperbaric treatments at altitude are performing a dive at altitude and therefore require more decompression than at sea level. Tenders locking into the chamber for brief periods should be managed according to the Diving At Altitude procedures (paragraph 9-13). Tenders remaining in the chamber for the full treatment table must breathe oxygen during the terminal portion of the treatment to satisfy their decompression requirement.

The additional oxygen breathing required at altitude on Treatment Table 5, Treatment Table 6, and Treatment Table 6A is given in Table 17-6. The requirement pertains both to tenders equilibrated at altitude and to tenders flown directly from sea level to the chamber location. Contact NEDU for guidance on tender oxygen requirements for other treatment tables.

17-9 POST-TREATMENT CONSIDERATIONS

Tenders on Treatment Tables 5, 6, 6A, 1A, 2A, or 3 should have a minimum of a 18-hour surface interval before no-decompression diving and a minimum of a 24-hour surface interval before dives requiring decompression stops. Tenders on Treatment Tables 4, 7, and 8 should have a minimum of a 48-hour surface interval prior to diving.

17-9.1 **Post-Treatment Observation Period.** After a treatment, patients treated on a Treatment Table 5 should remain at the recompression chamber facility for 2 hours. Patients who have been treated for Type II decompression sickness or who required a Treatment Table 6 for Type I symptoms and have had complete relief should remain at the recompression chamber facility for 6 hours. Patients treated on Treatment Tables 6, 6A, 4, 7, 8 or 9 are likely to require a period of hospitalization, and the Diving Medical Officer will need to determine a post-treatment observation period and location appropriate to their response to recompression treatment. These times may be shortened upon the recommendation of a Diving Medical Officer, provided the patient will be with personnel who are experienced at recognizing recurrence of symptoms and can return to the recompression facility within 30 minutes. All patients should remain within 60 minutes travel time of a recompression facility for 24 hours and should be accompanied throughout that period. No patient shall be released until authorized by a DMO.

Treatment table profiles place the inside tender(s) at risk for decompression sickness. After completing treatments, inside tenders should remain in the vicinity of the recompression chamber for 1 hour. If they were tending for Treatment Table 4, 7, or 8, inside tenders should also remain within 60 minutes travel time of a recompression facility for 24 hours.

***Table 17-7.** Tender Oxygen Breathing Requirements. (Note 1)*

		Altitude		
Treatment Table (TT)		Surface to 2499 ft	2500 ft. - 7499 ft.	7500 ft. - 10,000 ft.
TT5 Note (2)	without extension	:00	:00	:00
	with extension @ 30 fsw	:00	:00	:20
TT6 Note (2)	up to one extension @ 60 fsw or 30 fsw	:30	:60	:90
	more than one extension	:60	:90	:120
TT6A Note (2)	up to one extension @ 60 fsw or 30 fsw	:60	:120	:150 Note (3)
	more than one extension	:90	:150 Note (3)	:180 Note (3)

Note 1: All tender O_2 breathing times in table are conducted at 30 fsw. In addition, tenders will breathe O_2 on ascent from 30 fsw to the surface.

Note 2: If the tender had a previous hyperbaric exposure within 18 hours, use the following guidance for administering O_2:
For TT5, add an additional 20 minute O_2 breathing period to the times in the table.
For TT6 or TT6A, add an additional 60 minute O_2 breathing period to the times in the table.
For other Treatment tables contact NEDU for guidance.

Note 3: In some instances, tender's oxygen breathing obligation exceeds the table stay time at 30 fsw. Extend the time at 30 fsw to meet these obligations if patient's condition permits. Otherwise, administer O_2 to the tender to the limit allowed by the treatment table and observe the tender on the surface for 1 hour for symptoms of DCS.

17-9.2 **Post-Treatment Transfer.** Patients with residual symptoms should be transferred to appropriate medical facilities as directed by qualified medical personnel. If ambulatory patients are sent home, they should always be accompanied by someone familiar with their condition who can return them to the recompression facility should the need arise. Patients completing treatment do not have to remain in the vicinity of the chamber if the Diving Medical Officer feels that transferring them to a medical facility immediately is in their best interest.

17-9.3 **Flying After Treatments.** Patients with residual symptoms should fly only with the concurrence of a Diving Medical Officer. Patients who have been treated for decompression sickness or arterial gas embolism and have complete relief should not fly for 72 hours after treatment, at a minimum.

Tenders on Treatment Tables 5, 6, 6A, 1A, 2A, or 3 should have a 24-hour surface interval before flying. Tenders on Treatment Tables 4, 7, and 8 should not fly for 72 hours.

17-9.3.1 **Emergency Air Evacuation.** Some patients will require air evacuation to another treatment or medical facility immediately after surfacing from a treatment. They will not meet surface interval requirements as described above. Such evacuation is done only on the recommendation of a Diving Medical Officer. Aircraft pressurized to one ata should be used if possible, or unpressurized aircraft flown as low as safely possible (no more than 1,000 feet is preferable). Have the patient breathe 100 percent oxygen during transport, if available. If available, an Emergency Evacuation Hyperbaric Stretcher to maintain the patient at 1ata may be used.

17-9.4 **Treatment of Residual Symptoms.** After completion of the initial recompression treatment and after a surface interval sufficient to allow complete medical evaluation, additional recompression treatments may be instituted. If additional recompression treatments are indicated a Diving Medical Officer must be consulted. Residual symptoms may remain unchanged during the first one or two treatments. In these cases, the Diving Medical Officer is the best judge as to the number of recompression treatments. Consultation with NEDU or NDSTC may be appropriate. As the delay time between completion of initial treatment and the beginning of follow-up hyperbaric treatments increases, the probability of benefit from additional treatments decreases. However, improvement has been noted in patients who have had delay times of up to 1 week. Therefore, a long delay is not necessarily a reason to preclude follow-up treatments. Once residual symptoms respond to additional recompression treatments, such treatments should be continued until no further benefit is noted. In general, treatment may be discontinued if there is no further sustained improvement after two consecutive treatments.

For persistent Type II symptoms, daily treatment on Table 6 may be used, but twice-daily treatments on Treatment Tables 5 or 9 may also be used. The treatment table chosen for re-treatments must be based upon the patient's medical condition and the potential for pulmonary oxygen toxicity. Patients surfacing from Treatment Table 6A with extensions, 4, 7, or 8 may have severe pulmonary oxygen toxicity and may find breathing 100 percent oxygen at 45 or 60 feet to be uncomfortable or even intolerable. In these cases, daily treatments at 30 feet may also be used. As many oxygen breathing periods (25 minutes on oxygen followed by 5 minutes on air) should be administered as can be tolerated by the patient. Ascent to the surface is at 20 feet per minute. A minimum oxygen breathing time is 90 minutes. A practical maximum bottom time is 3 to 4 hours at 30 feet. Treatments should not be administered on a daily basis for more than 5 days without a break of at least 1 day. These guidelines may have to be modified by the Diving Medical Officer to suit individual patient circumstances and tolerance to oxygen as measured by decrements in the patient's vital capacity.

17-9.5 **Returning to Diving after Recompression Treatment.** Divers diagnosed with any POIS or DCS shall be referred to a DMO for clearance prior to returning to diving. In most cases, a waiver of the physical standards will be required from BUPERS via BUMED. Refer to Bureau of Medicine and Surgery Manual (MANMED) P117 Article 15-102 for guidance.

17-10 NON-STANDARD TREATMENTS

The treatment recommendations presented in this chapter should be followed as closely as possible unless it becomes evident that they are not working. Only a Diving Medical Officer may then recommend changes to treatment protocols or use treatment techniques other than those described in this chapter. Any modifications to treatment tables shall be approved by the Commanding Officer. The standard treatment procedures in this chapter should be considered minimum treatments. Treatment procedures should never be shortened unless emergency situations arise that require chamber occupants to leave the chamber early, or the patient's medical condition precludes the use of standard U.S. Navy treatment tables.

17-11 RECOMPRESSION TREATMENT ABORT PROCEDURES

Once recompression therapy is started, it should be completed according to the procedures in this chapter unless the diver being treated dies or unless continuing the treatment would place the chamber occupants in mortal danger or in order to treat another more serious medical condition.

17-11.1 **Death During Treatment.** If it appears that the diver being treated has died, a Diving Medical Officer shall be consulted before the treatment is aborted. Once the decision to abort is made, there are a number of options for decompressing the tenders depending on the depth at which the death occurred and the preceding treatment profile.

- If death occurs following initial recompression to 60, 165, or 225 on Treatment Tables 6, 6A, 4 or 8, decompress the tenders on the Air/Oxygen schedule in the Air Decompression Table having a depth exactly equal to or deeper than the maximum depth attained during the treatment and a bottom time equal to or longer than the total elapsed time since treatment began. The Air/Oxygen schedule can be used even if gases other than air (i.e., nitrogen-oxygen or helium-oxygen mixtures) were breathed at depth.

- If death occurs after leaving the initial treatment depth on Treatment Tables 6 or 6A, decompress the tenders at 30 fsw/min to 30 fsw and have them breathe oxygen at 30 fsw for the times indicated in Table 17-6. Following completion of the oxygen breathing time at 30 fsw, decompress the tenders on oxygen from 30 fsw to the surface at 1 fsw/min.

- If death occurs after leaving the initial treatment depth on Treatment Tables 4 or 8, or after beginning treatment on Treatment Table 7 at 60 fsw, have the tenders decompress by continuing on the treatment table as written, or consult NEDU for a decompression schedule customized for the situation at hand. If neither option is possible, follow the original treatment table to 60 fsw. At 60 fsw, have the tenders breathe oxygen for 90 min in three 30-min periods separated by a 5-min air break. Continue decompression at 50, 40 and 30 fsw by breathing oxygen for 60 min at each depth. Ascend between stops at 30 fsw/min. At 50 fsw, breathe oxygen in two 30-min periods separated by a 5-min air break. At 40 and 30 fsw, breathe oxygen for the full 60-min period followed by a 15-min air break. Ascend to 20 fsw at 30 fsw/min and breathe oxygen for 120 min. Divide the oxygen time at 20 fsw into two 60-min periods separated by a 15 min air break. When oxygen breathing time is complete at 20 fsw, ascend to the surface at 30 fsw/min. Upon surfacing, observe the tenders carefully for the occurrence of decompression sickness.

17-11.2 Impending Natural Disasters or Mechanical Failures. Impending natural disasters or mechanical failures may force the treatment to be aborted. For instance, the ship where the chamber is located may be in imminent danger of sinking or a fire or explosion may have severely damaged the chamber system to such an extent that completing the treatment is impossible. In these cases, the abort procedure described in paragraph 17-11.1 could be used for all chamber occupants (including the stricken diver) if time is available. If time is not available, the following may be done:

1. If deeper than 60 feet, go immediately to 60 feet.

2. Once the chamber is 60 feet or shallower, put all chamber occupants on continuous 100 percent oxygen. Select the Air/Oxygen schedule in the Air Decompression Table corresponding to the maximum depth attained during treatment and the total elapsed time since treatment began.

3. If at 60 fsw, breathe oxygen for period of time equal to the sum of all the decompression stops 60 fsw and deeper in the Air/Oxygen schedule, then continue decompression on the Air/Oxygen schedule, breathing oxygen continuously. If shallower than 60 fsw, breathe oxygen for a period of time equal to the sum of all the decompression stops deeper than the divers current depth, then continue decompression on the Air/Oxygen schedule, breathing oxygen continuously. Complete as much of the Air/Oxygen schedule as possible.

4. When no more time is available, bring all chamber occupants to the surface (try not to exceed 10 feet per minute) and keep them on 100 percent oxygen during evacuation, if possible.

5. Immediately evacuate all chamber occupants to the nearest recompression facility and treat according to Figure 17-1. If no symptoms occurred after the treatment was aborted, follow Treatment Table 6.

17-12 ANCILLARY CARE AND ADJUNCTIVE TREATMENTS

WARNING Drug therapy shall be administered only after consultation with a Diving Medical Officer and only by qualified inside tenders adequately trained and capable of administering prescribed medications.

Most U.S. military diving operations have the unique advantage over most other diving operations with the ability to provide rapid recompression for the victims of decompression sickness (DCS) and arterial gas embolism (AGE). When stricken divers are treated without delay, the success rate of standard recompression therapy is extremely good.

Some U.S. military divers, such as Special Operations Forces, however, may not have the benefit of a chamber nearby. Diving missions in Special Operations are often conducted in remote areas and may entail a lengthy delay to recompression therapy in the event of a diving accident. Delays to treatment for DCS and AGE significantly increase the probability of severe or refractory disease. In these divers, the use of adjunctive therapy (treatments other than recompression on a treatment table) can be provided while the diver is being transported to a chamber. Adjunctive therapies may also be useful for divers with severe symptoms or who have an incomplete response to recompression and hyperbaric oxygen.

Note that the adjunctive therapy guidelines are separated by accident type, with DCS and AGE covered separately. Although there is some overlap between the guidelines for these two disorders (as with the recompression phase of therapy), the best adjunctive therapy for one disorder is not necessarily the best therapy for the other. Although both DCS and AGE have in common the presence of gas bubbles in the body and a generally good response to recompression and hyperbaric oxygen, the underlying pathophysiology is somewhat different.

17-12.1 Decompression Sickness.

17-12.1.1 **Surface Oxygen.** Surface oxygen should be used for all cases of DCS until the diver can be recompressed. Use of either a high-flow (15 liters/minute) oxygen source with a reservoir mask or a demand valve can achieve high inspired fractions of oxygen. One consideration in administering surface oxygen is pulmonary oxygen toxicity. 100% oxygen can generally be tolerated for up to 12 hours. The patient may be given air breaks as necessary. If oxygen is being administered beyond this time, the decision to continue must weigh the perceived benefits against the risk of pulmonary oxygen toxicity. This risk evaluation must consider the dose of oxygen anticipated with subsequent recompression therapy as well.

17-12.1.2 **Fluids.** Fluids should be administered to all individuals suffering from DCS unless suffering from the chokes (pulmonary DCS). Oral fluids (water, Gatorade-like drinks) are acceptable if the diver is fully conscious, able to tolerate them. If oral fluids cannot be tolerated by the patient, intravenous fluids should be administered. There is no data available that demonstrates a superiority of crystalloids (normal saline or Lactated Ringers solution) over colloids (such as Hetastarch compounds (Hespan or Hextend)) for DCS, but D5W (dextrose in water without electrolytes) should not be used. Since colloids are far more expensive than Lactated Ringers or normal saline, the latter two agents are the most reasonable choices at this time. The optimal amount of crystalloids/colloids is likewise not well-established but treatment should be directed towards reversing any dehydration that may have been induced by the dive (immersion diuresis causes divers to lose 250-500 cc of fluids per hour) or fluid shifts resulting from the DCS. Fluid overloading should be avoided. Urinary output, in the range of 0.5-1.0cc/kg/hour is evidence of adequate intravascular volume.

Chokes (pulmonary DCS) causes abnormal pulmonary function and leakage of fluids into the alveolar spaces. Aggressive fluid therapy may make this condition worse. Consult a DMO (or NEDU) for guidance.

17-12.1.3 **Anticoagulants.** Since some types of DCS may increase the likelihood of hemorrhage into the tissues, anticoagulants should not be used routinely in the treatment of DCS. One exception to this rule is the case of lower extremity weakness. Low molecular weight heparin (LMWH) should be used for all patients with inability to walk due to any degree of lower extremity paralysis caused by neurological DCS or AGE. Enoxaparin 30 mg, or its equivalent, administered subcutaneously every 12 hours, should be started as soon as possible after injury to reduce the risk of deep venous thrombosis (DVT) and pulmonary embolism in any paralyzed patients. Compression stockings or intermittent pneumatic compression are alternatives, although they are less effective at preventing DVT than LMWH.

17-12.1.4 **Aspirin and Other Non-Steroidal Anti-Inflammatory Drugs.** Routine use of anti-platelet agents in patients with neurological DCS is not recommended, due to concern about worsening hemorrhage in spinal cord or inner ear decompression illness. Use of these agents may also be risky in combat divers who may be required to return to action after treatment of an episode of DCS.

17-12.1.5 **Steroids.** Steroids are no longer recommended for the treatment of DCS. No significant reduction in neurological residuals has been found in clinical studies for DCS adjunctively treated with steroids and elevated blood glucose levels associated with steroid administration may actually worsen the outcome of CNS injury.

17-12.1.6 **Lidocaine.** Lidocaine is not currently recommended for the treatment of any type of DCS.

17-12.1.7 **Environmental Temperature.** For patients with evidence of brain or spinal cord damage, the current evidence recommends aggressive treatment of elevated body temperature. When treating victims of neurological DCS, whenever practical, hot environments that may cause elevation of body temperature above normal should be avoided. The patient's body temperature and vital signs should be monitored regularly.

17-12.2 Arterial Gas Embolism.

17-12.2.1 **Surface Oxygen.** Surface oxygen should be used for all cases of AGE as it is for DCS.

17-12.2.2 **Lidocaine.** Lidocaine has been shown to be potentially beneficial in the treatment of AGE. Current recommendations suggests a dosing end-point to achieve serum concentrations producing an anti-arrhythmic effect. An intravenous initial dose of 1 mg/kg followed by a continuous infusion of 2-4 mg/minute, will typically produce therapeutic serum concentrations. If an intravenous infusion is not established, intramuscular administration of 4-5 mg/kg will typically produce a therapeutic plasma concentration 15 minutes after dosing, lasting for around 90 minutes. Doses greater than those noted above may be associated with major side effects, including paresthesias, ataxia, and seizures. Therefore, Lidocaine should only be administered under the supervision of a DMO or other qualified physician.

17-12.2.3 **Fluids.** The fluid replacement recommendations for the treatment of AGE differ from those of DCS. Fluid replacement recommendations for AGE differ from DCS because the CNS injury in AGE may be complicated by cerebral edema, which may be worsened by an increased fluid load, thus causing further injury to the diver. If fluid replacement is conducted, colloids are probably the best choice due to their mechanism of action in maintaining intra-vascular volume and minimizing extra-vascular leakage. Particular care must be taken not to fluid overload the injured diver suffering from AGE by adjusting IV rates to maintain just an adequate urine output of 0.5cc/kg/hour. A urinary catheter should be inserted in the unconscious patient and urinary output measured.

17-12.2.4 **Anticoagulants.** Anticoagulants should not be used routinely in the treatment of AGE. As noted previously in paragraph 17-12.1.3 on anticoagulants in DCS, Enoxaparin 30 mg, or its equivalent, should be administered subcutaneously every 12 hours, after initial recompression therapy in patients suffering from paralysis to prevent deep venous thrombosis (DVT) and pulmonary embolism.

17-12.2.5 **Aspirin and Other Non-Steroidal Anti-Inflammatory Drugs.** Routine use of anti-platelet agents in patients with AGE is not recommended.

17-12.2.6 **Steroids.** Steroids are no longer recommended for the treatment of AGE. No significant reduction in neurologic residual has been shown with adjunctive treatment with steroids for AGE and elevated blood glucose levels associated with administration of steroids may worsen the outcome of CNS injury.

17-12.2.7 **Environmental Temperature.** For patients with evidence of brain or spinal cord damage, the current evidence recommends aggressive treatment of elevated body temperature. When treating victims of neurological DCS, whenever practical, hot environments that may cause elevation of body temperature above normal should be avoided. The patient's body temperature and vital signs should be monitored regularly.

17-12.3 **Sleeping and Eating.** The only time the patient should be kept awake during recompression treatments is during oxygen breathing periods at depths greater than 30 feet. Travel between decompression stops on Treatment Table 4, 7, and 8 is not a contra-indication to sleeping. While asleep, vital signs (pulse, respiratory rate, blood pressure) should be monitored as the patient's condition dictates. Any significant change would be reason to arouse the patient and ascertain the cause.

Food may be taken by chamber occupants at any time. Adequate fluid intake should be maintained as discussed in paragraph 17-8.3.1.

17-13 EMERGENCY MEDICAL EQUIPMENT

Every diving activity shall maintain emergency medical equipment that will be available immediately for use in the event of a diving accident. This equipment is to be in addition to any medical supplies maintained in a medical treatment facility and shall be kept in a kit small enough to carry into the chamber, or in a locker in the immediate vicinity of the chamber.

17-13.1 Primary and Secondary Emergency Kits. Because some sterile items may become contaminated as a result of a hyperbaric exposure, it is desirable to have a primary kit for immediate use inside the chamber and a secondary kit from which items that may become contaminated can be locked into the chamber only as needed. The primary emergency kit contains diagnostic and therapeutic equipment that is available immediately when required. This kit shall be inside the chamber during all treatments. The secondary emergency kit contains equipment and medicine that does not need to be available immediately, but can be locked-in when required. This kit shall be stored in the vicinity of the chamber.

The contents of the emergency kits presented here are not meant to be restrictive but are considered the minimum requirement. Additional items may be added to suit local medical preferences.

The Primary Emergency Kit is described in Table 17-8. The Secondary Emergency Kit is described in Table 17-9.

17-13.2 Portable Monitor-Defibrillator. All diving activities/commands shall maintain an automated external defibrillator (AED), preferably with heart rhythm visualization capability, from an approved Authorized Medical Allowance List (AMAL). Diving activities with assigned Diving Medical Officer are recommended to augment with a fully capable monitor defibrillator.

CAUTION **AED's are not currently approved for use under pressure (hyperbaric environment) due to electrical safety concerns.**

Table 17-8. *Primary Emergency Kit.*

Diagnostic Equipment
Stethoscope
Otoscope (Ophthalmoscope optional) and batteries
Sphygmomanometer (aneroid type only, case vented for hyperbaric use)
Reflex Hammer
Tuning Fork
Pinwheel
Tongue depressors
Thermometer/temperature measurement capability (non-mercury type)
Disposable exam gloves
Skin Marker
Pocket Eye Chart (Snellen)
Emergency Treatment Primary Survey Equipment and Medications
Oropharyngeal airways (#4 and #5 Guedel-type or equivalent)
Nasal airways (#32F and #34F latex rubber)
Lidocaine jelly (2%)
Self-Inflating Bag-Valve Mask (Disposable BVM)
Suction apparatus with appropriate suction tips
Tension pneumothorax relief kit with 3.25 inch, large-bore catheter on a needle
Cricothyrotomy kit
Adhesive tape (2 inch waterproof)
Elastic-Wrap bandage for a pressure bandage (2 and 4 inch)
Pressure dressing
Appropriate Combat Tourniquet
Trauma Scissors
Sterile 4X4s
Cravats
NOTE: One Primary Emergency Kit is required per chamber system, e.g. TRCS requires one. Additional Medical Equipment Authorized for Navy Use (ANU) in a chamber can be found in the Medical Equipment section of the ANU on the NAVSEA website. Contact the Senior Medical Officer at the Navy Experimental Diving Unit for any questions regarding specific pieces of medical equipment for use in the chamber.

Table 17-9. Secondary Emergency Kit.

Emergency Treatment Secondary Survey Equipment and Medications

- Alternative emergency airway device (recommend intubating laryngeal mask airway disposable LMA Fastrach™kit, size 4 – 5)
- Syringe and sterile water for cuff inflation (10 cc)
- Sterile lubricant
- Qualitative end-tidal CO_2 detector (colorimetric indicator)
- Chest tube
- BD Bard Parker Heimlich Chest Drain Valve (or other device to provide one-way flow of gas out of the chest)
- #11 knife blade and handle
- Sterile gloves (size 6 – 8)
- Surgical masks (4)
- 10% povidone-iodine swabs or wipes
- 1% lidocaine solution
- 21 gauge. 1 ½ -inch needles on 5 cc syringes (2)
- Curved Kelly forceps

Intravenous Infusion Therapy

- Catheter on a needle unit, intravenous (16 and 18 gauge - 4 ea)
- Adult interosseous infusion device (IO) for rapid vascular access
- Intravenous infusion sets (2 standard drip and 2 micro-drip)
- Syringes (5, 10 and 30 cc)
- Sterile needles (18, 22 and 25 gauge)
- Normal saline (1 liter bag (4))
- IV Start Kit (10% Povidone-Iodine swabs or wipes, 2 x 2 gauze sponges, Bioclusive dressing, ¾ -inch adhesive tape, phlebotomy tourniquet)
- Band aids
- Sam™ Splint

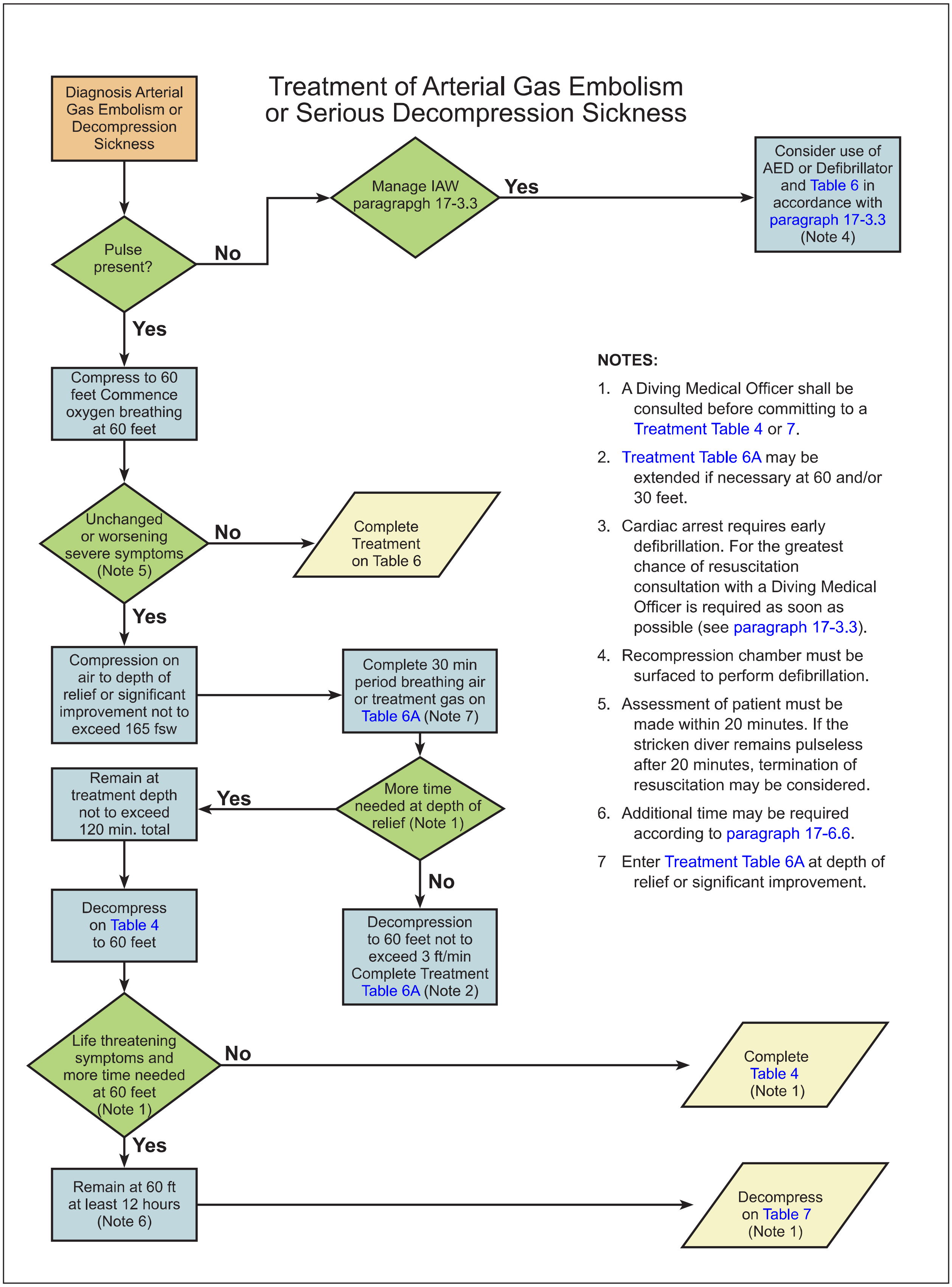
Miscellaneous

- Pulse Oximeter (Nonin 9500/8500 series)
- Nasogastric tube
- 60 cc Toomey Syringe (Optional)
- Urinary catheterization set with collection bag (appropriate size (12F–14F) Foley-type sterile catheters)
- Assorted suture material (0-silk with and without curved needles)
- Sharps disposable box
- Disposable Minor Surgical Tray can substitute for items listed below:
  - Straight and curved hemostats (2 of each)
  - Blunt straight surgical scissors
  - Needle driver
  - Sterile towels
  - Sterile gauze pads

NOTE 1: Whenever possible, preloaded syringe injection sets should be obtained to avoid the need to vent multi-dose vials or prevent implosion of ampules. Sufficient quantities should be maintained to treat one injured diver.

NOTE 2: One Secondary Emergency Kit is required per chamber system (i.e., TRCS requires one).

NOTE 3: A portable oxygen supply with an E cylinder (approximately 669 liters of oxygen) with a regulator capable of delivering 12 liters of oxygen per minute by mask/reservoir or 2 liters by nasal canula is recommended whenever possible in the event the patient needs to be transported to another facility.

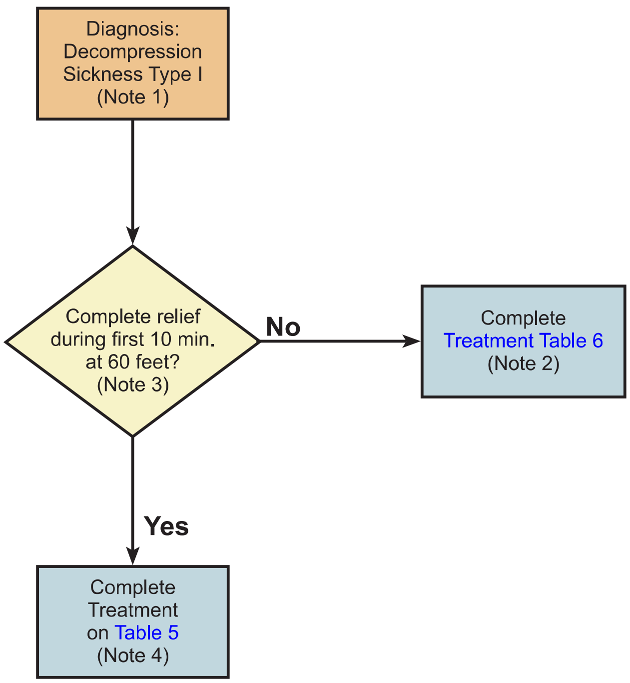


NOTES:

1. A Diving Medical Officer shall be consulted before committing to a Treatment Table 4 or 7.
2. Treatment Table 6A may be extended if necessary at 60 and/or 30 feet.
3. Cardiac arrest requires early defibrillation. For the greatest chance of resuscitation consultation with a Diving Medical Officer is required as soon as possible (see paragraph 17-3.3).
4. Recompression chamber must be surfaced to perform defibrillation.
5. Assessment of patient must be made within 20 minutes. If the stricken diver remains pulseless after 20 minutes, termination of resuscitation may be considered.
6. Additional time may be required according to paragraph 17-6.6.
7. Enter Treatment Table 6A at depth of relief or significant improvement.

Figure 17-1. Treatment of Arterial Gas Embolism or Serious Decompression Sickness.

Treatment of Type I Decompression Sickness



NOTES:

1. If a complete neurological exam was not completed before recompression, treat as a Type II symptom.
2. Treatment Table 6 may be extended up to four additional oxygen-breathing periods, two at 30 feet and/or two at 60 feet.
3. Diving Supervisor may elect to treat on Treatment Table 6.
4. Treatment Table 5 may be extended two oxygen-breathing periods at 30 fsw.

Figure 17-2. Treatment of Type I Decompression Sickness.

17-13.3 Advanced Cardiac Life Support (ACLS) Drugs and Equipment. All commands with chambers that participate in the local area bends watch shall maintain those drugs recommended by the American Heart Association for ACLS. These drugs need to be in sufficient quantities to support an event requiring Advanced Cardiac Life Support. These drugs are not required to be in every dive kit when multiple chambers/kits are present in a single command. In addition, medications for the treatment of anaphylaxis, which can occur related to marine life envenomation, including Epinephrine 1:1000 solution, Diphenhydramine IM or PO and Hydrocortisone Sodium Succinate IV will be maintained in adequate quantities to treat one patient.

Emergency medical equipment in support of ACLS includes cuffed endotracheal tubes with adapters (7-8 mm), malleable stylet (approx. 12" in length), laryngoscope with blades (McIntosh #3 and #4, Miller #2 and #3). Additional mechanical devices for verification of endotracheal tube placement are also authorized, but not required (Toomey-type or 50cc catheter tip syringe or equivalent).

NOTE **Some vendors supply pre-packed ACLS kits with automated replenishment programs (examples of which can be found on the Naval Expeditionary Combat Command (NECC) AMAL).**

17-13.4 **Use of Emergency Kits.** Unless adequately sealed against increased atmospheric pressure (i.e., vacuum packed), sterile supplies should be re-sterilized after each pressure exposure; or, if not exposed, to pressure, the sterile supplies should be replaced at package expiration date. Drugs shall be replaced when their expiration date is reached. Not all drug ampules will withstand pressure.

NOTE **Stoppered multi-dose vials with large air volumes may need to be vented with a needle during pressurization and depressurization and then discarded.**

Both kits should be taken to the recompression chamber or scene of the accident. Each kit is to contain a list of contents and have a tamper evident seal. Each time the kit is opened, it shall be inventoried and each item checked for proper working order and then re-sterilized or replaced as necessary. Unopened kits are inventoried quarterly. Concise instructions for administrating each drug are to be provided in the kit along with current American Heart Association Advanced Cardiac Life-Support Protocols. In untrained hands, many of the items can be dangerous. Remember that as in all treatments **YOUR FIRST DUTY IS TO DO NO HARM.**

17-13.4.1 **Modification of Emergency Kits.** Because the available facilities may differ on board ship, at land-based diving installations, and at diver training or experimental units, the responsible Diving Medical Officer or Diving Medical Technician are authorized to augment the emergency kits to suit the local needs.

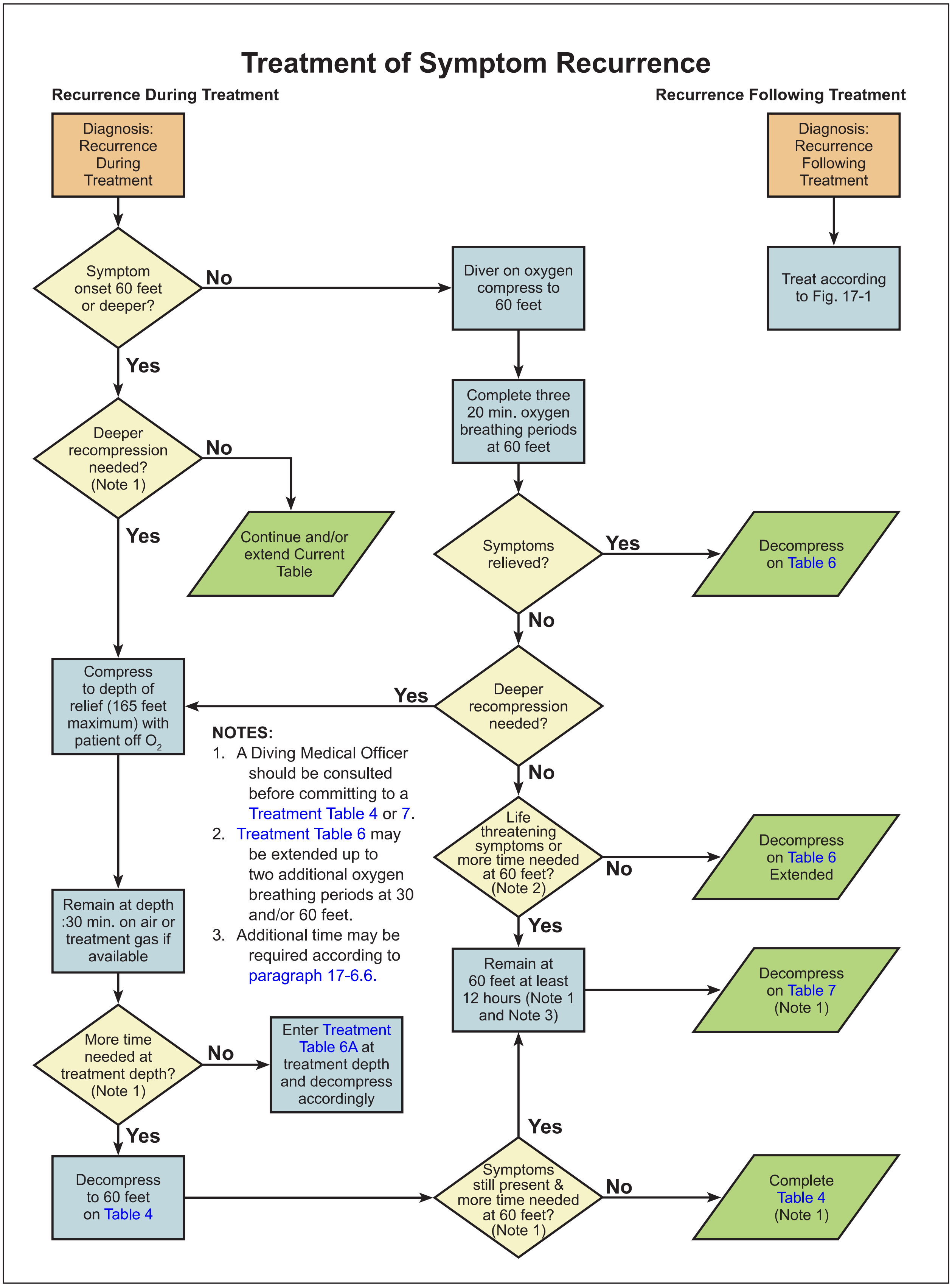


Figure 17-3. Treatment of Symptom Recurrence.

Treatment Table 5

1. Descent rate - 20 ft/min.
2. Ascent rate - Not to exceed 1 ft/min. Do not compensate for slower ascent rates. Compensate for faster rates by halting the ascent.
3. Time on oxygen begins on arrival at 60 feet.
4. If oxygen breathing must be interrupted because of CNS Oxygen Toxicity, allow 15 minutes after the reaction has entirely subsided and resume schedule at point of interruption (see paragraph 17-8.10.1.1)
5. Treatment Table may be extended two oxygen-breathing periods at the 30-foot stop. No air break required between oxygen-breathing periods or prior to ascent.
6. Tender breathes 100 percent O_2 during ascent from the 30-foot stop to the surface. If the tender had a previous hyperbaric exposure in the previous 18 hours, an additional 20 minutes of oxygen breathing is required prior to ascent.

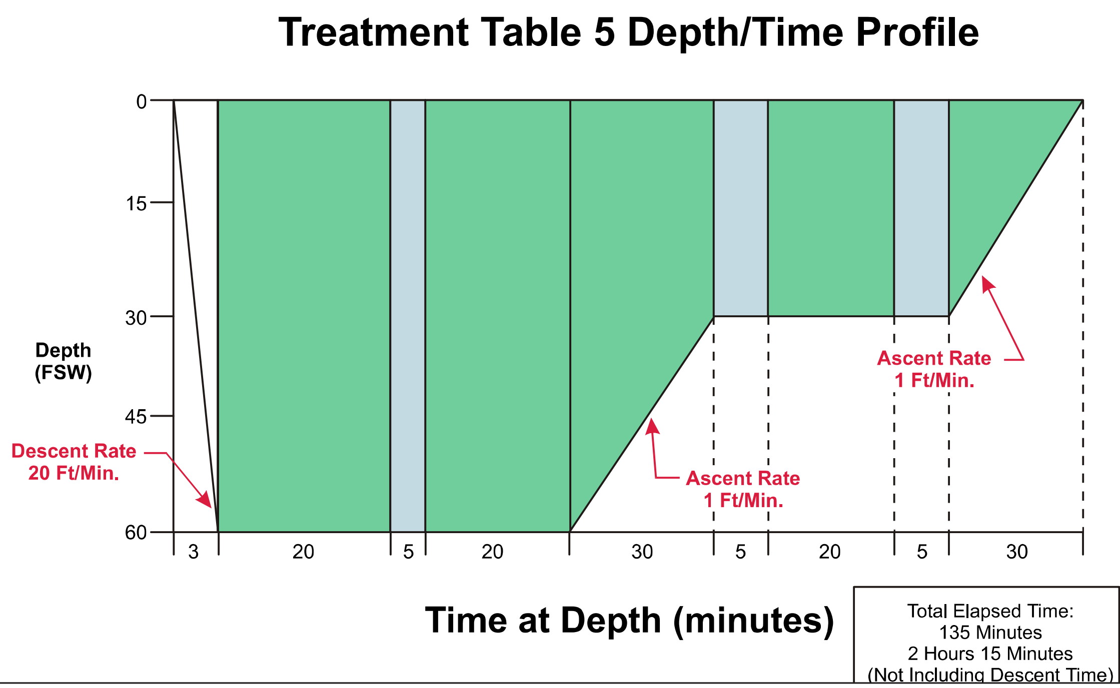


Figure 17-4. Treatment Table 5.

Treatment Table 6

1. Descent rate - 20 ft/min.
2. Ascent rate - Not to exceed 1 ft/min. Do not compensate for slower ascent rates. Compensate for faster rates by halting the ascent.
3. Time on oxygen begins on arrival at 60 feet.
4. If oxygen breathing must be interrupted because of CNS Oxygen Toxicity, allow 15 minutes after the reaction has entirely subsided and resume schedule at point of interruption (see paragraph 17-8.10.1.1).
5. Table 6 can be lengthened up to 2 additional 25-minute periods at 60 feet (20 minutes on oxygen and 5 minutes on air), or up to 2 additional 75-minute periods at 30 feet (15 minutes on air and 60 minutes on oxygen), or both.
6. Tender breathes 100 percent O_2 during the last 30 min. at 30 fsw and during ascent to the surface for an unmodified table or where there has been only a single extension at 30 or 60 feet. If there has been more than one extension, the O_2 breathing at 30 feet is increased to 60 minutes. If the tender had a hyperbaric exposure within the past 18 hours an additional 60-minute O_2 period is taken at 30 feet.

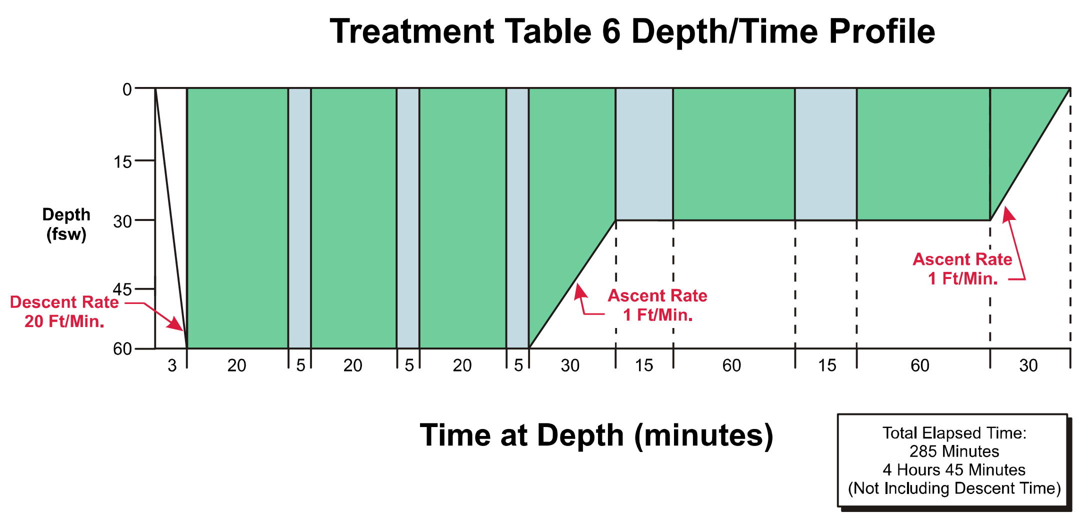


Figure 17-5. Treatment Table 6.

Treatment Table 6A

1. Descent rate - 20 ft/min.
2. Ascent rate - 165 fsw to 60 fsw not to exceed 3 ft/min, 60 fsw and shallower, not to exceed 1 ft/min. Do not compensate for slower ascent rates. Compensate for faster rates by halting the ascent.
3. Time at treatment depth does not include compression time.
4. Table begins with initial compression to depth of 60 fsw. If initial treatment was at 60 feet, up to 20 minutes may be spent at 60 feet before compression to 165 fsw. Contact a Diving Medical Officer.
5. If a chamber is equipped with a high-O_2 treatment gas, it may be administered at 165 fsw and shallower, not to exceed 3.0 ata O_2 in accordance with paragraph 17-8.9. Treatment gas is administered for 25 minutes interrupted by 5 minutes of air. Treatment gas is breathed during ascent from the treatment depth to 60 fsw.
6. Deeper than 60 feet, if treatment gas must be interrupted because of CNS oxygen toxicity, allow 15 minutes after the reaction has entirely subsided before resuming treatment gas. The time off treatment gas is counted as part of the time at treatment depth. If at 60 feet or shallower and oxygen breathing must be interrupted because of CNS oxygen toxicity, allow 15 minutes after the reaction has entirely subsided and resume schedule at point of interruption (see paragraph 17-8.10.1.1).
7. Table 6A can be lengthened up to 2 additional 25-minute periods at 60 feet (20 minutes on oxygen and 5 minutes on air), or up to 2 additional 75-minute periods at 30 feet (60 minutes on oxygen and 15 minutes on air), or both.
8. Tender breathes 100 percent O_2 during the last 60 minutes at 30 fsw and during ascent to the surface for an unmodified table or where there has been only a single extension at 30 or 60 fsw. If there has been more than one extension, the O_2 breathing at 30 fsw is increased to 90 minutes. If the tender had a hyperbaric exposure within the past 18 hours, an additional 60 minute O_2 breathing period is taken at 30 fsw.
9. If significant improvement is not obtained within 30 minutes at 165 feet, consult with a Diving Medical Officer before switching to Treatment Table 4.

Treatment Table 6A Depth/Time Profile

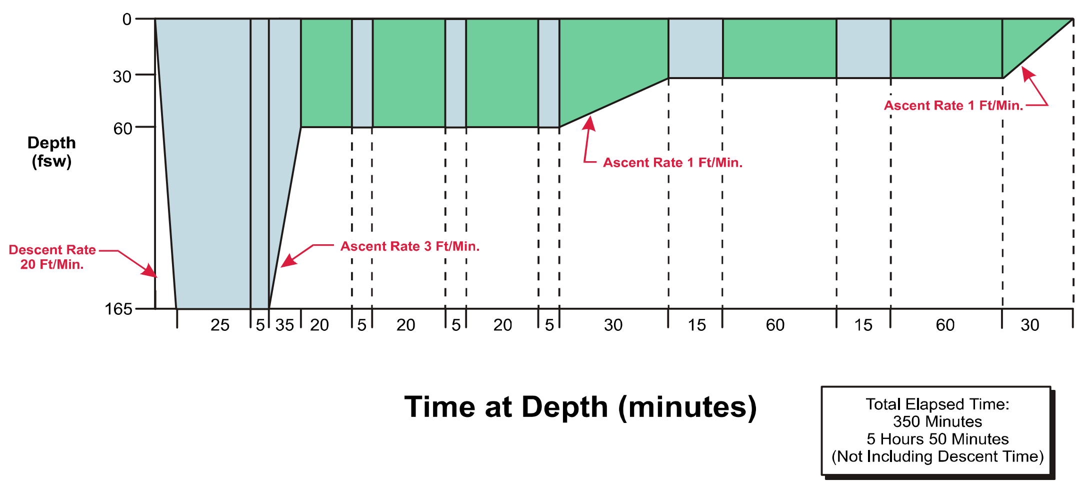
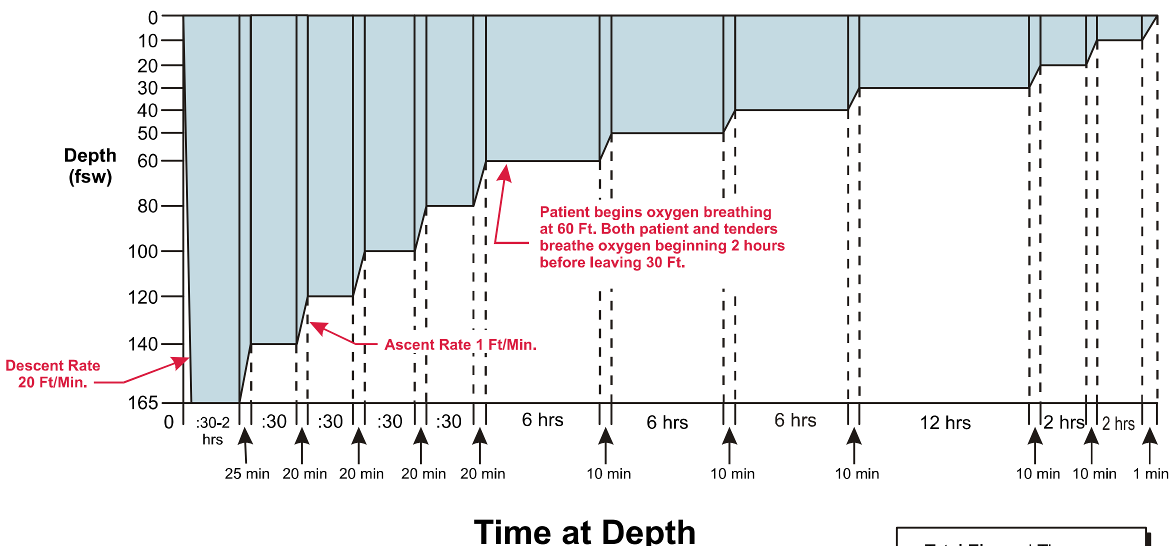


Figure 17-6. Treatment Table 6A.

Treatment Table 4

1. Descent rate - 20 ft/min.
2. Ascent rate - 1 ft/min.
3. Time at 165 feet includes compression.
4. If only air is available, decompress on air. If oxygen is available, patient begins oxygen breathing upon arrival at 60 feet with appropriate air breaks. Both tender and patient breathe oxygen beginning 2 hours before leaving 30 feet. (see paragraph 17-6.5).
5. Ensure life-support considerations can be met before committing to a Table 4. (see paragraph 17-8.10.1.1) Internal chamber temperature should be below 85° F.
6. If oxygen breathing is interrupted, no compensatory lengthening of the table is required.
7. If switching from Treatment Table 6A or 3 at 165 feet, stay a maximum of 2 hours at 165 feet before decompressing.
8. If the chamber is equipped with a high-O_2 treatment gas, it may be administered at 165 fsw, not to exceed 3.0 ata O_2. Treatment gas is administered for 25 minutes interrupted by 5 minutes of air.

Treatment Table 4 Depth/Time Profile



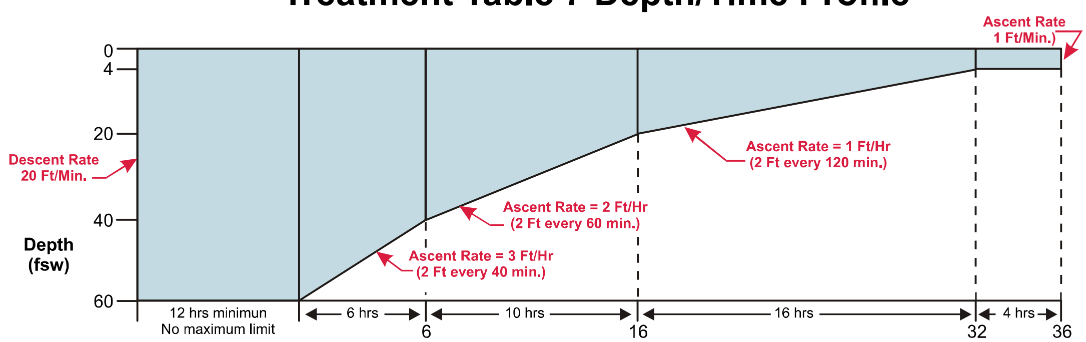
Total Elapsed Time:
39 Hours 6 Minutes
(30 Minutes at 165 fsw) to
40 Hours 36 Minutes
(2 Hours at 165 fsw)

Figure 17-7. Treatment Table 4.

Treatment Table 7

1. Table begins upon arrival at 60 feet. Arrival at 60 feet is accomplished by initial treatment on Table 6, 6A or 4. If initial treatment has progressed to a depth shallower than 60 feet, compress to 60 feet at 20 ft/min to begin Table 7.
2. Maximum duration at 60 feet is unlimited. Remain at 60 feet a minimum of 12 hours unless overriding circumstances dictate earlier decompression.
3. Patient begins oxygen breathing periods at 60 feet. Tender need breathe only chamber atmosphere throughout. If oxygen breathing is interrupted, no lengthening of the table is required.
4. Minimum chamber O_2 concentration is 19 percent. Maximum CO_2 concentration is 1.5 percent SEV (11.4 mmHg). Maximum chamber internal temperature is 85°F (paragraph 17-6.5).
5. Decompression starts with a 2-foot upward excursion from 60 to 58 feet. Decompress with stops every 2 feet for times shown in profile below. Ascent time between stops is approximately 30 seconds. Stop time begins with ascent from deeper to next shallower step. Stop at 4 feet for 4 hours and then ascend to the surface at 1 ft/min.
6. Ensure chamber life-support requirements can be met before committing to a Treatment Table 7.
7. A Diving Medical Officer should be consulted before committing to this treatment table.

Treatment Table 7 Depth/Time Profile



Time at Depth (hours)

Figure 17-8. Treatment Table 7.

Treatment Table 8

1. Enter the table at the depth which is exactly equal to or next greater than the deepest depth attained in the recompression. The descent rate is as fast as tolerable.
2. The maximum time that can be spent at the deepest depth is shown in the second column. The maximum time for 225 fsw is 30 minutes; for 165 fsw, 3 hours. For an asymptomatic diver, the maximum time at depth is 30 minutes for depths exceeding 165 fsw and 2 hours for depths equal to or shallower than 165 fsw.
3. Decompression is begun with a 2-fsw reduction in pressure if the depth is an even number. Decompression is begun with a 3-fsw reduction in pressure if the depth is an odd number. Subsequent stops are carried out every 2 fsw. Stop times are given in column three. The stop time begins when leaving the previous depth. Ascend to the next stop in approximately 30 seconds.
4. Stop times apply to all stops within the band up to the next quoted depth. For example, for ascent from 165 fsw, stops for 12 minutes are made at 162 fsw and at every two-foot interval to 140 fsw. At 140 fsw, the stop time becomes 15 minutes. When traveling from 225 fsw, the 166-foot stop is 5 minutes; the 164-foot stop is 12 minutes. Once begun, decompression is continuous. For example, when decompressing from 225 feet, ascent is not halted at 165 fsw for 3 hours. However, ascent may be halted at 60 fsw and shallower for any desired period of time.
5. While deeper than 165 fsw, a helium-oxygen mixture with 16-36 percent oxygen may be breathed by mask to reduce narcosis. A 64/36 helium-oxygen mixture is the preferred treatment gas. At 165 fsw and shallower, a HeO_2 or N_2O_2 mix with a ppO_2 not to exceed 3.0 ata may be given to the diver as a treatment gas. At 60 fsw and shallower, pure oxygen may be given to the divers as a treatment gas. For all treatment gases (HeO_2, N_2O_2, and O_2), a schedule of 25 minutes on gas and 5 minutes on chamber air should be followed for a total of four cycles. Additional oxygen may be given at 60 fsw after a 2-hour interval of chamber air. See Treatment Table 7 for guidance. If high O_2 breathing is interrupted, no lengthening of the table is required.
6. To avoid loss of the chamber seal, ascent may be halted at 4 fsw and the total remaining stop time of 240 minutes taken at this depth. Ascend directly to the surface upon completion of the required time.
7. Total ascent time from 225 fsw is 56 hours, 29 minutes. For a 165-fsw recompression, total ascent time is 53 hours, 52 minutes, and for a 60-fsw recompression, 36 hours, 0 minutes.

Depth (fsw)	Max Time at Initial Treatment Depth (hours)	2-fsw Stop Times (minutes)
225	0.5	5
165	3	12
140	5	15
120	8	20
100	11	25
80	15	30
60	Unlimited	40
40	Unlimited	60
20	Unlimited	120

Figure 17-9. Treatment Table 8.

Treatment Table 9

1. Descent rate - 20 ft/min.
2. Ascent rate - 20 ft/min. Rate may be slowed to 1 ft/min depending upon the patient's medical condition.
3. Time at 45 feet begins on arrival at 45 feet.
4. If oxygen breathing must be interrupted because of CNS Oxygen Toxicity, oxygen breathing may be restarted 15 minutes after all symptoms have subsided. Resume schedule at point of interruption (see paragraph 17-8.10.1.1).
5. Tender breathes 100 percent O_2 during last 15 minutes at 45 feet and during ascent to the surface regardless of ascent rate used.
6. Patient may breathe air or oxygen during ascent.
7. If patient cannot tolerate oxygen at 45 feet, this table can be modified to allow a treatment depth of 30 feet. The oxygen breathing time can be extended to a maximum of 3 to 4 hours.

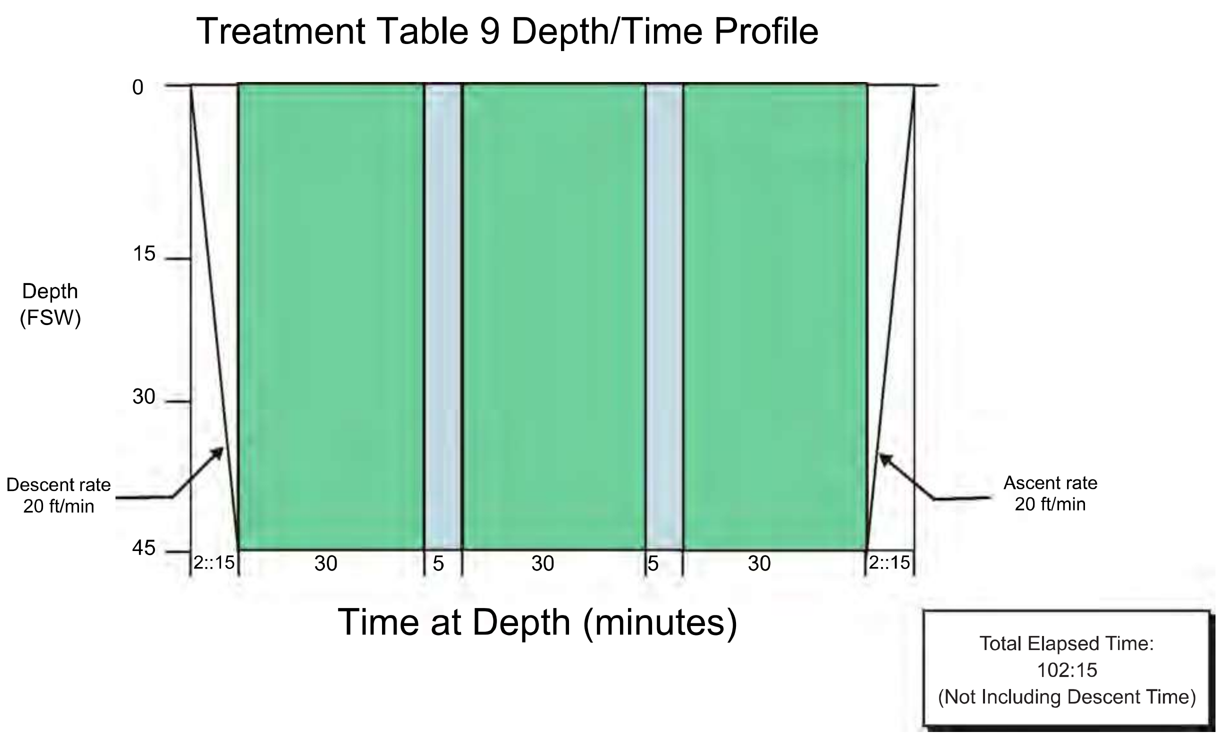


Figure 17-10. Treatment Table 9.

Air Treatment Table 1A

1. Descent rate - 20 ft/min.
2. Ascent rate - 1 ft/min.
3. Time at 100 feet includes time from the surface.

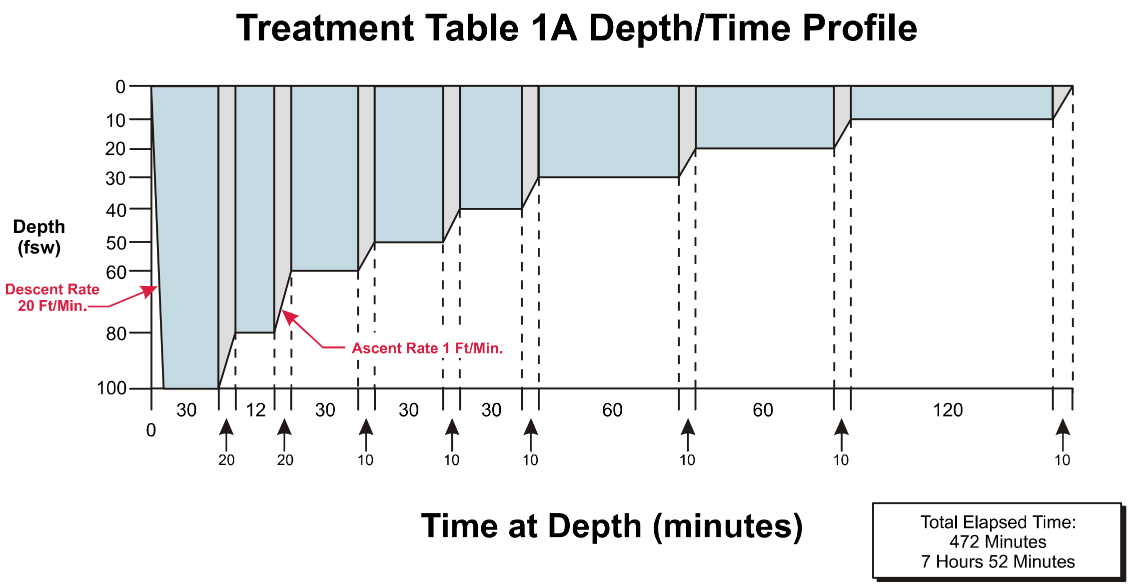


Figure 17-11. Air Treatment Table 1A.

Air Treatment Table 2A

1. Descent rate - 20 ft/min.
2. Ascent rate - 1 ft/min.
3. Time at 165 feet includes time from the surface.

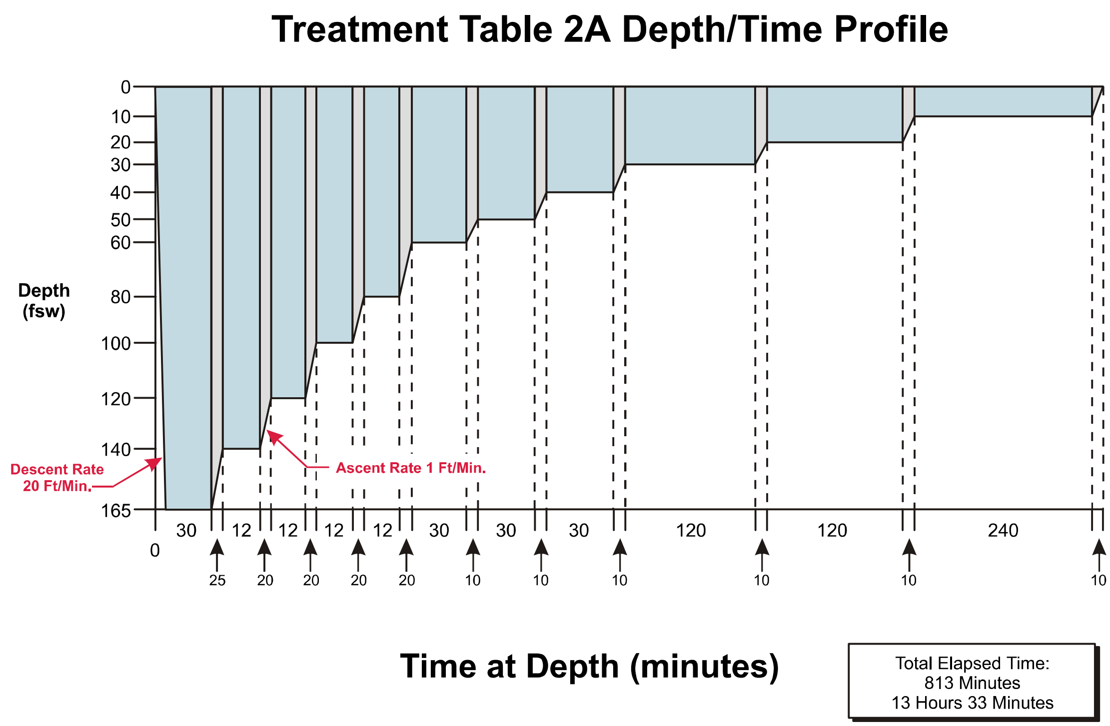


Figure 17-12. Air Treatment Table 2A.

Air Treatment Table 3

1. Descent rate - 20 ft/min.
2. Ascent rate - 1 ft/min.
3. Time at 165 feet-includes time from the surface.

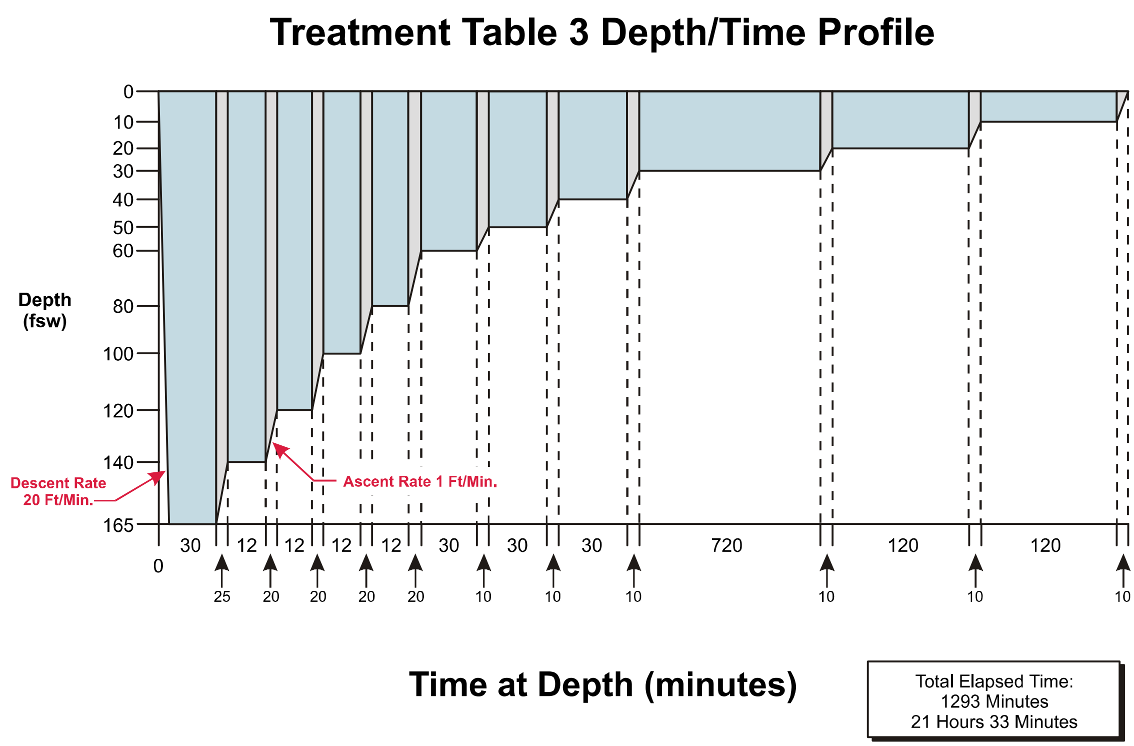


Figure 17-13. Air Treatment Table 3.

Training Objectives for a Diving Medicine

This guidance includes all the training objectives agreed by the Diving Medical Advisory Committee, the European Diving Technology Committee and the European Committee for Hyperbaric Medicine in 2011.

Rev 1 - 2013

INTRODUCTION

The purpose of this document is to define more closely the training objectives in diving physiology and medicine that need to be met by doctors already fully accredited or board-certified in a clinical speciality to national standards.

It is based on topic headings that were originally prepared for a working group of European Diving Technology Committee (EDTC) and the European Committee of Hyperbaric Medicine (ECHM) as a guide for diving medicine some 20 years ago by J.Desola (Spain), T.Nome (Norway) & D.H.Elliott (U.K.).

The training now required for medical examiners of working divers and for specialist diving medicine physicians was based on a EDTC/ECHM standard 1999 and subsequently has been enhanced by the Diving Medical Advisory Committee (DMAC), revised and agreed in principle by DMAC, EDTC and ECHM in 2010 and then ratified by EDTC and ECHM in 2011. The requirements now relate to an assessment of competence, the need for some training in occupational medicine, the need for maintenance of those skills by individual 'refresher training'. Formal recognition of all this includes the need to involve a national authority for medical education.

These objectives have been applied internationally to doctors who provide medical support to working divers. (Most recreational instructors and dive guides are, by their employment, working divers and so the guidance includes the relevant aspects of recreational diving. Although the term "diver" refers to anyone who breathes at pressure from an underwater source of gas, the scope of training is in fact greater than that and includes those who work at pressure in a dry environment, such as compressed air workers, and those in deeper caissons and tunnels who use mixed gas and saturation techniques. (Though rare, the unique problems of professional and competitive breath-hold divers are also mentioned.) The training required for a hyperbaric oxygen physician is not covered here.

SCOPE OF DIVING

The term “working diver” is used **for all divers who dive for a reward.** This is a legal term that, in addition to working for money, includes those who dive in return for some non-monetary reward. Thus previously unregulated divers, such as some part-time fishermen, are now required to comply with their national diving regulations regardless of their principal employment and this appears to have led to a reduction of incidents.

The “Working diver” is the preferred term because, though the distinction is not essential, it covers all categories of commercial and professional divers. These terms are synonymous but sometimes imply a different working style, viz:

- **A commercial diver** tends to be employed full-time for diving duties, primarily by an offshore, inshore or inland diving company, port or other water-related authority:
    - **Offshore diver** (oil and gas industry, salvage, wind farms at sea**)**
    - **Inshore diver** (outfalls, harbours, marine buoys, most fish-farming, etc)
    - **Inland diver** (hydro-electric schemes, bridges, weirs, sewers etc)

- **A professional diver includes one who may not be working full-time as a diver, but who** is employed in another primary role that also requires diving tasks:
    - **Military divers** for ship husbandry, mine disposal, etc
    - **Public Service Divers** including Coastguard helicopter and Police divers for body recovery and SAR, divers in Fire & Rescue depts, City Hall etc
    - **Cameramen** for underwater photo shoots or filming,
    - **Diving instructors and guides** in the recreational diving industry. This covers all aspects of recreational diving. he diving doctor also needs to know about the special techniques of competitive breath-hold (apnoeic) divers.
    - **Marine and other scientists** (includes associated university students)
    - **Insurance assessors,**
    - **Aquarium and swimming pool attendants** (eg for helicopter dunker training)
    - **Open-sea harvesting** (of scallops etc) **and fish-farming**

TRAINING OBJECTIVES

The first edition of this revised guidance had paragraphs based on the structure and numbering of the Joint ECHM/EDTC Training Standards (1997) but, because of some differences of content between that, the original EDTC-ECHM document with its deeper scope (that led to DMAC Guidance 29) this further restructuring now seems practical for course providers and candidates. With the international growth of all diving, these new detailed training objectives are focussed primarily on international standards of competency in providing medical support for the working diver, thereby acknowledging that they include but must be broader than just the training objectives in diving needed for hyperbaric therapy. Medical cover for the working diver needs to include every category of diving.

Some doctors wish to become competent in both diving and hyperbaric medicine and so care has been taken to reduce duplication by the use of training objectives, where appropriate, that apply to both of these medical fields. For this reason HBO is addressed in this document only where it is relevant to diving.

Each training objective stands on its own and does not depend on others for interpretation. This means, theoretically, that the order in which they are presented is not significant but, for convenience, they have been placed in topic groups which should be a more practical format for training providers

Throughout this document, note also that the words of the training objectives that follow are each to be understood as beginning with this phrase:

"On completion of this training, the candidate is expected to - "

1 PHYSIOLOGY & PATHOLOGY OF DIVING AND HYPERBARIC EXPOSURE:

1.1 HYPERBARIC PHYSICS

- understand Archimedes‘ principle, including the differences between being negatively, neutrally and positively buoyant, and apply this to the underwater working environment,.
- understand atmospheric pressure, the universal gas law, general gas laws, other related gas laws (Boyle, Charles, Gay-Lussac) and be able to make all the relevant calculations, e.g. be able to calculate partial pressures, surface-equivalent values, pressure-volume and density changes at depth. Should be able to calculate the volume of compressed breathing gas needed for a given duration of specified activity at a specific pressure.
- understand Poisuelle’s equation and be aware of the effects of changes in density and changes in diameter on air flow.
- calculate the effect upon the subsequent measurement of content per unit volume when samples taken at depth are decompressed to atmospheric pressure for analysis. Be aware that this expansion can reduce an unacceptable gas partial pressure or particulate count at depth to one that may be undetectable at the surface.
- convert between the different temperature units (degrees Centigrade, Fahrenheit, Kelvin and Rankin)
- understand Laplace’s equation and its application to changes of bubble mechanics in the diving environment.
- understand Pascal’s principle of pressure transmission in fluids and how this principle may affect a diver in the water.
- understand the significance of temperature changes with compression and decompression.
- be familiar with converting between imperial, metric and other units of pressure used
- be aware of the need to adjust for the difference between the concept of “gauge pressure“ (as still used by many engineers) and the absolute values of pressure.
- understand Henry’s Law of gas equilibrium and the time dependence of gas equilibrium in fluid. (Review gas diffusion gradients in the tissues and pulmonary gas exchange .)
- understand the speed, transmission and reflections of sound waves in water, the units of sound pressure and energy underwater, and their attenuation by other factors. Apply this to various underwater sources: sonar, seismic etc.
- be familiar with the effect of various breathing gases on speech distortion at depth and the limitations of “helium unscramblers“.
- understand the influence of surface waves in various sea states upon transient changes of pressure on the diver at depth or on ’stops’
- understand the influence of a mask on the apparent displacement of perceived images and the effect of depth underwater on colour transmission and perception

1.2 DIVING RELATED PHYSIOLOGY
(FUNCTIONAL ANATOMY, RESPIRATION, HEARING AND EQUILIBRIUM CONTROL, THERMOREGULATION)

- understand the interactions upon underwater equilibrium of the loss of visual reference points in poor visibility and some loss of proprioception, especially if concurrent with ear-clearing difficulties
- understand the effect of lung volume on diver's in-water neutral buoyancy and the impact of increased rate of physical work and minute volume and hyperventilation

Respiratory

- explain the differences between normobaric and hyperbaric physiology (strong focus on gas physiology, gas transport, etc.)
- be aware of the special air-packing techniques of competitive apnoea divers that may change vital capacity and other parameters beyond physiological norms and of the complications of advanced breath-hold diving
- understand respiratory external dead space as influenced by various underwater breathing apparatus circuits and helmet designs
- understand the vertical pressure gradient over the immersed chest and the eupnoeic point in relation to counter-lung or demand-valve positioning
- understand the limitations imposed by increased density on ventilation and the external work of breathing
- understand the implications of underwater breathing apparatus (uba) on the work of breathing and how it changes with density and gas mix
- be able to understand technical reports on the adequacy of a uba (new design or in accident reports)
- understand the hazards of "Skip-breathing" to prolong scuba tank duration
- understand airway structure and hyperbaric gas flow in relation to diver velocity of ascent

Hearing

- understand the attenuation of sound at the ear when it is transmitted (i) through water only (ii) through water plus a neoprene hood (iii) through dry gas within a helmet

Thermal

- understand the physiology of thermoregulation and what determines human limits when exposed to sudden cold immersion (cold shock) or slow prolonged cooling.
- understand the responses to slow body cooling during immersion, and the relative roles of wet suits and dry suits.
- understand the advantages and disadvantages of providing thermal supplements (such as use of a surface-supplied hot-water suit) in relation to subsequent decompression safety.

- understand the respiratory loss of heat at greater depths especially in relation to gas density and the need for routine inspiratory gas heating
- recognise the hazards of respiratory heat loss when breathing cold gas at depth
- understand the thermal properties of the respired inert gases in relation to the increase of thermal capacity with increased pressure

1.3 HYPERBARIC PATHOPHYSIOLOGY OF IMMERSION

- understand the physiological effects of head-out immersion and supine submersion on cardiac output and tissue perfusion
- understand the hazard of hypoxia in ascent from a breath-hold dive especially if pre-dive hyperventilation has reduced CO2 drive
- understand the synergistic effects of raised partial pressure of respiratory gases in the causation of “deep-water blackout“ in deep air diving with hard work.
- understand the concept of CO2 retainers
- understand the need of training to prepare the individual to have a resilient psychological response for stress, particularly when handling a life-threatening situation.

Endurance

- assess the maximum dive duration as predetermined by the required decompression
- consider the nature of the task, the muscular and respiratory work (as increased with greater gas density) and diver’s motivation
- ecognise that industry guidance provides maximum in-water durations of excursions from a bell by a sat diver, e.g. 4 h for each man in a 2-man 8-h bell run.

1.4 PATHOPHYSIOLOGY OF DECOMPRESSION

- be aware of the history of and development of decompression theory
- be aware of the evidence surrounding the many mathematical and other hypotheses that relate to decompression theory and calculation, and including
  - the uptake and distribution of the respiratory gases at depth
  - effects due to the inspiration of the other so-called inert gases
  - bubble nuclei and bubble formation, growth and distribution
  - the separate role of bubble emboli arising from the alveoli
  - the implications for bubble effects of potential right-to-left shunts
  - surface activity at the blood-gas interface and its systemic effects
  - role of endothelium, blood constituents and other tissues in sequelae
- understand the basis of contemporary decompression theories (e.g, deep stops, rate of ascent, gas switching) and the limitations of their validation by manned testing and other techniques

- be aware of the concepts of superficial and deep counter-diffusion, their potential consequences and methods of avoidance
- relate the type of decompression to nature of any subsequent manifestations (Section 4.4)

1.5 ACUTE DYSBARIC DISORDERS: A BRIEF INTRODUCTORY SECTION ONLY

- understand the consequences of pressure-induced volume changes (barotrauma) in the various gas-containing spaces of the body
- recognise the many factors that can influence individual susceptibility to decompression illness, both acquired and natural.
- understand the different pathologies of DCI associated with
  - dissolved gas (DCS)
  - embolic gas (AGE)
  - both concurrently ("Type III DCS")
- recognise localised bubble formation in areas of hypoperfusion
- understand the role of the cellular elements of blood and the endothelium in the development of DCI
- understand that the pathology of decompression illness progresses with time after its onset and the possible implications

1.6 CHRONIC DYSBARIC DISORDERS ("LONG-TERM HEALTH EFFECTS")

General

- understand the principles of recognizing the presence of an occupational condition in a particular population of workers such as divers, of avoiding or minimising any contributory factors, of accepting any residual risk, of monitoring the population for effectiveness of control and the surveillance of individuals at risk for early diagnosis and management

Dysbaric osteonecrosis (DON)

- know the history of this condition in compressed-air workers (caisson and tunnel workers) and is subsequent identification in divers
- understand the application of occupational health principles to the problems of bone necrosis in divers and other pressure exposed workers.
- understand that DON is currently a larger problem in developing countries than the industrial world.
- know the approximate/estimated prevalence, the prolonged natural history and the relatively benign prognosis in most of those found to have early lesions.
- understand the management of this condition and be aware of the relatively benign significance of shaft lesions in contrast to the surgical interventions needed in some for structural collapse of the humeral or femoral head.

- understand the limitations of diagnostic screening if using less-hazardous MRI., In particular the implications of identification of early lesions (FICAT Stage 1), the differing pathological prognosis between dysbaric osteonecrosis (DON) and idiopathic femoral head necrosis (FHN) of adult males and the implications for management

CNS long-term health effects

- be aware of the possible implications of the insidious and long-term neurological and psychological manifestations reported in compressed air workers and divers and of the evidence for these. Recognise the multiple dysbaric and environmental factors that may contribute to such findings and the need for maintaining continuing vigilance

Other LTHE

- be aware of other reported long-term health effects related to
  - pulmonary function
  - hearing impairment
  - retinal angiographic findings

1.7 HBO-BASICS - PHYSIOLOGY AND PATHOLOGY

NOTE: a diving doctor associated with any treatment chamber that also treats non-diving conditions, must also attend an HBO Level 2B course. Those diving doctors who have no HBO responsibilities must nevertheless be capable of managing patient care and safety at raised environmental pressure in a chamber and of using infusions and ventilators.

- understand the basic effects of HBO
- know the approved indications for HBO therapy and the basis on which HBO works
- apply that knowledge to the diving environment (e.g. a diver with a crush-injury of the hand) particularly in saturation.

1.8 OXYGEN TOXICITY

- understand that at increased partial pressure and in relation to duration of exposure, O_2 is a general tissue toxin that has two principal manifestations (below) and also causes general vascular effects e.g. vasoconstriction at higher partial pressures
- understand that it also has important interactions with the effects with N_2 and CO_2

Pulmonary toxicity

- describe the pathophysiology of acute and chronic O_2 pulmonary toxicity
- recognise the need to monitor symptoms and pulmonary function during long exposures to elevated partial pressures of oxygen and understand the potential for confusion with the manifestations of breathing a dry gas.

- calculate the CPTD (cumulative unit pulmonary toxic dose (UPTD) or Oxygen Toxicity Units (OTU) over time as a guide but also to recognise the limitations of that prediction
- understand the relevance and importance of “oxygen breaks“ (i.e. normoxic or less hyperoxic interludes during an oxygen exposure.
- understand methods of calculating CPTD for repetitive exposures (over many days) and their limitations.
- understand the long term pulmonary sequelae of hyperoxia
- be able to clinically manage a case of DCI already suffering oxygen toxicity

Neurotoxicity

- be aware of the various molecular and cellular mechanisms suggested to cause neurological oxygen toxicity
- understand the factors that may reduce or increase cerebral O2 toxicity
- understand the clinical presentation and appreciate the seriousness to the diver of an underwater oxygen seizure
- understand the unreliability of prodromal symptoms
- recognise the need to check the O2 content of breathing gas and the maximum safe depth for using it.
- review the different pO2 limits for depth exposure published by various authorities (understand the potential value of maximum durations for each exposure level) and understand the influence of nature of the dive and equipment used in estimating the residual risk
- understand the safety advantages when the depth of the working diver and the surface-supplied gas mixture are both continuously monitored
- consider the actions to be taken by the diver when another diver has a seizure and understand the potential risk of secondary pulmonary barotraumas during ascent of a diver with ongoing seizures
- recognise the importance of each diver at risk having a secure airway (not merely a mouth-piece with a strap but ideally a helmet) in order to avoid drowning during a seizure
- manage a case of CNS oxygen toxicity in the chamber and how to re-enter the treatment table protecting both patient and attendants)

1.9 GENERAL PRESSURE EFFECTS

- be aware of the direct effects of pressure on the physiology of man (e.g. neural transmission, HPNS, compression arthralgia).

Narcosis of inert gases

- understand the different theories of patho-physiological inert gas effects
- understand the difference in anaesthetic potency between different inert gases.
- understand the clinical presentation of inert gas narcosis

- be able to use objective measures to assess levels of narcosis in another individual
- be aware of the effects of nitrogen narcosis upon decision-making at depth and the claimed benefit of adaptation
- be aware of the equivalent narcotic levels of the other inert gases that may be breathed intentionally or unintentionally (e.g. argon breathed as a welding contaminant)
- be aware that helium is not significantly narcotic (and is not related to HPNS)
- be aware that hydrogen is not inert but has narcotic properties and is also biologically active. Be aware that H2, though explosive, has been used as a component of a breathing mixture with extensive safety precautions

HNPS

- be aware of the clinical manifestations and adverse effects of the high pressure nervous syndrome (HPNS) at depth.
- understand that HPNS is *not* a manifestation of inert gas narcosis
- review the hypothetical causative mechanisms of HPNS
- understand that HPNS can be exacerbated by faster rates of compression and at warmer temperatures during compression and understand that HPNS can be ameliorated when the rate of compression is slower and the chamber is kept cool
- understand that the demonstrated amelioration of HPNS by the addition of a narcotic agent (such as 5% nitrogen) to inspired oxy-helium, can create difficulties for subsequent gas reclamation and purification, is not a direct reversal of HPNS and so is not used routinely.

1.10 MEDICATION UNDER PRESSURE

- provide advice on non-prescribed medication commonly used by some divers
- recognise that insufficient is known about the effectiveness of conventional drugs and their side-effects when prescribed for use at deeper depths where.
- be aware that some drugs affecting CNS function may have unpredictably increased or reduced effect depending on the circumstances when taken (treatment for psychiatric disorder, long term prophylaxis after successful treatment, conventional drugs for self-medication, drug abuse).
- be able to guide and risk analysis the use of antimalarials weighing (neuropsychological) side effects to malaria protection.

1.11 NON-DYSBARIC DIVING PATHOLOGIES

Hypothermia

- recognise the insidious effects of immersed body cooling and know the importance of rewarming in relation to resuscitation
- be aware that greater body cooling occurs at depth where thermal capacity of respired gas is increased at its greater density.
- be familiar with supplementary body heating (usually by hot-water suits) and need for supplementary respiratory gas heating.
- understand the importance of breathing gas heating at great depth and the potential for rapid development of symptoms
- recognise hypothermia as potentially common to all diving injuries and manage it both alone and in conjunction with other problems (e.g. DCI)

Raised temperature and the risk of hyperthermia

- understand that the use of hot-water suits potentially may lead to greater gas uptake and thus exacerbate DCI in decompression, particularly with SurD O2 procedures
- recognise the adiabatic heat of compression can have serious effects that have been fatal, when compounded by high humidity and the inability to dump heat by sweating.
- understand the reduced thermal comfort and safety limits associated with a heliox environment.

Fauna and flora

- be aware that marine flora are not generally hazardous but kelp may result in entanglement and that marine algae may be toxic and can cause allergic and irritant reactions).
- be aware of the hazardous marine fauna in the area of diving operations, the recognition and management of the principle
- be able to advise on appropriate contents of diver first aid kits with respect to the management of these hazards

Some other injuries and accidents

- manage acute illness or trauma sustained in the water and when there may be an obligation for some decompression stops. (A similar event that occurs at depth in saturation diving will be discussed later.)
- understand the pathophysiology and clinical presentation of near-drowning as well as treatment and post recovery complications
- manage sequelae of oil-mist contamination of breathing gas
- recognize salt-water aspiration syndrome (SWAS) as a risk in: choppy waters, especially with leaky regulators etc, in a differential diagnosis of immersion accidents and manage appropriately

- be aware that marine pathogenic bacteria that may infect a diver's wound are different from those at surface and, if culture and antibiotic sensitivities are necessary, the pathologist should be advised of the marine source
- be aware of the need for immunisation or other prophylaxis (e.g. for leptospirosis)
- manage suspected carbon monoxide poisoning sustained underwater from contaminated compressed air
- manage exposure to in-water chemical pollution with examples ranging from skin exposure, mucus membrane irritation, neurologic effects and carcinogens.
- manage exposure to contaminants in the chamber - manage sea-sickness and understand the impact of this and of its medications upon the diver and potential safety (e.g. how to vomit underwater?).

2 DIVING TECHNOLOGY AND SAFETY

2.1 BASIC SAFETY PLANNING:

- be aware that by working dive procedures are likely to be influenced by government rules that have significant variations between countries. Provided such rules are not broken, many diving companies will follow other industry guidance that often is more stringent.
- understand the greater constraints upon a working diver than on a recreational diver, including the need to
  - complete a specific task effectively
  - follow agreed procedures and emergency procedures
  - dive where and when required to do so.
- understand that the diver is responsible for aspects of his/her personal safety and for own physical fitness
- understand that after the working diver has passed the annual medical examination to confirm fitness to dive, he/she still has the responsibility to report via the local medic and/or supervisor any subsequent changes or illness
- be aware that the working diver is usually under the direct control of a surface supervisor and that line-management has responsibilities for health and safety
- understand the importance of formal pre-dive checks
- revise the basic principles of occupational medicine
- reinforce the need for workplace assessment (and not only when underwater).
  - hazard recognition
  - hazard assessment
  - risk avoidance
  - risk control.
  - acceptance of residual risk.
  - understand the importance of keeping permanent records.
- be aware of known hazards such as
  - physical: (noise, vibration etc)
  - biological: (bacteria, algae)
  - chemicals: (solvents, contaminant gases)
- implement the need for individual health surveillance following exposure.
- identify the role of safety awareness and safety manuals by the employers of divers and by the recreational diver training agencies. Evaluate the effectiveness of different requirements for health protection and monitoring.
- be knowledgeable about, and able to evaluate, the general administrative methods of safety management and monitoring used in industry.

- be able to implement a monitoring system to show continual improvement of safety indicators (with specific focus on medical consequences)
- be aware of the potential role of anonymous reporting
- check the availability and experience of medical advisory and emergency hotlines

2.2 COMPRESSED AIR

Compressed air work

- understand the nature of compressed air work in the dry without any immersion effects (Caisson work, Tunnelling etc)
- recognise the historic significance of early epidemiology of, for example, decompression sickness and bone necrosis because of the availability of large numbers of exposures
- understand the nature of hard physical work in regular shifts in a hot humid environment with possibility of a CO2 build-up
- review the nature of their decompression procedures that include surface decompression and some differences from tables used by divers
- recognise the occasional need for mixed gas saturation techniques to service the drilling shield in deep tunnelling work

Air chambers

- review operational procedures for dry diving and therapeutic chambers
- review chamber safety, particularly fire risks and oxygen
- recognise that the dry chambers are largely associated with, but not confined to, surface decompression and recompression.
- be aware that breathing air in dry chambers as attendants with patients or for training is routine. Attendants may need to follow oxygen-breathing as prescribed for them in the Tables.
- the availability of medical equipment for an operational surface decompression chamber should be audited by a Level II diving doctor (see 2.8)..

2.3 WET BELLS AND STAGES

- understand that the use of an open stage or 'wet' bell, in which the diver is exposed to the ambient pressure of the sea, provides a transport system to safely get the diver(s) to the worksite and a site for conducting prolonged decompression stops by working divers.
- understand that, suspended from a surface boat, the vertical range of movement of the stage or bell through the water during stops may be greater than that experienced by a diver who hangs onto an adjacent shot rope in the water.

2.4 SCUBA DIVING (AIR AND MIXED GAS)

- understand the advantages and limitations of scuba techniques, particularly for working divers, including recreational instructors, of
  - being independent of surface control and reliable communications
  - having a finite gas supply (with/without a reserve bottle)
  - the 'buddy' principle that is usually adhered to *versus* solo diving
- be aware of the need to correlate gas capacity of tanks with minute-volume needs and predicted decompression times
- be aware of the many in-water procedures relating to
  - tables and personal decompression computers
  - rates of ascent and use of a safety stop
- be familiar with in-water emergency procedures (such as recovery of an unconscious diver with a decompression obligation) and with associated equipment and procedures (such as buoyancy aids, signalling)
- understand the rare but real hazard of carbon monoxide contamination of compressed air tanks, testing procedures for CO, its diagnosis and treatment
- understand the use of nitrogen mixtures with enriched oxygen in scuba and associated depth limits. Nitrox gas mixing and filling techniques.
- understand the use of special gas mixtures in separate cylinders for sequential use in deep self-contained diving is one of several "technical" procedures taught by recreational instructors.
- recognise that the term "Technical diving" is variably defined.
- be aware of other scuba diving procedures (used by some diving scientists and camera-men) such as
  - prior placement of reserve tanks for lengthy penetrations
  - availability of 'hanging tanks' for decompression stops
  - feasibility and hazards of 'drift decompression'

2.5 SURFACE-SUPPLIED HOSE DIVING.

This may be undertaken from the surface wholly in the water, or from a stage or a wet bell. (Deep short-duration "bounce" hose dives that begin from a closed-bell capable of transfer-under-pressure are considered later, with saturation diving.)

Note that for air or oxygen-rich Nitrox diving, hose diving possibly from a stage or wet-bell, is considered by most authorities as being much safer than using scuba. Some national regulations also permit oxy-helium hose procedures with a stage or wet bell to be used deeper than 50m but with some limits of duration. All hose divers need also to carry a reserve or 'bale-out' bottle.

- understand the safety advantages of a having
    - a hose as a strong tether
    - depth monitoring by the surface supervisor
    - an unlimited gas supply if trapped
    - continuously available communications
- understand the implications for decompression procedures

2.6 STANDARD DRESS DIVING

Note that this equipment is no longer permitted for working divers in most countries because there is no provision for a breathing reserve in case the surface gas supply fails. However it is still used in some countries (and also by some amateur historical enthusiasts).

- understand advantages and limitations of this equipment.
- be aware that the diver's gas supply pressure is determined at the surface and so specific risks include squeeze, should the dive fall uncontrolled through the water column.
- recognise that uncontrolled blow-up, feet first, has also been fatal.

2.7 REBREATHER DIVING (SEMI-CLOSED AND CLOSED CIRCUIT)

- understand the advantages and limitations of the different configurations of self-contained breathing apparatus.
- recognise the possible applications for rebreather use
- understand the principal differences between
    - closed circuit pure oxygen
    - constant-mass flow
    - tidal-volume proportionate replacement
    - constant pO2 electronically controlled
- understand the extensive training and maintenance requirements needed to use safely the electronic self-mix rebreathers
- recognise the difference between a rebreather and the gas reclaim system used for deep commercial diving.

2.8 OTHER DIVING PROCEDURES

Underwater habitats

- Although practical procedures have been established, particularly by NOAA scientists, this would deserve supplementary review if re-introduced.

Surface decompression

- understand the procedures based on the historic use of 'crash surfacing' for salvage where strong tides did not permit in-water stops but where a deck chamber was available for recompression within 5 min of surfacing. This procedure remains in use in both military and commercial diving.
- know the procedural constraints for enhanced safety and the HSE studies that explored its safety in comparison with in-water decompression.
- be aware that the use of 'hot-water suits' at depth has been suggested to affect gas uptake and the safety of SurD chamber decompression
- be aware that the operational chambers that are used for this procedure require supplementary items of equipment for a medical emergency (see 2.2).

Nitrox and oxygen decompression stops

- be aware of the advantages and limitations of breathing oxygen-rich mixtures and/or oxygen during in-water decompression stops following air or heliox hose diving.

Scientific projects

- recognise that scientists who dive in their work usually do so within codes of practice that also outline the assessment of exceptional techniques (such as diving within trawl nets)

Deep bounce diving and TUP-diving

- introduce the students to these diving techniques (e.g. the use of a diving bell for short mixed-gas deep dives and the use of transfer under pressure bells) recognizing that these techniques are less used nowdays.

Saturation diving

Note - will be detailed in the next section but this stage

- understand the commercial advantages of saturation diving as the technique required by many jurisdictions for diving deeper than 50m but which, for technical reasons, may also be used at shallower depths.

2.9 CHARACTERISTICS OF VARIOUS DIVERS AND OTHERS WORKING UNDER PRESSURE

- understand the varying characteristics of various groups of divers and other who work at pressure
- e.g. **recreational** divers dive only for personal reasons and receive no payment or other reward for doing so. Understand that they can choose when and where to dive or, indeed, choose not to make a planned dive. Some recreational divers dive in caves, wrecks or deep water with advanced rebreathers and multiple gases, but at their own risk. Breath-hold/apneic diving falls within the same category.
- **working divers** are professional divers who may be employed either
  - full-time as divers or
  - primarily for other tasks, some of which include diving
- **caisson workers, tunnellers and others in compressed air** are not divers because they work at pressure in a dry environment. Thus they avoid the physiological problems associated with a hydrostatic pressure gradient over the body but they do have many medical problems that are similar to those of divers. Some deep bridge building and tunnelling has taken these workers to mixed-gas exposures as deep as 70m. Like those who have to enter very dense fluid (bentonite) to service a deep tunnel-cutting shield may have been recruited as saturation divers.

2.10 DIVING EQUIPMENT AS USED TO C.50M (SEE ALSO CHAMBERS, 2.2 & 2.8)

Breathing apparatus

- understand the physiological and respiratory acceptance criteria required for both laboratory and manned testing of new or modified underwater breathing apparatus before it is released as 'safe' for operational use
- understand how breathing resistance induces changes in respiratory pattern (e.g., diminished respiratory minute volume with increased dead space, increased gas density or increased work of breathing)
- become familiar with the general working principles of breathing apparatus as a minimum including demand regulators, rebreathers and free-flow systems and understand the nature and consequences of forseeable malfunctions

Diver monitoring

- be aware of various systems for on-line recording of diving data such as depth, inspired pO2, water and gas temperature, video surveillance and voice communication and the benefit for the surveillance of the diver as well as post-incident investigation.
- Understand the practical use/safety benefit of monitoring divers breathing rate through communication during underwater work.

- in-chamber video recordings and the need for these to be retained for an agreed duration after safe completion.
- understand the need for continuous monitoring at depth of chamber, bell and welding habitat atmospheres with alarms for the early detection of contaminants

Tools

- understand the effect of neutral buoyancy on the safety of tool use and the problems of in-water ergonomics in tool design
- be aware of injury hazards due to High Pressure water-jetting, burning-torches, pressure differentials etc
- understand the implications of the isolation of an injured diver in relation to safety/risk assessments

Thermal

- understand the working of thermal protection and the need for heating inspired gas at depth
- understand the potential problems of scalding from hot-water suits, and the potential contamination carried by that hot-water supply.

Other equipment

- understand the hazards associated with compressors and gas mixing devices, gas storage and delivery, control and recovery in hose diving.
- understand the design and use of totally protective suits for diving in contaminated fluids.
- be aware that sat divers equipment should include
  - bail-out UBA that needs to be heated,
  - neutrally buoyant umbilical with pre-determined length.
  - helium unscrambler,
  - tools designed for wearing gloves etc,
  - harness with lifting ring for emergency recovery from the water

2.11 DIVING TABLES AND COMPUTERS

NOTE that a detailed mathematical knowledge of decompression theory, while of great interest, is not essential to the practice of diving medicine (other than in some medico-legal cases)

Decompression theory and tables

- be aware of complexity and limitations of decompression theory (section 1.4). Review the further development of mathematical modelling and the many associated theories, but in summary only. In this context consider the limited manned testing of new tables, the problems met when applying them as written and the *ad hoc* modifications made by diving companies, some navies and individual divers to improve safety.
- know that diving at altitude requires compliance with special decompression adjustments

- know the DAN, DMAC and other recommendations related to the interval needed before flying after commercial or recreational diving and the limitations of that data
- be aware of rules governing repetitive diving
- be aware of the rules regarding upward and downward excursions from saturation depths (*covered later*).
- be aware that over the years all commercial tables have tended to converge by trial and error towards pragmatic solutions that seem to work.
- while adherence to the given tables is appropriate decompression tables cannot eliminate the risk of decompression illness and that individual variation means some incidents will occur after apparently safe exposures while apparently unsafe exposures do not necessarily result in incidents.

Dive computers

- recognize the main algorithms used in the software of dive computers (decompression computers) and computer based decompression programs.
- understand that they are widely perceived as providing an acceptable level of safety and relatively safe decompression solutions but considered controversial for use in commercial and military diving.

Decompression risk

- understand the concept of risk in relation to computer and table usage
- realise that compliance with accepted tables does not always prevent DCI
- realise also that to go beyond the safe limit does not mean inevitable DCI.

2.12 REGULATIONS AND STANDARDS FOR DIVING

- be aware of the wide variety of national regulations that relate to working divers around the world (some have prescriptive rules on details whereas others ascribe management responsibility to all participants for their outcomes)
- identify regulations and Codes of Practice (COPs) and norms (ISO, CEN) that are relevant to the nationalities of course attendees and how these relate to international codes of practice and recognise the importance of these where there are no regulations
- be aware of international guidance that is related to recreational diving, it's possible lack of legal authority but its relevance to cases in the civil courts
- maintain expertise by maintaining familiarity with current research and recognize availability of valuable written information in technical reports, non-medline listed meeting abstracts and international series of underwater symposia.

3. SATURATION DIVING

3.1 SATURATION MODE

- be aware of the history of saturation development:
- US Navy research (George Bond) leading to seabed habitats of Man-in-Sea (Ed Link), Conshelf (Jaques Cousteau) and Sealab (US Navy). Shallow seabed habitats (mostly NOAA).
- be aware of the start of commercial saturation (Westinghouse: Smith Mountain Dam) and further development into the North Sea and worldwide. Commercial development to ca. 350 m.

3.2 PHYSIOLOGY OF DEEP EXPOSURE

- be aware of the study of the effects of pressure on aquatic animals living at depth and on diving animals normally at or near the surface.
- recognise the manifestations of HPNS, with its convulsive and other hazards.
- be aware of laboratory studies on man to as deep as 700 m and the possibility of long-term sequelae of deep exposure

3.3 COMPRESSION

- understand factors, such as a cool environment, that ameliorate HPNS during slow compression and rest periods
- understand that compression rate and absolute ambient pressure will affect the HPNS risk and that the risk may be reduced by slowing compression rate and introducing stops
- assess the use of added gaseous nitrogen to ameliorate HPNS and recognise that for the trivial fact that compression starts from a normobaric air environment a certain low percentage of N2 will be present even when using heliox for sat life support, decreasing with time by dilution.

3.4 AT DEPTH IN LIVING CHAMBER

- understand the challenge of maintaining O2 within narrow partial pressure limits at great depths.
- understand the various methods for intermittent and continuous measurement of chamber and bell atmosphere contaminants. Understand the challenge of using high sensitivity/high specificity equipment with low maintenance cost and robustness. Understand that the threshold limit value is related to the mass of the contaminant per volume unit of chamber

gas. Understand that unless the detector is placed within the chamber, the detection threshold must be lower as gas will expand during decompression to a sensor or instrument placed on the outside the chamber

- review the clinical management in saturation of coincidental illness or injury when arising at depth from
  - injury in the water (e.g., crushed chest / traumatic amputation)
  - illness in the chamber (e.g., acute abdomen, cerebrovascular accident)
  - injury in the chamber (e.g., evisceration over toilet seat)
- understand the contingency measures required for the management of an offshore diving accident, particularly serious illness or injury within a saturation chamber and the preparations needed in advance to provide prolonged medical and surgical support at depth
- the need for
  - a diver medic in each sat team;
  - reliable 24h communications ashore,
  - duty medical officer available to fly out.

3.5. BELL EXCURSIONS

- consider the clinical management of illness in the water (e.g., wrong gas)
- understand emergency procedures for ill or injured divers out of a bell:
- rescue by flooding plus man-lift or winch,
- resuscitation in the vertical or semi-recumbent mode;
- first aid by bellman;
- recognise need for a 'lost' bell to have through-water communications and tapping code, transponder, enough gas and water for > 24h,
- be aware of risks of using bell's weight release if fitted
- understand the urgency of heat conservation. Review passive insulation of bell and diver, plus respiratory heat exchange and limited active heating of bell by supplementary heat,
- if a 'lost' bell cannot be recovered easily expect to be asked for medical prediction on survivability prognosis and physiological aspects of rescue methods.
- understand emergency evacuation of a split-level sat system using a hyperbaric lifeboat (HRV) with atmosphere control. Serious hazards of seasickness, dehydration, gas contamination, secondary injury and, with supplementary heating and survival suits <u>or</u> cooling, some risks to thermal balance prior to onshore recovery (consider DMAC guidance note 31 as well).

4 FITNESS TO DIVE

4.1 FITNESS TO DIVE CRITERIA AND CONTRAINDICATIONS (FOR DIVERS, TUNNEL WORKERS AND HBOT CHAMBER PERSONNEL, BUT NOTE THAT HBOT-PATIENTS ARE NOT INCLUDED HERE)

- consider each organ system in relation to diving: cardiovascular, pulmonary, urogenital, neurological, skin, etc.
- be able to interpret and apply the published clinical recommendations in relation to the fitness assessment of an individual diver or pressure worker
- be able to incorporate recent risk-based assessment in medicine into fitness for diving work, e.g. cardiovascular risk scores
- understand the different needs of fitness assessments between those in long-term employment as divers or working at raised environmental pressure, and those who dive only for their own recreation
- be able to assess the effects of prescribed and self-administered medications upon diving
- consider underlying patho-physiology and side effects of the drugs (eg anti-malarials) when diving
- consider the effect of environmental pressure on pharmacological actions
- assess the hazards of substance abuse and illicit drugs (recognising that for many employees this means dismissal)
- assess the impact of HIV status on diving and lengthy stays in saturation
- be able to explain to the non-diving clinician the critical aspects of a diving or pressure-exposure that may be relevant to an individual being referred for consultant opinion.
- be able to assess fitness to return to diving or pressure exposure following an illness or injury for which there may be no specific guidance
- be aware of factors influencing personal DCI susceptibility (e.g.post-dive exercise)
- be aware of conditions in divers (recurrent urolithiasis, salmonella carrier state) that may allow surface oriented diving but preclude saturation diving
- conduct health surveillance as indicated by the nature of the diving history e.g. dysbaric osteonecrosis, where the condition may affect a future diving status
- be fully aware of the influence of immaturity, youth, disability or old age upon the safety factors that need to apply in diving, particularly in recreational diving.

4.2 FITNESS TO DIVE ASSESSMENT

- be competent to perform, apply and/or interpret the clinical and physiological investigations needed to assess fitness of the working diver and others, as defined in authorative guidance
- be able to perform and interpret lung function tests (pre- & post exercise; pre- & post bronchodilator)
- be able to perform and interpret exercise tests
- be able to evaluate an-ECG and audiometry
- be able to understand the use and limitation of echocardiography and other techniques for PFO screening
- have a clear understanding of the role and application of “functional assessments“ as performed by occupational therapists and how these should be applied to divers.
- be able, if requested, to assess the fitness of a recreational diver, to use own clinical judgement and follow appropriate guidance to reach a justifiable conclusion

4.3 FITNESS TO DIVE STANDARDS (PROFESSIONAL AND RECREATIONAL)

Although the same at Levels 1 and 2D, in both basic teaching and periodic revision, teaching styles may differ

- be aware that employer organisations may require a higher pass standard than many national legal minimum requirements for working divers
- be aware that a CEN norm exists concerning fitness for recreational diving.
- be aware of specific legislation existing in many countries, where “disabled“ persons should be accommodated in workplaces where it is safe to do so.
- be aware of the different legal requirements for fitness of working divers that are specified by various national authorities and ensure that all have been met or exceeded
- be aware that the physiological ranges for normal pulmonary function varies between ethnic groups
- be aware that recreational training agencies may be required to follow some local regulations but that many set their own criteria, some of which may be minimal.

5 DIVING ACCIDENTS

5.1 DIVING INCIDENTS AND ACCIDENTS

- understand that in recreational diving, accidents are usually triggered by diver error whereas in a working dive there are many additional contributory factors. The consequence of diving accidents may be trivial, cumulative or catastrophic.
- recognise that incidents may occur
  - on descent e.g. ear barotrauma;
  - at depth e.g. respiratory gas effects
  - on ascent e.g. pulmonary barotrauma, or
  - at any time e.g. equipment failure; coincidental injury
- understand that factors may include
  - environment (e.g. poor visibility or inadequate surface support)
  - the diver (e.g. CO2 build-up or concealed medical problem)
  - equipment.
- understand the importance of familiarity with all emergency drills at depth
- identify emergency resources available. For diving work some authorities require a dedicated chamber on site or, for some activities, within two-hours travelling time. Prepare and rehearse emergency procedures that will follow triage principles 'emergency', 'urgent' or 'timely' et cetera.

5.2 EMERGENCY MEDICAL SUPPORT (WITH NO CHAMBER ON SITE)

Note that medical life support and trauma life support is covered by requirements outside this guidance, e.g. ILCOR guidelines for CPR,ATLS, ACLS-programmes etc, and so is not repeated here.

- assess a diver recovered from the water for omitted decompression and/or barotrauma and their implications. Also assess for hypothermia.
- recognise clinically that a number of serious accidents (e.g. propeller trauma) cannot be moved easily or may not be suitable for recompression,
- understand the need to plan for the logistics of emergency medical care before diving in remote locations. Consider contingency planning for evacuation, the local availability of treatment gases, life support equipment, medications etc and of a recompression chamber and other medical support – in advance of diving.

- recognise the need for complete and accurate communication between those present and a remote adviser or provider
- consider the earliest time for evacuation or travelling by air
- keep personal log of communications, assessment, treatment and outcome

5.3 BAROTRAUMA: ENT(OTORHINOLARYNGOLOGICAL), DENTAL, CUTANEOUS, CONJUNCTIVAL, ETC

(PULMONARY DECOMPRESSION BAROTRAUMA IS CONSIDERED WITH DCI)

- understand the pathology of compression and decompression barotrauma in the head and neck region.
- recognise and treat ENT events in a chamber or at the surface
  - external ear and tympanic membrane injury due to ear-plugs or a hood
  - middle ear injury with poor equalisation
  - round window and inner ear injury
- recognise the effects of "squeeze"
  - of a mask upon the conjunctiva
  - of a dry suit on the skin
  - of an uncorrected descent on the chest of a Standard Diver
- recognise sore throat, change in voice or crepitus in the anterior triangle of the neck etc. as a sign of pulmonary decompression barotrauma *(reviewed elsewhere)*

5.4 PHYSICAL INJURIES

- recognise the very different injuries that can be inflicted by various marine animals and, for those that sting or are venomous, know the specific first aid and definitive treatments
- understand that marine pathogens have different characteristics from terrestrial ones
- be aware that injuries from underwater tools, especially of the hands, are not uncommon among working divers.
- be aware of hazards from electrical in-water field forces from impressed currents
- realise that significant underwater explosions can cause pulmonary barotrauma and other internal organ injury and manage accordingly
- know that an injury from a water-jetting gun may have only a small entry wound but that the damage may be extensive internally.
- be able, perhaps together with an experienced supervisor, to assess the ability of an injured diver after recovery to comply with all emergency procedures before a return to operational diving

5.5 ACCIDENT INVESTIGATION OF DIVING ILLNESS OR INJURY

- know the procedures that divers and diving doctors should follow to secure evidence on the causation of any diving accident or illness.
- be able to advise a pathologist involved particularly if interpreting the significance of bubbles at autopsy (see alo chapter 7)

6. DECOMPRESSION ILLNESSES

6.1 PATHOPHYSIOLOGICAL BASIS AND MECHANISMS OF DCI

"DCS" (Decompression sickness)

- understand the wide range of symptomatology which may arise in the course of decompression illness" e.g.
  - musculo-skeletal manifestations of DCS, and how the presentation can then guide management, e.g. joint pain that is deep and changes with movement *vs.* superficial pain and no change with movement.
  - cutaneous manifestations associated with decompression ("les puces"; rashes)
  - lymphatic disorders (local oedema)
  - fatigue and malaise
  - respiratory DCS ("chokes")
  - peripheral and central neurological deficits (including "staggers") and particularly the distinction between 'spinal' and 'cerebral' DCS and understand the different theories of neurological decompression illness (e.g. spinal cord DCS as embolic, venous stasis, autochthonous bubbles, watershed theory, etc),
  - - hypovolaemia

"PB" & "AGE" (pulmonary barotrauma and arterial gas embolism)

- understand the pulmonary, systemic and neurological pathophysiology and sequelae of decompression barotrauma

Other DCI presentations

- differentiate classic gas embolism and/or decompression sickness from less common biphasic presentations and/or PFO-associated manifestations
- recognise the importance of this assessment for determining DCI treatment
- be aware of the learning value of historic accounts of different presentations and of those cases following treatments that have since been abandoned

- know the range of symptoms, signs and the patterns of presentation of DCI characteristically arising from different types of diving or chamber exposures (for instance compressed air workers in contrast to divers)

Assessment

- be aware of the practical limitations of the on-site examination of divers, e.g. with possible vertigo
- know the timescales of DCI onset and understand the significance of subsequent deterioration
- know the natural history of untreated decompression illness
- understand the importance and the recognition of symptom denial
- have a basic understanding of superficial and deep counter-diffusion

Examination

- understand the detail medical history to be obtained from the diver, buddy, supervisor etc.
- be able to balance the need for rapid recompression and the time needed to take the history and examination. Consider completion of this in the chamber at pressure.
- be able to conduct a full but rapid general clinical (inc neurological) examination at the surface and understand the need to complete the examination on arrival at treatment depth to identify the residual manifestations.
- understand the physical limitations imposed on examination when breathing air at 50m, particularly those related to auscultation and percussion,
- understand the limitations imposed upon a basic assessment when the chamber is too small to permit standing.
- maintain a fluid balance chart

6.2 DIFFERENTIAL DIAGNOSIS OF DECOMPRESSION ILLNESS

- understand that different reasons for divers failing to report - recognise that a person recovered from the seabed unconscious has a wide differential diagnosis which may include DCI
- be aware of different skin disorders (e.g. suit squeeze, urticaria, marine pathogens) that may mimic decompression illnesses *-vs-*. superficial inert diffusion *-vs-* cutis marmorata
- be aware of the difficulties of assessing subjective paraesthesia, dizziness, drowsiness and headache
- be able to evaluate other possible differential diagnoses
- be aware of immersion pulmonary oedema and the usual benign development when surfaced and oxygen breathing
- be aware of the differential diagnosis of loss of consciousness on the surface

6.3 MANAGEMENT OF DECOMPRESSION INCIDENTS AT THE SURFACE

- understand the value of 100% O2 administration for suspected DCI and the need for oral or intravenous rehydration
- know that nitrous oxide / oxygen (e.g. “entonox”) used for analgesia is a probable bubble amplifier
- recognise that 100% O2 may not be available in all emergency rooms or ambulances. Be aware of the different oxygen delivery systems which can provide high concentrations of oxygen (closed system may be available for cpap and is appropriate)
- be aware that decompression paraplegia on surfacing has been clinically reversed almost immediately by recompression where onset has occurred right next to a diving chamber
- understand that DCS is a rare diagnosis in working divers, even though depth/time exposures are generally greater than recreational, and that in surface-supplied hose diving, AGE is rare
- be aware of the various national, military and diving-company networks providing medical support in emergency for recreational, military and working diving accidents
- be aware that the emergency rooms of the hospital may not have any checklists for or experience of DCI management
- be aware of the special role of agencies such as DAN to educate recreational divers about the medical problems of recreational diving and provide an international network to facilitate the medical treatment of emergencies.
- be able to advise on adjunctive medical therapy, including bladder management, pressure points, etc
- understand the need for rapid transfer, especially urgent if there is continuing deterioration.
- in some urgent cases, recompression has been first and detailed examination at depth to assess residua has followed, but recent studies suggest that initial severity is a better predictor of outcome than delay to treatment.
- always conduct a medical assessment at the treatment depth as the baseline for any subsequent deterioration
- ensure the collection of relevant data for the purpose of immediate management and future follow-up

6.4 MEDICAL MANAGEMENT, RECOMPRESSION TABLES AND STRATEGIES

If multiplace chamber is on site

- understand the value of rapid recompression
- consider whether recompression should be done first, and then an examination at depth for residua before deciding on the subsequent course.
- if distant, recognise the importance of doctor travelling to the chamber if feasible and be competent to judge when this is important.

If a one-man chamber is on site

- make a full assessment before compression
- know the limitations of access during treatment and the hazards that can be met
- understand the pressure and time limits of the tables used in these circumstances

In-water recompression (IWR)

- know that unplanned IWR can exacerbate DCI pathology
- be aware of successful protocols (shallow O2) and how these are to be implemented, which pre-conditions should be met, etc.
- be fully aware of the limitations and hazards of this treatment and of the equipment preparation, planning and training needed *before* any dive begins. When previously planned, IWR is used by some dive teams in remote locations
- consider the case for IWR (e.g. deep technical diver on a rebreather with no chamber in a remote area) and the associated risks.

If evacuation is needed from the dive location to a recompression centre

- understand the problems of transfer ("Medevac") especially with altitude exposure and duration whether by plane or by road
- ensure full consultation with the evacuation team before transfer and with the receiving unit
- provide continuous oxygen, i-v fluids and other treatment as discussed with receiving unit

Table selection

- be familiar with the many treatment algorithms available, including those for cases that arise during planned decompression, those that arise after surfacing and those used in difficult cases, especially when deep or saturation chambers are available. Understand their relative merits and application of different tables.
- understand the widely-accepted algorithms available for cases arising in saturation diving and the use of oxygen-enriched mixtures at depth.
- be aware that historical empirically-derived treatment algorithms for compressed air workers are different from treatment tables for divers.
- be able to advise on alterations to recompressions, including adding extensions, and also changing from one table to another

Decompression on completion of treatment

- recognise the importance to the working diver of achieving a full recovery without residua, the possible advantages of achieving this during the initial recompression treatment and the implications in relation to returning to dive. if he/she is to be able to return to work. Understand the options of extending the initial recompression to achieve this.
- understand the advantages and disadvantages of a prolonged initial recompression treatment compared to a shorter treatment followed by an interval then subsequent recompression such as repeated HBO
- be able to assess the decompression obligation of the chamber attendant

Air-range recompression

- be aware of the need to achieve the maximum benefit at an early stage in management and that residua will compromise diver's future employability.
- understand that an on-site chamber is an essential component of surface decompression and is an operational chamber that can be used for emergency treatment of working divers. If none available on site, pre-dive planning should identify availability of transport and suitable chamber.
- understand the legislative industrial standards for proximity of recompression chambers.
- be able to produce a contingency plan for recompression after surface decompression diving taking account of th use of the chamber for subsequent divers decompression
- become familiar with the wide variety of treatment protocols for decompression injuries around the world that use different pressure and oxygen algorithms supplemented by a variety of fluids and drugs. Most are usually successful but all are liable to encounter seemingly difficult cases with relapse or deterioration.
- know that the major failures of treatment include
  - failure to recognise the seriousness of post-dive symptoms
  - failure to recompress promptly
  - failure to recompress for an adequate depth and/or duration
  - failure to deliver adequate oxygen concentration (poor compliance with BIBS use
  - failure to get an early second opinion for an inadequate response
- be aware of the opportunities to delay decompression until the treatment at depth has achieved its maximum benefit and the potential hazards
- be aware of the delayed dysexecutive syndrome which may occur in association with cerebral DCI
- include basic ancillary care in severe neurological cases (urinary catheterisation, pressure points, passive range of movement, anti-thrombotic treatment).

Tables for air-range DCI

- in selecting an appropriate procedure accept that there is insufficient case information for the use of evidence-based analysis
- recognise that each treatment centre will be familiar with its own algorithm and protocols and may prefer them (there are recognised risks associated with use of new procedures).
- monitor recovery with regular checks and, if relapse occurs, modify the treatment procedure
- know that the therapeutic tables being used around the world within treatment algorithms identified by name may have significant local variations and the depth time profile should be considered in detail.

  Note that some algorithms are based on military needs (eg USN Diving Manual) and some alternative procedures have been adopted from Canadian, British, French and other military sources. These may not have the flexibility of alternative procedures that have been found by experience to be useful in other diving environments.

- know that in emergency, almost any air chamber can be converted into saturation with an O2 analyser, sufficient inert gas plus O2 supplies, with an improvised CO2 scrubber and the availability of additional watch-keepers. Understand the risks of engaging a saturation treatment in a chamber not prepared for this.

Treatment of DCI from deeper surface-orientated bounce dives
(i.e. not in saturation systems - see later)

- know that there is limited experience in treating DCS from deep surface-orientated mixed gas diving.
- experience in this area has demonstrated the importance of having a chamber on site.

Heliox bounce diving (in-water, or from an open bell)

- be aware of the various treatment options available and their advantages and disadvantages in relation to the type of diving undertaken and the time of onset of symptoms. Recognise the potential value of being able to recompress in a heliox environment although an air recompression may provide adequate treatment in some circumstances.

DCI in saturation diving

- understand the differences between incidents occurring after excursion from storage and those occurring during a saturation decompression and the implications for recompression, enriched oxygen mixture breathing and stabilisation period after resolution before further decompression
- understand the problems associated with delivery of treatment gas mixture at great depth

Ancillary treatment

- understand importance of fluid balance (but avoid exacerbation of pulmonary DCS)
- be familiar with the guidance and developments in drug and other ancillary treatments
- be competent at depth and during pressure changes with limitations and modification of interventions, such as ventilatory support, pleurocentesis, catheterisation, i/v cannulation, catheter and other cuffs, of i.v. infusions

In all cases

- remember the value of an early telephone discussion with another doctor experienced in this field
- know the importance of regular re-assessment at depth to detect any early deterioration.
- continue assessment for any relapse after surfacing and treat as appropriate
- for persistent residua consider repetitive HBO therapy during recovery period
- after maximal recovery, assess when the patient may travel safely by air but be aware of the hazards of hypoxia at altitude.
- arrange appropriate follow-up for the individual (and for statistical review)

6.5 REHABILITATION OF DISABLED DIVERS

After decompression injury

- understand that this task of rehabilitation usually applies to diving accidents after neurological deficit. When recommended, implementation of a rehab programme is not usually the direct responsibility of the diving doctor.
- recognize the need to start rehabilitation processes early, especially for bladder and spinal cord DCS
- recognise the importance of referral to a specialist spinal injury unit
- recognise that any residua in a working diver may prevent a return to diving employment

After other accidents

- recognise that personal follow-up procedure may be crucial for avoiding posttraumatic stress disorder (PTSD) or somatoform reactions.
- understand that commercial divers tend to sustain hand and finger injuries and that a return to diving is dependent on confirming their ability to perform all emergency procedures.
- a little-known feature of such injuries is a painful intolerance of cold in the distribution of the cutaneous nerves and some have been solved by directing the flow from the hot-water suit through gloves to exit at finger-tips.
- be able to apply the concepts of impairments, disabilities and incapacities to the workplace environment and advise management on policies.
- try to convince the diving companies' clients that a prophylactic recompression for omitted decompression or some doubtful symptom should not be discouraged due to classification as a "Lost Time Injury" but rather promoted as a means to avoid medical injury.

7. DIVING ACCIDENT INVESTIGATION

Recreational accidents

- consider dives beyond the diver's competence, an error of judgement, violation of accepted procedures, an unforeseeable equipment failure, environmental factor or coincidental medical events
- ensure personal statements, obtain photos, recover and seal equipment, and ensure that dive records are collected
- get samples of cylinder gas and, in rebreathers, from counterlung
- obtain / retain / check medical records
- specify time of collection of samples of blood, urine or other specimens with a witnessed chain of custody
- photograph wounds, bites, envenomation, areas of subcutaneous emphysema
- provide specialist advice at autopsy, particularly the value of a whole CT-scan but also on the limitation of interpretation of any bubbles and their distribution; Advise pathologists as requested with different autopsy protocols and know how these are implemented and interpreted. Check for bullae, blebs, haemorrhages of lungs and any PFO

Commercial accidents

- similar but be aware that commercial divers also sustain underwater industrial injuries (e.g. crane driver sheds load; a ship moves off station etc) *see also accident management*
- be aware that decompression illness or drowning are not the usual modes of death in commercial diving fatalities
- know that diving companies follow similar established protocols under official supervision that include retention of audio and video records. Interact as appropriate with government inspectors.
- know how to manage fatalities offshore, especially if deceased is in saturation

Accident assessment and reports

- consider medical involvement in civil litigation, third party responsibility and insurance reports
- know the principles of expert evidence and the hazards of interpretation and report writing
- be able to provide objective analysis of relevant scientific publications
- be able to review experience gained from accident investigation and civil litigation proceedings arising from previous diving incidents and the relevant sources of published information
- be aware of the differencies in national legislations concerning the interpretation of diving emergencies as "accident" and the according consequences for insurance coverage

8 RECOMPRESSION CHAMBERS

Distribution and purpose

- recognise that most recreational diving is relatively remote from recompression facilities. The use of chambers located in hospitals or other medical facilities follows established procedures and recompression tables appropriate for cases after an inevitable delay.
- understand that, in contrast, many working divers are required to be provided with recompression facilities on site or, if at less decompression risk, within short travelling time. Also understand that chambers for many commercial air-diving locations are primarily for surface decompression
- recognise that an air chamber is not appropriate for deeper mixed-gas diving because, if not responsive to shallow recompression, gases other than air may be needed at deeper depths, preferably with atmosphere monitoring and control.
- Saturation divers may require recompression after a downward excursion conducted in one of the saturation chamber system compartments.
- note that operational diving facilities may not be recognised as equipment for medical use and that nevertheless the standard of medical care in diving chambers needs to approach that available in a hospital HBO unit.

Chamber design and procedures

- recognise the purposes of different chamber designs (multiplace, monoplace, and chambers designed for transporting divers at pressure), their components and safe operating procedures.
- be aware of safety regulations and Codes of Practice
- be aware of mandatory and recommended HBO indications.
- understand the constraints of using of various items of medical, diagnostic, monitoring and therapeutic equipment and of ensuring good nursing care of a sick or injured diver in a chamber

9 MISCELLANEOUS

- recognise the importance of data collection / statistics / evaluation / reports
- be aware of the hazards of compression chambers with particular reference to fire
- be aware of current trends in research related to diving
- understand the role, limitations and capabilities of paramedics in this field
- understand that the management and organisation of a diving chamber is not a diving doctor’s responsibility but awareness of this is needed by doctors who advise on the treatment of divers remotely

10 ASPECTS OF PRACTICAL TRAINING:

10.1 FITNESS OF THE COURSE PARTICIPANTS

- The requirement to assess the fitness of the course participants for a chamber dive: if temporarily unfit the candidate can complete the rest of course but if permanently unfit, the student will not be able to accept relevant clinical responsibilities within a compression chamber. Depending on job-description, a doctor's fitness to dive will need to be maintained in-date as long as has 'on-call' responsibilities

10.2 PRACTICAL REVISION OF EXAMINATION SKILLS

- Useful practical skills include e.g.: Neurological, pulmonary function, ENT examination, audiology, anthropometry, exercise testing.

10.3 EXPERIENCE NITROGEN NARCOSIS

- Compression to depth with demonstration of the minor difficulties of mental arithmetic and communication and to provide familiarity with medical work in a chamber environment

10.4 SIMULATED CASES IN CHAMBER

- For skills in medical management: treat a number of simulated diving casualties (probably at lesser depths) with the emphasis on the practical difficulties of a unit in a remote location.

10.5 SKILLS REVISION

- attendees are to gain appropriate life-support certificates elsewhere because in date advanced life support training is a continuing requirement
- must be familiar with the range of oxygen provision units

10.6 UNDERWATER EXPERIENCE

- induce a greater respect for the working diver (cumbersome clothing, heavy gear, water entry and exit, uncomfortable breathing, poor communication, cold water and leaks)
- possibly try to use a hammer and nails underwater to make a wooden frame.

10.7 DEMONSTRATIONS

- visit diving contractors base or on location to learn from senior divers about their work.
- visit a saturation system (rarely possible, but a Q&A session with experienced sat diver can be invaluable).

*NOTE: Practice in **paramedic teaching** is no longer part of this course when this teaching is completed in a nationally-approved training centre.*