DIVER EDUCATION SERIES

The First Responder

Lee H. Somers

Michigan Sea Grant College Program

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Lee H. Somers, PhD

INTRODUCTION

During the 1980s the number of recreational scuba divers trained and actively participating in the sport has increased significantly. Presently, there are more than 2.5 million Americans trained in scuba diving, and this number is increasing by thousands each year. Diving equipment and diver education have evolved to keep pace with modern technology, marketing, and the requirements of a more sophisticated diving population.

The University of Rhode Island's Underwater Accident Data Center has reported an average of 147 fatal scuba diving accidents in the United States annually since 1970 [35]. In spite of the increase in the number of active divers, the number of annual diving fatalities appears to be on the decline. However, the number of non-fatal diving accidents appears to be increasing. During 1981-82, 117 non-fatal sport diver accidents involving **neurologic injury** were reported to the National Diving Accident Network (DAN) [18, 19, 36].

Diving accident management is a vital part of a diver's training. Fortunately, the Divers Alert Network (DAN) based at The Duke University Medical Center, is available 24 hours a day to provide diving accident management information and assistance to divers, instructors, emergency medical personnel, and physicians [36]. The availability of this service has both simplified and complemented the training of divers, physicians, and other support personnel. **However, the most important role in diving accident management is that of the first person(s) on the scene -- the buddy, divemaster, instructor, or boat operator.**

An accident management network consists of a number of **responders.** Seven basic responder groups are usually involved in the management of a serious diving accident, such as decompression sickness or an air embolism. The role of the **first responder** is obvious -- rescue, first aid, and acquisition of medical services. Immediate and proper first aid can make the difference between life or death and ultimately, the successful management/treatment of the injury.

The **second response group** includes the professional emergency medical technicians and paramedics who will manage the injured diver during transport to a local medical facility. At a local hospital or clinic the **third response group** includes the emergency room physicians and support personnel. This group will evaluate the nature of the injury, stabilize the patient, and arrange for prompt transport to a hyperbaric medical facility. Improper medical management and unnecessary delay at this point can significantly compromise the patient's recovery potential.

At this time, a **fourth response group** may be required for medical consultation and information on the availability of hyperbaric treatment facilities -- this is DAN. Unfortunately, many physicians are not schooled in the management of pressure-related or diving injuries. DAN provides a vital service to both the diving and medical communities.

The **fifth response** is the medical/technical team that will transport the patient to a hyperbaric medical facility. Depending on the condition of the patient and the distance, either ground or air transport may be used. Generally, the most rapid means of transport is desirable. Most hospitals with hyperbaric chambers have helicopter landing facilities, and the increasing popularity and availability of medical helicopter services increases the likelihood of the use of air transport. For long distance transport, small jet air ambulances that can pressurize to sea level pressure during high altitude flight may be used.

Upon arrival at the hyperbaric facility a special medical team trained in the treatment of diving injuries will take charge of the patient -- the **sixth response group**. This team will manage the patient through one or more hyperbaric treatments and subsequent recovery. In serious cases, a final or **seventh response group** including both physical and mental therapists may be required as a part of the rehabilitation program for the victim.

The care provided by the **first responder** is the vital link in the chain of events that will ultimately determine the victim's future. Divers, instructors, divemasters, and boat operators are encouraged to assess their personal level of training and competence in rescue, first aid, and accident management.

THE FIRST RESPONDER: A PERSONAL PROFILE

The ability of the **first responder** to rescue a distressed diver and properly manage a pressure-related injury will, of course, depend on the level of training that the individual has received. Depending on the type of course and the instructor, the training in accident management provided to entry level diving students ranges from essentially **none** to reasonably comprehensive. Some instructors are reluctant to address the serious nature of diving-related injuries in fear of the possibility of heightening the anxiety level of the student. The scared student may "drop-out" of diving; thus a loss of potential revenue to the entire diving industry. Most entry level divers are encouraged to seek continuing education through advanced and specialty diving course offerings. Unfortunately, only a relatively limited number of individuals actually continue up the education ladder.

Very few entry level diving students are trained and competent in life saving, first aid, and cardiopulmonary resuscitation (CPR). The first step in developing a **good first responder** is the acquisition of American Red Cross (ARC) or equivalent training in Basic Life Support CPR, Standard and/or Advanced First Aid, and Advanced Lifesaving. Many divers and instructors may challenge this statement on the basis that such a requirement is too time consuming and expensive for the average individual. They may fear that if people get the impression that they must go to such extremes to be good divers, they might reject diving in favor of another sport. However, training and certification in these three areas can be accomplished in about 40 hours, depending on the type of course, at minimal cost to the student. ARC chapters throughout the country offer thousands of courses each year. And I suggest that every citizen, not just scuba divers, should have at least some level of competence in CPR, first aid, and lifesaving.

Ideally, the above-mentioned training should be a pre-requisite to entry level scuba diver training. It is very difficult for a diving instructor to teach in-water rescue and resuscitation techniques unless the student has a basic understanding of lifesaving and CPR fundamentals. First aid for pressure-related accidents is somewhat unique to the sport and not addressed in ARC first aid training. However, first aid fundamentals such as the management of shock, thermal problems, and injury assessment procedures are addressed in ARC courses, and these fundamentals are basic to proper diving accident management. Unfortunately, it is unlikely that the day will ever come when a prospective diving student will be required to provide evidence of such training prior to entering a diving course. In fact, we must consider ourselves fortunate if some entry level divers can swim 200 yards and stay afloat for 10 minutes without the use of mask, fins, or snorkel. A few individuals suggest that even this swimming requirement is too rigid and demanding of prospective students.

Fortunately, all of the diving instruction agencies have developed and promoted **diver rescue and accident management speciality courses** [9, 10, 11, 12, 18, 20, 27, 28, 29, 30, 40, 42, 51]. All scuba divers are encouraged to complete such a course as soon as possible following entry level training. These speciality courses include 20 to 50 hours of instruction depending on the instructor and the sanctioning agency's requirements. However, divers must keep in mind that these type of courses may not provide comprehensive coverage in the fundamentals of standard first aid, CPR, and lifesaving. Additional ARC or equivalent training may be required.

CAUSES AND PREVENTION OF DIVING ACCIDENTS

The University of Rhode Island National Underwater Accident Data Center publishes annual reports on fatal scuba diving accidents in the United States [35], and the Michigan Sea Grant College Program has sponsored a review of scuba diving accidents in the state of Michigan [25]. As previously stated, the currently available scuba diving accident data base in the United States only addresses fatalities, not incidents which involve non-fatal injury.

The term "accident" is perhaps misleading. Most scuba diving injuries and fatalities **are not accidents** in the sense of being random and totally unpredictable. Most often the causes of the injury or fatality are readily apparent when the environmental conditions, the equipment, training, and capabilities of the diver, and diving procedures are analyzed. The **prevention** of an injury or fatality involves assuring that there is a reasonable match between the performance capability of the diver and the demands of the environment. For example, a novice scuba diver with no training in river diving procedures and only limited experience in calm water diving is at significantly higher risk when entering a fast moving river than an experienced diver specifically trained in river techniques. Prevention of potential injury or fatality, therefore, involves altering an immediate potential cause of a mishap (by not diving in the strong current) and acquiring proper training/experience before attempting such a dive in the future.

The following are examples of contributing causes of diving incidents that may result in diver injury or fatality:

* **Performance/judgment errors**

    Exceeding abilities

    Lack of or insufficient training for a particular diving activity

    Diving alone or improper buddy diving

    Loss of control in current, surf, or waves

    Failure to adhere to dive plan

    Failure to recognize risk factors

    Failure to exercise proper safety precautions

    Failure to acknowledge personal health factors

    Failure to use decompression tables/devices properly

    Failure to provide a "margin of safety"

* **Bad judgment in using equipment**

  No alternate air source

  Improperly maintained equipment

  Use of malfunctioning equipment

  No or inadequate pre-dive equipment inspection

  Inaccurate depth gauge

  Failure to monitor scuba pressure gauge

  Overweighting

  Failure to use a watch or depth gauge

  Inadequate or insufficient equipment for a given diving situation

  Improper use of decompression devices and other diving equipment

  Inadequate training in the use of equipment in both routine and emergency diving situations

* **Environmental conditions**

  Lack of training for specific environmental conditions such as ice, caves, surf, kelp, cold, current, and so on

  Failure to analyze environmental conditions prior to committing to a dive

  Strong current, heavy surf, and adverse weather

Risk is the possibility of loss or injury. It can be a statistic which implies the likelihood that injury or death will occur. **Benefit** is something conducive to personal or social well-being. **Safety** is the condition of relative freedom from harm or risk. In diving one must strive to maximize safety and benefit and minimize risk. A particular diving situation may be assessed in terms of **risk-benefit** or, in other words, what benefits will be derived from the dive in light of the risk involved.

Keep in mind that it would be impossible to totally eliminate risk from any part of society, let alone scuba diving. Willingness, and even need, to take risks and challenge ourselves can result in important growth experiences. The decision that a diver must make is, **"What is an acceptable risk?"** Furthermore, the amount of risk that is acceptable for one individual is not necessarily acceptable for another, as capabilities and desires may differ considerably. Recognition of personal limitation is a fundamental basis for safe diving and the prevention of accidents.

Divers can alter these limitations by improving their capabilities through training, physical conditioning, and experience. It is equally important to recognize that capabilities can be reduced due to exhaustion, emotional stress, alcohol consumption, cold, equipment malfunction, and environmental adversities. Individuals can protect themselves by recognizing and admitting to reduced capabilities. Environmental hazards can be reduced by selecting another dive site or waiting for better conditions. Arriving at an acceptable level of risk involves maintaining an adequate margin of safety, and this requires the **use of good judgment** [33].

Judgment is the process of forming an opinion by discerning and comparing. It means deciding if a particular diving situation is acceptable--safe or unsafe--for a given diver. It may mean postponing a dive. In general, a person who routinely takes risks that exceeds his or her abilities is probably **"unsafe."** Exceeding one's abilities may actually be the primary cause of scuba diving injuries and fatalities.

In summary, being aware of the causes of accidents will help you to prevent them. Both your enjoyment and your safety are best assured through understanding your personal capabilities and limitations and those of your companions and equipment. Participation in a given dive should be a conscious decision, based on sound judgement.

BEING PREPARED: ESSENTIALS OF ACCIDENT MANAGEMENT RESPONSE

Mental Preparation. To deal with an injury in a diving situation, you must have a working knowledge of accident management and first aid. You must be able to organize a response and apply it to the situation at hand. Adequate planning includes preparing a simple, yet effective, emergency plan for the particular dive site so that you may provide proper care and evacuation for the injured party. A prudent group leader will visualize the "worst accident scenario" for a given location and diving activity and mentally rehearse the management of that hypothetical accident. Some leaders/divers will actually sketch an accident management flow diagram. Others will systematically develop specific procedures for each dive site and record them on note cards or in a note book that can be placed in their first aid kit or briefcase. Once the accident has occurred it is often too late to identify the most satisfactory course of action.

The accident management plan will include, but not necessarily be limited to, the following:

* Communications (location of nearest telephone, ship-to-shore radio, etc.);

* Transportation (boat, aircraft, emergency vehicle);

* Emergency medical/paramedical and advanced life-support service (location and contact procedures);

* Location of nearest hospital or medical facility;

* Diver Alert Network number for consultation; and

* Name, address, and telephone number(s) of a relative or guardian for each diver in party (in the event that permission for treatment, consultation, or unusual medical procedures is required).

Physical Preparation. Physical preparation involves the ability to actually perform rescue and first aid. Reading a book on giving CPR is a good place to start; however, this provides incomplete knowledge until the physical experience of actually doing CPR has been repeated often enough to master the skill. Some dive clubs and advanced diving classes actually stage "practice accidents" so that members can rehearse.

Group Preparation. Although all members of a dive group should have a working knowledge of first aid and accident management, a few individuals will generally have more advanced knowledge and experience. These individuals must be identified by the leader and known to all members of the group. Ideally, a dive leader will have advanced first aid training and/or will specifically include a person with such capability in the dive group. All members of the group must consider what they would do if someone was injured or lost. Too often **NO ONE** ever thinks about the unfortunate possibility of an accident occurring.

Material Preparation. Material preparation for management of a potential accident includes acquiring, testing, organizing, and packaging appropriate equipment and supplies needed for the diving activity. In addition to all personal diving equipment, this includes personal and group first aid items. Naturally, divers traveling to the Caribbean will not be able to include a backboard and oxygen delivery system in their first aid kit. However, both individual divers and dive groups must make every effort to include (or assure availability of) such items for both local and expedition or vacation outings.

THE DIVER'S FIRST AID KIT

All divers or dive groups should carry a first aid kit. Individual diver kits should be small and compact, yet contain the necessary items to deal with cuts, abrasions, sprains, pain, burns, and so on, in accord with routine first aid requirements [1, 2, 5, 23, 26, 33]. Additional items may be required for specific geographic locations (i.e., a kit for tropical ocean diving will generally include items not generally considered necessary for northern quarry diving). The diver's first aid kit should include, but not necessarily be limited to, the following:

* Assorted dressings and bandages (adhesive bandages, sterile gauze pads, roller gauze, athletic tape, triangular bandage, and elastic bandage);
* Antiseptic and cleansing solutions (alcohol pads, povidone iodine solution/swabs, etc.)
* Pain relief (aspirin or equivalent);
* Decongestant;
* Motion sickness preventive (boat diving);
* Sunscreen and burn medication;
* Snake bite kit (for some geographic areas);
* Vinegar (for tropical diving);
* Heat producing packet (or materials for heating water: for tropical diving);
* Tweezers and/or needle;
* Pocket mask; and
* Oxygen delivery system.

Consult my publications on hazardous marine life and adventure travel for more information on special first aid kit requirements [44, 45].

The most important item of equipment for dealing with a true diving emergency is an **oxygen delivery system.** The ability to immediately administer 100% oxygen to a victim of air embolism, decompression sickness, or carbon monoxide poisoning cannot be over emphasized. Although the administration of oxygen by first aiders is not endorsed by the American Red Cross, all divers are encouraged to learn how to operate a simple oxygen delivery system and adminster oxygen to diving accident victims. The equipment is relatively simple and similar in principle to scuba. Administering oxygen to a conscious, spontaneously breathing person with this equipment is not difficult and is usually safe [36]. Special courses are available from community colleges (EMT courses) and some diving organizations to assist divers in learning to use oxygen delivery equipment and understanding airway management.

Proper management of a victim of an air embolism includes keeping the victim in a left-side-head-down position at an angle of 30 degrees. Ideally, a special stretcher or backboard is a desirable addition to the first aid kit. However, because of travel and space restrictions the first aider may be required to improvise in many situations.

Many people draw a false sense of security from the physical presence a first aid kit. Without the knowledge of what to use or when to use it, the items in a kit are useless. The competent first aider should be able to accomplish a number of first aid procedures with no more than two bare hands and the materials normally found in a diver's equipment bag and the surroundings.

RESPONDING TO A DIVING ACCIDENT

When a diving accident occurs, many things must be done. Some must be done immediately, while others must be delayed until the situation is better understood and the victim is safe from further injury. The following steps have been adapted from mountaineering first aid practices [33] and, in order of priority, can be followed with any diving accident.

Take Charge of the Situation. The designated leader or first aid (medical) person must take charge of the situation immediately in order to maximize group response in minimum time. Available personnel must be organized and specific tasks assigned. If no leader has previously been designated, then someone must become the self-appointed leader and assume these responsibilities. Other members of the party must become good followers.

Rescue the Victim. If the victim is still in the water, rescue efforts will generally be initiated by the nearest diver or buddy. If the divers are a long way from the beach or boat, the divemaster may elect to dispatch other swimmers or a pick-up boat to provide assistance. In-water resuscitation may be necessary during return to base if the distance is great. However, avoid unnecessary delays in moving the victim to a safe, stable platform. Management of an unconscious victim in the water or removing that victim from the water into a boat or on to a beach can be a difficult task requiring considerable strength and/or special equipment/techniques. A team of only two divers can find themselves in a difficult, if not impossible, situation if one of the divers is rendered unconscious. Furthermore, a very small diver might have great difficulty in handling a larger diver. Use discretion in selecting diving partners and always have beach/boat support personnel. Rescue techniques and in-water resusitation is discussed in various diver rescue manuals [7, 8, 12, 37, 40, 42].

Occasionally, a diver will surface and report separation from and loss of a buddy underwater. If the lost diver has not surfaced in accord with prescribed procedures, an underwater search must be immediately organized. Before committing to an underwater search, the water's surface must be thoroughly searched by visual scanning and with the pick-up boat. Concurrently, an underwater search team is selected, equipped, briefed, and, if the surface search is unsuccessful, deployed. Systematic underwater search is discussed in several diving textbooks and search and rescue manuals [24, 29, 30, 37]. Generally, the simple circle search pattern is most effective for an untrained search team to organize and execute. Ideally, the search should begin at the last known position of the lost diver. A circle search line can be attached to a heavy anchor or submerged object. All dive leaders and, ideally, all divers, should include a simple reel or line bag with at least 100 feet of line in their personal dive kit.

DO NOT EXPOSE UNQUALIFIED PERSONS TO UNNECESSARY RISK DURING SEARCH AND RESCUE OPERATIONS. Select the underwater search team carefully. Assign novice divers to perform selected surface tasks. Ideally, a prudent dive leader will have selected one or more potential underwater search teams in advance as part of the emergency planning procedure.

Frequently, the victim of a diving-related illness or injury will be on the boat or beach before symptoms appear. Keep in mind that symptoms of decompression sickness will generally appear within one hour following the dive; however, delays up to 36 hours have been documented. Air embolism is generally evident within minutes of the barotrauma.

Perform Urgent First Aid Procedures. The first responsibility of the "first responder" or first aider is to treat conditions that can cause loss of life. In the water this often means provisions for immediate flotation in order to prevent possible drowning. Keep in mind that a conscious victim can lose consciousness without warning.

Evaluate the victim at once, at a minimum, to determine if breathing has stopped, if there is no pulse, or if bleeding is severe. Treat these conditions immediately!

Protect the Victim. Now that immediate life-threatening factors such as drowning, breathing, circulation, and bleeding have been addressed, measures must be taken to protect the victim from further physical and **emotional** harm. Whatever the extent of the injury, the victim will require protection from the environment, either hot or cold. Talk to the victim, explaining what you are doing and what you intend to do. Do not allow a crowd to surround the victim! Do not discuss the critical nature of the victim's condition with other persons where he can overhear the discussion! Do not add to the victim's emotional distress by expressions of regret about his condition!

Do provide the victim with gentle and encouraging expressions of reassurance! Keep in mind that certain marine life injuries, such as the bite of the blue-ringed octopus involves the injection of a neurotoxin and a neuromuscular blocker, resulting in a painless skeletal paralysis. The victim's conscious state is initially normal in such cases, even though he may not be able to open his eyes or respond to his environment. Even when administering CPR in such cases, reassure the victim, who may hear you but cannot communicate to you. Let him know that everthing will be all right and that you understand his condition.

NEVER LEAVE THE VICTIM UNATTENDED! Even a conscious and apparently stable victim of air embolism, decompression sickness, gas supply contamination, or some marine life injuries can cease breathing without warning.

Check for Other Injuries. Once the life-threatening emergencies have been identified and controlled, the victim should be examined in detail to determine if there are any other problems, either major or minor.

Plan a Course of Action. Once urgently needed first aid has been given, protection from the environment provided, and other injuries/problems identified/corrected, time must be spent planning further tasks. Basically, the situation needs an objective analysis and the development/execution of a comprehensive plan of action.

Execute the Plan. After a complete examination of the entire accident situation and development of a course of action, execute the plan. Generally, this involves acquisition of emergency medical services, transportation to a medical facility, stabilization of the patient at that facility, and, in the case of decompression sickness and air embolism, transport to a hyperbaric treatment facility.

The responsibilities of the first aider will generally be completed when the victim's care is transferred to the emergency medical team. **However**, the leader/first responder should follow the victim's care through the system to insure that proper measures are taken to deal with the diving-related illness or injury. In the event that emergency medical personnel or hospital/clinic personnel are not knowledgeable in the proper management procedures for pressure-related accident victims, the first responder may have to provide further assistance in seeking appropriate consultation and care. Ideally, in my opinion, the first responder (or a designated member of the dive team) should accompany the victim to the final treatment facility if at all possible. Not only can this person assure that proper care is given, he may be able to provide valuable information about the accident situation and victim to the treatment team. All divers should include a copy of the DAN manual [36] in their kits. The manual can be very valuable to emergency and medical personnel who are unfamiliar with diving-related accidents and their management.

DEALING WITH LIFE-THREATENING EMERGENCIES

Absence of breathing or a pulse may result in death after only a few minutes. Since the diving accident victim is often in or under water when the incident occurs, many serious diving-related accidents must ultimately be managed as near-drownings regardless of the initial cause. Near-drowning is no doubt the most common life-threatening situation encountered in diving. If the victim is not breathing, the first responder must begin mouth-to-mouth artificial respiration as soon as possible. When there is no pulse evident, cardiopulmonary resuscitation (CPR) is necessary.

When you approach an apparently unconscious victim, you must immediately check for absence of breathing and pulse [33]:

* **CHECK FOR RESPONSE.** Speak loudy to the victim and gently touch or shake; if no response, open airway.

* **OPEN AIRWAY.** If there is no reason to suspect a neck or back injury, tilt the head back and place one hand on the victim's forehead. Place the tips of the fingers of the other hand under the bony part of the victim's chin, and lift the jaw up and forward.

  If there is reason to expect a neck or back injury, use the jaw thrust method. Place your hand on each side of the victim's head, and push the base of the jaw up and forward. Do not tilt the head back.

* **CHECK FOR BREATHING.** With your head turned so that you can observe the victim's chest and abdomen, place your ear and cheek next to the victim's nose and mouth. **LOOK** for movement of chest and abdomen. **LISTEN** for breath sounds. **FEEL** for air movement against the side of your cheek.

  If you see chest or abdomen movement without hearing or feeling air movement, suspect airway obstruction. Recheck head/jaw position to assure that airway is open.

* **IF THE VICTIM IS NOT BREATHING,** give four quick breaths and proceed with resuscitation effort as required.

* **CHECK FOR CIRCULATION.** Place your index and middle fingers on the victim's voice box and then slide your fingers down the side of the victim's neck to the space between the voice box and neck muscle. Feel for

a pulse. If a pulse is present, continue with mouth-to-mouth artificial respiration. If not, give CPR.

Keep in mind that victims of **cold-water submersion** (water below 68° F.) may be successfully resuscitated even though they have remained submerged without breathing for more than 30 minutes [38]. Consequently, a near-drowned diver should receive complete resuscitation efforts even though the period of submergence may be relatively long.

The procedures for safe and effective mouth-to-mouth artificial respiration and cardiopulmonary resuscitation are beyond the scope of this booklet. Learning to administer CPR requires special training and practice on mannequins in accord with American Red Cross or equivalent training/certification procedures [1, 2, 3].

Major wounds can cause severe, life-threatening bleeding. Although not as common in diving accidents as absence of breathing and pulse, severe bleeding can also be fatal in minutes. Quick, decisive action is mandatory. Severe bleeding injuries in diving are more likely to be associated with such incidences as shark attack or being struck by a boat propeller.

Severe bleeding may be controlled by applying direct pressure to the bleeding area. If the wound is on a limb, elevate the bleeding extremity. If these measures do not control bleeding, application of pressure to an artery, at a pressure point, can reduce the flow of blood through the artery. If these measures fail, and the wound is on an extermity, a tourniquet may be required. **The decision to apply a tourniquet is in reality a decision to risk sacrifice of a limb in order to save a life.** Specific first aid procedures for the management of severe bleeding are addressed in American Red Cross first aid courses and manuals [1, 2]. All divers are encouraged to complete a basic and/or advanced ARC first aid course.

BASIC FIRST AID

This booklet has been prepared to address the management of specific diving and pressure related illnesses and injuries. However, divers must also be capable of administering proper first aid for other types of injuries. For example, more divers are probably injured in motorbike accidents on Bahamian and Caribbean islands in a single year than in diving-related incidences over a 10 year period.

One of my former students reported an incident involving a diver entering the water using the backward roll method from a boat. Another diver, already in the water, was rendered unconscious when the entering diver's scuba cylinder struck her on the head. Fortunately, the injured diver only sustained a mild concussion. However, skull fracture and cervical (neck) injury could have resulted in life-threatening or crippling consequences. Ironically, the divemaster never even considered the possibility of such serious injuries, "dragged" the unconscious/dazed victim into the boat without precaution, and allowed the individual to continue diving upon regaining consciousness.

Any diving expedition leader will routinely deal with a variety of minor injuries including cuts, abrasions, insect bites, blisters, sprains, and sunburn. On the other hand, the leader must be prepared to provide first aid for neck, head, and back injuries; temperature-related problems such as hypothermia and heat stroke; drug abuse; fracture; and burns. Basic injury management procedures are included in numerous manuals and textbooks [1, 2, 6, 23, 26, 37, 51]. As previously stated, all divers, and especially divemasters and instructors, are encouraged to complete the ARC first aid training program or its equivalent. Furthermore, dive expedition leaders are encouraged to carry a complete first aid kit, especially when diving in remote locations. For general first aid information I recommend that the diver acquire and read, at a minimum, the following manuals:

* "Standard First Aid and Personal Safety" [1]
* "Mountaineering First Aid" [33]

EXAMINATION OF THE INJURED DIVER

Once the first responder has rescued the distressed diver, dealt with immediate and life-threatening injuries, and taken measures to protect the diver from further harm, a **complete assessment** of the diver's condition must be completed. You must identify if the diver has any other conditions or injuries which pose potential risk to the individual's well-being. In addition, you must be in a position to provide complete information to emergency and medical personnel. Finally, you must have a **baseline** by which to recognize subsequent changes in the victim's condition.

Assuming that the victim is conscious, introduce yourself to the victim and give some indication of your first aid capability. **Ask the victim if you may help her.** The victim has the right to refuse your assistance. Additional explanation may help the victim to accept aid. Keep in mind that the victim may not be aware of the seriousness of her injury/illness.

Even if the victim appears to be unconscious, not breathing, and unable to communicate, she may be able to hear everything you say and be aware of what is happening. You must reassure the victim that she will be all right and that you understand her condition.

Do not discuss the serious nature of a badly injured victim's condition directly in the presence of the victim. The resulting emotional trauma can add considerable complication to the subsequent management of the injury or illness. You can actually "create" psychosomatic symptoms, especially in victims of suspected decompression sickness.

Ask the victim the following:

* What happened?

* How did it happen?

* When did it happen?

* What hurts?

* Do you have any other problems? Medical conditions? Allergies?

* Are you exhausted? Cold? Hot?

Information gained from a conscious victim is important in identifying first aid needs. In the event that the victim later loses consciousness, this information may be very important to the emergency medical personnel and attending physician. Ask similar questions of others who might have witnessed the accident or who know the victim. Record all information.

In examining a victim the following basic principles should serve as a guide [33]:

* Do no further harm to the injured person.

* Be complete and systematic.

* Use direct observation.

* Compare left and right body parts.

* Have one person do the examination.

* Record all of your findings.

* Record both signs (observable indications) and symptoms (sensations reported by the victim).

Since this booklet deals primarily with diving and pressure-related injuries or illnesses, the details of examining a trauma victim such as someone involved in a mountaineering accident, motor vehicle accident, or similar incident will not be addressed. Readers are referred to "Mountaineering First Aid" for an excellent discussion of performing a "head-to-toe examination" of a trauma victim [33].

Vital Signs

Observing and recording vital signs is an essential part of any examination. These signs include pulse, breathing, skin color and temperature, pupillary reaction, state of consciousness, sensation of pain, and ability to move. Vital signs must be recorded initially and periodically thereafter. If the victim's injury is apparently minor, frequent taking of vital signs is not necessary. However, in a seriously injured or apparently unstable victim, vital signs should be taken every ten to fifteen minutes. These vital signs are very important in determining if the victim's condition is stabilizing or deteriorating.

A complete record of the examination and the vital signs must be documented in writing. Record information in a notebook or on a special examination form (Figure 1).

Pulse. Pulse can be felt at the wrist or on the neck. Count the number of beats in fifteen seconds and multiply by four. Also note the strength and regularity/irregularity of the pulse. An adult's pulse rate is normally 60 to 80 per minute; 80 to 100 per minute in children. Fear and exercise may increase heart rate.

Breathing. An adult normally takes 12 to 15 breaths per minute (20 to 30 for young children). Determine if breathing is deep or shallow and easy or labored (difficult). Is there the presence of gurgling sounds or sputum/froth coming from the mouth or nose? Such conditions as labored breathing and/or froth could be a sign of pulmonary barotrauma.

Skin. Normal skin coloration has an underlying reddish tone. Absence of this tone is seen as ashen or pale color in light-skinned persons or dull ashen gray in dark-skinned persons. Bluish tones may indicate oxygen deficiency or carbon dioxide retention due to inadequate ventilation or circulatory deficiencies. A mottled appearance may indicate decompression sickness. Note the presence of sweat (or lack of perspiration on an exceptionally hot day) and if the skin is unusually warm or cool.

Pupils of the Eye. Abnormal pupil response can be an indication of central nervous system dysfunction or head injury. This observation is very important in assessing diving accident victims and will be discussed in more detail later. Size variations, movement, and reaction to light should be documented.

State of Consciousness. The victim's state of consciousness is another indication of central nervous system function. Note departures from normal alertness, combativeness, confusion, speech (clear or slurred), or personality changes evident to persons who know the victim.

VITAL SIGN RECORD

Record TIME	BREATHS		PULSE		PULSES BELOW INJURY	PUPILS	SKIN	STATE OF CONSCIOUSNESS	OTHER
	Rate	Character	Rate	Character					
		Deep, Shallow, Noisy, Labored		Strong, Weak, Regular, Irregular	Strong Weak Absent	Equal Size, React To Light, Round	Color Temperature Moistness	Alert, Confused, Unresponsive	Pain, Anxiety, Thirst, Etc.

FIGURE 1. Vital Sign Record [33].

Pain and Movement. Specific complaints of pain in lower back, legs, and joints may be symptoms of decompression sickness. Lack of reaction to pain producing stimuli may denote damage to the central nervous system. Even an unconsciousness person will move away from pain stimuli if there is no paralysis of appropriate muscles. When you touch an injured victim ask if he can feel the touch. Movement should be accomplished easily upon command. Such tests should begin with small movements such as asking the victim to wiggle toes or fingers. Then progress to the use of large muscle groups. Strength tests, to be discussed later, are commonly used to determine neurological deficits. Note any specific pain reactions or deficiencies and movement capabilities.

The Neurologic Examination

The first responder will seldom have to perform a neurologic examination. However, in the event that an accident occurs in a remote location where neither emergency medical services or physician services are available, the first responder may have to provide a detailed assessment of the victim's condition to physicians by radio or telephone. In suspected cases of air embolism and decompression sickness, obvious neurological symptoms or lack of such symptoms may be very important in determining the seriousness of the illness and a proper course of action.

By following a simple guide, any diver should be able to perform a neurologic examination. Contrary to popular belief, doing a neurologic examination does not require much training or even an understanding of the nervous system. It only requires the ability to recognize and report **obvious abnormalities.** Most neurological symptoms are obvious, even to untrained people, but their significance is missed. What is often lacking is the discipline to thoroughly evaluate a distressed diver and look for the less obvious symptoms. The examination procedures given here have been modified from those given by Daugherty for use by diver-medics in commercial offshore diving [15].

A neurologic examination performed by a first aider is not intended to serve as a major diagnostic factor. Most often diagnosis is made by competent physicians at a medical facility. The examination does not test every single nervous function. However, it can be complete enough to detect and monitor important problems. The initial examination serves as a baseline for repeated evaluations. The examination can be directed by a physician by radio/telephone or later discussed with a physician in determining an appropriate course of action. The examining first aider should systematically follow the guidelines given below and record the results of her findings (including the time of the initial and subsequent examinations).

Mental Consciousness. Ask the diver who he is, where he is, and the approximate time of day. Test memory by asking simple questions about his dive buddy, the dive location, what he ate at his last meal, his mother's maiden name, etc. Have him perform simple arithmetic problems in his head. Do not use trick questions! All that is expected is the ordinary mental function that everyone is assumed to have.

Ordinary conversation is often the best mental examination procedure. The first aider can observe the diver's response to questions and instructions, then ask specific questions if she becomes suspicious. Mood and personality changes are often a subtle sign of brain dysfunction, and may only be obvious to someone who knows the diver well. If you, the first aider, do not know the diver, have someone who does present during the evaluation.

An excellent example of "personality change" was demonstrated when a resident in an emergency room interpreted the rather dull, unintelligent responses of a sheriff's department diver as "normal for a person in that profession." He was preparing to discharge the patient when a diving physician arrived on the scene. The line-tended scuba diver had been rapidly and unsuspectingly pulled to the surface as a result of signal misinterpretation by a tender. The circumstances of the incident prompted the diving physician to perform a more thorough examination. Slight neurologic dysfunction was detected and the diver was recompressed. The diver immediately responded to treatment and exhibited pleasant, outgoing, and intelligent personality characteristics after the treatment. In this case a victim of air embolism was almost discharged without treatment.

Cranial Nerves. The examiner does not have to know the names and Roman numbers of the cranial nerves; such knowledge is unnecessary and soon forgotten. The first aider should learn to recognize functional abnormalities and report them in simple terms (i.e., "the right side of the face sags" or "the left eye cannot look outward").

Eyes. While following a moving finger, both eyes should track the movement together, up and down and side to side. Both pupils should be round and approximately the same size. When a light is shined into one eye, both pupils should react; test both eyes. Pupils should constrict when gaze is shifted from far away to 4 or 6 inches in front of the nose.

Face. Both sides should move equally when the diver is asked to raise her eyebrows, frown, close her eyes tightly, smile, or show her teeth.

Mouth. The soft palate (soft fleshy back part of mouth) and uvula (small, fleshy process hanging down from the middle of the soft palate above the back of the tongue) should rise when the diver says "AH". When the tongue is stuck out it should not deviate to either side and the diver should be able to wiggle it from side to side.

Hearing. Ask the diver if she notices anything unusual about her hearing such as roaring, humming, or ringing in the ears. With the diver's eyes closed, test her ability to hear whispers or the rubbing of fingers together. See how far from her ears the diver can hear the sound. Compare with your own hearing.

Neck Muscles. Have the diver turn her chin sideways against the palm of your hand. Feel the force and observe the neck muscle contraction on each side. Pull down on the wrist and have the diver shrug each shoulder upward against this resistance. Both sides should have approximately equal strength and movement.

Strength. The strength of major muscle groups can be assessed by feeling the force exerted by the victim against a resistance applied by the examiner. The right and left sides of the body are compared.

Upper Extremities. To test grip strength have the victim grip the examiner's index and middle finger and tell him to squeeze as hard as possible. Grip the diver's hand and have him pull and push against the resistance. Keep in mind that the dominant hand and arm may be stronger; note significant differences. Have the victim hold his hands straight out in front and have him attempt to bring his hands together and apart against a resistance. Have the victim hold his elbows out to the side and resist pressure applied to force them downward.

Trunk. Weakness in the trunk is more obvious since the victim will have difficulty sitting, standing, walking, or remaining upright. Test include observing sit-ups and straight leg lifts.

Lower Extremities. Have the diver do deep-knee bends and toe-ups on one foot at a time. Hold the victim's ankle and ask him to straighten and bend the knee against resistance. Have the victim raise his big toe and hold it strongly against resistance.

Sensation. Numerous tests are possible, but only a few are significant to the first responder. Sensations often obvious to the victim are pain, numbness, tingling, hot-cold, or a wooly, heavy feeling in extremities. The examiner should keep in mind that an injured victim will generally have some sensation or feeling. Therefore, ask the victim, "Does this feel normal?", not "Can you feel this?"

Light Touch. Drag fingers lightly over the front and back of the victim's arms, trunk, and legs with particular attention to the fingers, toes, palms and soles of feet. Touch the hairs on the arms and legs lightly. Compare the right and left sides.

Sharpness and Dullness. Using the point and head of a safety pin or the point and eraser of a sharp pencil, press on the skin and ask the victim to identify sharp versus dull sensation. Compare the right and left sides and keep in mind that some areas will normally be more sensitive than others. Gently drag the point of the pin across the body surface (vertically on the body and around the extermities) looking for strips of dullness or different feeling. Take care to not scratch the skin.

Position. With her eyes closed, have the victim determine the direction in which the examiner is moving various joints (up or down).

Balance and Coordination. The examiner should try these tests himself in order to have some idea of their difficulty.

Gait. This may be the best all-purpose test. Ordinary walking is a deceptively simple act which we do without thought. Howver, it is impossible to do normally without an intact nervous system. Slight abnormalities in a person's walk are surprisingly easy to detect, even by an untrained observer. The test can be made more difficult by having the diver walk heel to toe (forward and backward) in tightrope fashion. If on a vessel, be certain to consider response to natural vessel motion. Also, in examining a stranger be certain to determine by inquiry whether the individual has any normal gait variations (i.e., a limp).

Rhomberg Test. Have the victim stand with feet together, arms outstretched, and then close his eyes. Most people will weave a little, but the victim should be able to stand in this manner without falling over or leaning severely in one direction.

Alternating Movements. The diver should be able to jog in place, tap toes, and clap hands smoothly without clumsiness.

Orientation in Space. Without looking, have the diver touch his index fingers over his head, separate, and touch again. Have the victim alternately touch his right and left index finger tips to his nose with eyes closed. While sitting and with the eyes closed, have the diver put the heel of one foot on the opposite knee, then slide the heel down the shin bone to the big toe. Repeat with other foot. With eyes open, have the diver place his index finger into the center of the examiner's palm, which is held in different locations, alternating right and left sides.

Unconscious Victim. The most important factor to consider in this case is the fact that the diver is unconscious. Unless it is immediately evident without doubt that the unconscious state resulted from some other problem such as physical trauma, drug usage, etc., the diver must be considered to be a victim of air embolism or decompression sickness. Even in cases such as trauma and drugs this possibility cannot be totally dismissed. I recall one suspected air embolism victim that I treated who had reportedly consumed quantities of a hallucinogen and alcoholic beverage prior to diving. The diver apparently surfaced rapidly as if in panic and lost consciousness. Since an objective neurologic exam could not be performed, even when the victim regained consciousness, recompression was absolutely necessary. The victim responded to treatment and was subsequently discharged without residual effects.

The first aider can do little but monitor the victim, assure breathing and circulation, and give appropriate first aid for suspected air embolism. In the event that the consulting physician wants to gain some insight into the neurologic state of the victim, he may direct the first aider to test sensation to pain by pinching muscles, fingertips, or toes, or jabbing with a pin. The normal response is withdrawal of the limb or other protective response. Failure to respond usually means that there is no feeling in that area.

Another pain response test is to use the knuckle of the index or middle finger to press hard into the sternum (breast bone) with a rotating or grinding motion. This can cause great pain, but do no harm (unless unreasonable pressure is applied). The victim may respond in a variety of ways depending upon the state of coma. Note if all extremities react to this stimulus. Compare upper to lower, right to left. If the victim clearly responds to pain but fails to move a limb, this suggests paralysis or severe weakness.

Hold both eyes open to observe reaction to light and if the pupils are approximately equal. Note if the eyes will track or if one moves and not the other.

As previously stated, the first responder will seldom, if ever, have to perform a neurologic examination. In the rare situation of isolation from immediately available medical services, the first aider might have to examine a victim and report the findings to a physician by radio or telephone. However, there are situations in which a dive buddy or leader may use some of the above procedures (primarily those requiring observation only) to determine if a diver has been adversely affected during an emergency ascent or other type of incident. For example, if a diver experiences an uncontrolled ascent, that diver should not be allowed to immediately submerge again. Rather, the diver should return to base (boat or shore) under positive flotation, relax, and be observed for at least 30 minutes. The observer must take great care to not alarm or emotionally distress the diver with probing questions. Simply observe for obvious indications of normal body function or dysfunction. If dysfunction is noted, appropriate measures must be initiated to further evaluate the diver and administer proper first aid.

The Incident

A complete understanding and documentation of the circumstances or conditions of the accident can be very important in determining the appropriate first aid measures and, ultimately, the medical management of the victim. For example, a diver experiencing neurological deficiencies following an **emergency ascent** must be considered as an air embolism victim. Neurological deficiencies or joint pain following a day of extensive diving close to or beyond the no-decompression limits suggest a high probability of decompression sickness. On the other hand, a person who complains of discomfort in a knee joint following a single dive to 30 feet is probably **not** suffering from decompression sickness.

The first responder should, if possible, obtain a complete pre-incident history of the victim and activities including, but not necessarily limited to, the following:

* Signs/symptoms of respiratory infection (common cold, coughing, etc.) prior to the dive;

* Depth and duration of all dives within the past 24 hours (include previous days if diving is conducted every day);

* Recalculation of dive schedules and repetitive dives in order to determine if there were any mistakes in the original calculations;

* Does the diver recall any incidence of physical injury such as twisting a knee, back strain, etc., associated with the dive in question or other activities prior to or following the dive;

* Amount of sleep, alcohol consumption, food intake, and exercise/strenuous activity in past 24 hours;

* Prior incidences of decompression sickness, pulmonary barotrauma, and other diving (pressure) related illinesses; and

* Exertion level and thermal condition during dive(s) in question.

QUESTIONABLE SITUATIONS

Sometimes a diver will experience fatigue, a variety of minor pains, and, simply, feel "poorly" following a dive. There are countless factors that could account for such symptoms or "feelings." Quite often the diver must ask herself, "What are the chances of my having decompression sickness?" Ironically, fatigue is a symptom of decompression sickness. However, if every diver who complained of fatigue following a dive or at the end of a diving day were to submit herself for treatment of decompression sickness, large hyperbaric chambers would be required at or near all dive sites. The diver and the dive leader must be prepared to "sort out" the possibility of real decompression sickness versus simple fatigue and general physical discomforts associated with exercise and environment.

There are no simple rules for such determinations except judgment, common sense, and objectivity. Emotional distress and fear of decompression sickness can produce a host of psychosomatic symptoms, especially if other persons begin to support the premise of serious illness. **If a diver complains of discomfort or illness following a dive, the possibility of decompression sickness or pulmonary barotrauma must always be considered.** However, immediate and hasty diagnosis of a minor discomfort or illness as a serious diving-related injury or illness can lead to difficult and expensive consequences.

Ideally, it would be desirable for any individual who is suspected to be a victim of air embolism or decompression sickness to be transported to a hyperbaric facility and examined by a diving physician as a precautionary measure. Unfortunately, this could most often be an expensive and complicated procedure. For example, let's assume that the incident occurs on a Caribbean island. In haste, a decision might be made to immediately transport a questionable victim back to Miami for treatment. The "panicked" leader orders a jet air ambulance from the states to pick up the victim and deliver him to Miami.

Most private air ambulances will not take off unless payment is appropriately guaranteed or the bill is paid in advance. The cost of this service from the locations in the Caribbean to the states may run as high as $7,000 to $10,000. Upon arrival in Miami, the victim may be found to be asymptomatic and hyperbaric treatment not necessary. A more prudent decision would have been to monitor the victim for a short time to determine if the symptoms subsided or intensified. In addition, a telephone call to DAN at Duke University would have provided the leader with consultation and assistance in developing a proper and reasonable course of action.

In cases of minor, and probably non-diving related, discomforts the diver and dive leader should objectively analyze the dive schedules and activities for the day (and prior days of consecutive diving) to determine if there have been any mistakes or violations of proper diving schedules. The diver should simply **relax** and not submit to further emotional or physical stress. The diver should maintain an awareness of increased severity of symptoms. For example, if a diver with minor pain or discomfort in the knee has only injured the knee by twisting or physical contact, the discomfort should not worsen significantly if the individual relaxes and does not place weight on the leg. Also, the pain should intensify if the painful area or joint is physically touched or pressed against. However, if the discomfort is a result of decompression sickness, it will probably intensify and spread within a few hours, even if the diver is resting. In addition, discomfort should not intensify with touching. Furthermore, other areas of the body may develop symptoms indicative of decompression sickness. In cases of intensifying or spreading pain and development of neurological abnormalities, serious injury must be suspected and appropriate management measures begun.

Some authorities recommend that a person experiencing minor, questionable discomforts following a dive (or series of dives) be placed on **precautionary oxygen breathing** for a period of one to two hours. One dive tour leader reported an incident involving a diver who had made multiple dives each day for several days. The dives were probably within the no-decompression limits; however, since the diver was using an underwater propulsion vehicle for multi-level dives, exact depth-time relationships could not be established. Following a repetitive dive the diver complained of severe headache, neck pain, and extreme fatigue. The diver was directed to rest and breathe oxygen for an hour or so and the discomforts disappeared. Wisely, the tour leader recommended that this individual forgo diving for the remainder of the trip. Was this diver suffering from decompression sickness? Possibly? Probably? Questionable? Would the diver have experienced more serious symptoms if oxygen breathing had not been initiated? We will never know. One can only speculate at this point. The use of precautionary oxygen breathing at atmospheric pressure may be of considerable value. Possibly, it may prevent the development of further complications. However, more research and medical information will be necessary in order to determine if this is to be designated as a standard practice in recreational diving situations. **Keep in mind that this practice should not be considered as a substitute for proper hyperbaric treatment of decompression sickness.**

Unfortunately, the "unlikely" may occur in diving. A young, healthy female completed a single dive to 60 feet for 30 minutes. Following the dive she developed symptoms of decompression sickness. Subsequent hyperbaric treatment relieved all symptoms. According to accepted diving tables the no-decompression limit for a dive to 60 feet is 50 to 60 minutes (depending on the table selected). A young, healthy male diver completed a single dive to 40 feet for about 40 minutes. Four to five hours following the dive he flew in a commerical airliner and developed joint pain. His condition was subsequently diagnosed as decompression sickness and several hyperbaric treatments were administered. Even so residual joint discomfort remains two years following the incident. According to several publications, this diver was considered "safe" for flying. A diving instructor reported to a hyperbaric chamber facility with pain in both arms approximately 36 hours after a properly executed dive. Hyperbaric treatment on a standard table relieved the discomfort and he was later released from the hospital symptom free.

In 1976 Spencer reported on the evaluation of divers using ultrasonic detection to determine the presence or absence of venous gas emboli (VGE) following exposure to pressure [46]. In this study he found that, "There are bends-prone and bubble-prone individuals who, if they dive, should do so only in very shallow water, i.e., less than 30 feet in depth." His findings demonstrated that there is a strong individual propensity to form VGE, which correlates with susceptibility to decompression sickness.

Unfortunately, the recreational diver does not have the luxury enjoyed by some military and commercial divers where hyperbaric chambers are more readily available and a commom diagnostic technique is "a test of pressure." If the suspect diver is placed under pressure (recompressed in a hyperbaric chamber) and the discomfort is relieved, the standard procedure is to treat for decompression sickness. In the event that the symptoms are not relieved, further and complete medical evaluation is necessary to determine if the diver is actually a victim of decompression sickness or otherwise. However, even this procedure is not foolproof. In one incident wrist pain in a military diver was not relieved and re-occurred following several hyperbaric treatments. A subsequent X-ray revealed a wrist bone fracture. It is unlikely that the individual ever had decompression sickness.

ADMINISTERING OXYGEN

The administration of oxygen by first aiders has been questioned by some **non-diving authorities.** Oxygen is considered to be a drug, and there are laws in some states which regulate the use of oxygen. Rescuers and divers should be aware of such laws, especially if they specifically forbid the use of oxygen in a first aid situation.

Supplemental oxygen is a valuable adjunct in the first aid management of air embolism and decompression sickness. Breathing oxygen will eliminate some nitrogen from the body by producing a pressure gradient between the problem bubble(s) and the surrounding tissues. This favors resolution of the bubble since this pressure gradient, or driving force, causes nitrogen in the bubble to dissolve in the bloodstream and be eliminated through the lungs. Any increase in oxygen being supplied to the injured area will also be physiologically beneficial, especially if brain tissue is involved [36].

Administering oxygen to a conscious, spontaneously breathing individual is not difficult and is usually safe with the proper equipment. The concentration of inhaled oxygen should be as near 100% as possible in order to achieve maximum benefit. A **demand-type oxygen breathing unit with a tight-fitting, double seal mask** and an adequate oxygen flow rate is necessary to deliver the required concentration. Constant flow devices (inhalators) using nasal cannula, simple elongated face masks, partial rebreather masks, etc., will only deliver low, ineffective concentrations (25% to 60%) depending on the metered flow rate. In the event that only a constant flow device is available, deliver oxygen at a flow rate of 10 liters per minute [14].

If the victim is unconscious or not breathing spontaneously, oxygen administration becomes more complicated. In this situation the first aider must have a thorough understanding of airway management and the use of adjunctive equipment. As in the case of CPR, such techniques and equipment are beyond the scope of this booklet. The diver and dive leader can only be encouraged to acquire additional special training. Many community colleges offer Emergency Medical Technician courses which include this training [13]. The use of oxygen in the early stages of managing a diving accident victim may reduce or totally relieve the symptoms within a short time. If this does happen, do not be deceived into thinking that the problem has been completely resolved. Oxygen breathing should be continued, the victim transported to the nearest medical facility, and a diving physician consulted. Oxygen breathing at atmospheric pressure must not be considered as a substitute for hyperbaric treatment in cases of decompression sickness and air embolism [36].

IN-WATER RECOMPRESSION

The equipment and techniques for in-water recompression have been discussed by Edmonds for application in managing diving accidents in extremely remote tropical areas [21]. However, the standard of care in the American diving and diving medicine community does not advocate such procedures and, in fact, discourages any attempts at in-water recompression. It has been found that the victim is usually further compromised by incomplete treatment, additional nitrogen uptake, and cold. If oxygen is used the high risk of oxygen toxicity must also be considered. If the initial symptoms are serious, the results are usually disastrous. **IN-WATER RECOMPRESSION SHOULD NEVER BE ATTEMPTED!** [36]

SERIOUS DIVER INJURY: AIR EMBOLISM AND DECOMPRESSION SICKNESS

The two most potentionally disabling and life-threatening conditions that can result from exposure of an individual to elevated ambient pressure situations such as scuba diving are air embolism and decompression sickness. Air embolism, resulting from the entry of air bubbles into circulation as a result of pulmonary barotrauma, can occur in water depth as shallow as 4 feet. It is most common among trainees, inexperienced divers, and infrequent divers. Decompression sickness involves nitrogen being released from solution in the form of bubbles in body tissues as a result of inadequate decompression procedures. This condition is more common among experienced and frequent divers who dive beyond depths of 30 feet.

Pulmonary Barotrauma

In a diminishing pressure situation, e.g., a scuba diver ascending from depth, the air in the lungs is expanded because of decreasing external pressure. If the normal exhalation route of the expanding air is interrupted either voluntarily, by breath holding, or involuntarily, from local respiratory tract obstruction, the intrapulmonary pressure progressively distends the alveoli (air sacs) and rupture of lung tissue may ensue. A pressure differential of about 100 mm Hg (2 psi or 4 feet of seawater equivalent) may be sufficient to rupture lung tissue. From the point of rupture, the air may disperse along the bronchi and enter the mediastinum (tissues surrounding the heart) to create **mediastinal emphysema.** A diver with a mediastinal emphysema may exhibit such manifestations as substernal pain (especially during exercise), breathing difficulties (including shortness of breath), change in voice, and even collapse (fainting) due to direct pressure on the heart and great vessels. Cyanosis (blueness of skin, lips, and fingernails) may be evident.

From the mediastinum, the air frequently migrates into the subcutaneous tissues (**subcutaneous emphysema**), most often in the neck and supraclavicular region (over the collar bone). This will be evident by enlargement and feeling of fullness around the neck, voice changes, breathing difficulties, and crepitation (cracking sensation or sound when skin is touched in enlarged areas).

If there is a weakened area on the surface of the lung, air may rupture directly into the pleural space (chest cavity) causing the lung to collapse. This is a **pneumothrox** and may involve partial or complete collapse of a lung. As the diver continues to ascend, the air trapped in the pleural space expands at the expense of the collapsing lung and may eventually cause displacement of the heart and great vessels. This is a very serious complication because both respiration and circulation may be impaired. Manifestations include chest pressure and sharp pain, breathing difficulties (shortness of breath and rapid, shallow breathing), and cyanosis.

These conditions in themselves generally do not require hyperbaric treatment. **However, the victim must be continuously**

monitored and immediately placed under the care of a physician. If signs or symptoms of any of these conditions are evident, the first responder must suspect that the injured diver has also experienced an air embolism until proven otherwise by a physician. Keep in mind that more serious and life-threatening manifestations may appear at any time.

Air Embolism

The most serious consequence of alveolar rupture is the release of air bubbles into pulmonary circulation, and via the pulmonary vein, left heart, aorta, and carotids, into cerebral circulation. The cerebral area is most frequently affected since the diver is usually in an erect or head-up position during ascent, and the bubbles tend to rise. Any bubble too large to pass through an artery will lodge and obstruct circulation to adjacent areas or organs. This is an **air embolism.**

The wide spectrum of symptoms and signs associated with cerebral air embolism include severe headache, vertigo (dizziness), visual disturbances (blurred or lost vision), nausea, paralysis (hemiplegia or involvement of one side of body), seizures, stupor, limb numbness, weakness, cessation of breathing, and loss of consciousness [49]. Death may result from coronary and/or cerebral occlusions with cardiac arrhythmias, respiratory failure, circulatory collapse, and irreversible shock [34]. The diver may or may not experience discomfort or pain in the chest prior to or during tissue rupture. The tearing of lung tissue may result in the discharge of a bloody froth from the victim's mouth; however, the absence of bloody froth does not preclude the possibility of air embloism [47].

The onset of symptoms is generally dramatic and sudden, usually occurring within seconds of surfacing, or even prior to surfacing. In a review of 39 cases of air embolism, Dick and Massey found that 69% of air embolism victims had symptoms upon surfacing and 91% had symptoms within 10 minutes of surfacing. Rarely, symptoms began as long as 12 hours following the dive. Forty-one percent of the victims in this study became unconscious within minutes of surfacing [18, 19].

Decompression Sickness

Decompression sickness is a pressure-related illness which results from a reduction in ambient pressure sufficient to cause the formation of bubbles from gases dissolved in body fluids and tissues. During exposure to elevated ambient pressure, inert gas in the breathing medium dissolves into the diver's body. During ascent or decompression, some quantity of this inert gas in the tissues must diffuse into the blood, travel to the lungs, and be released from the body in expired air. If decompression exceeds some critical rate, the tissues will not release the gas rapidly enough and will become saturated. When this happens, some of the inert gas comes out of solution in the form of bubbles, and if enough bubbles develop, manifestations of decompression sickness result.

The signs and symptoms of decompression sickness are variable in nature and intensity depending on location and magnitude of the bubbles. Localized pain has always been considered as the most predominant symptom of decompression sickness, occurring in about 89% of all cases, according to early studies and the U. S. Navy [17, 47, 48]. The recent Dick and Massey report on 70 cases of sport diver decompression sickness indicates that the progressive onset of limb numbness and paresthesias (sensation of pricking, tingling, and creeping on the skin) are the most common symptoms, evident in 56% and 34% of the cases, respectively [18]. Limb weakness was more common than paralysis. Limb paralysis was noted in 8 of the 70 cases. Other signs and symptoms included dizziness, nausea, mild headache, and loss of coordination. Twelve (about 17%) of the cases of decompression sickness exhibited symptoms within 10 minutes of surfacing and 44% of the cases were evident within one hour of surfacing. Twenty-four percent of the victims became symptomatic more than 6 hours following a dive and 2 divers developed decompression sickness more than 24 hours following a dive.

Skin itching and mottling are considered to be a sign of mild decompression sickness and may precede the development of more severe symptoms. The onset of pain is often gradual with progression in severity and extent. A localized pain may extend centrifugally to involve a progressively larger area. Generally, the pain is neither aggravated nor alleviated by local motion or palpation (touch). Joint and tendinous structures are the most common locations of pain symptoms.

Transient blurring of vision and other visual disturbances occasionally accompany more serious manifestations of decompression sickness. Respiratory distress is a rare symptom of delayed development of substernal "burning" sensation that may intensify and spread. The victim can become cyanotic (blue) and the condition may advance into clinical shock with subsequent loss of consciousness.

Marked fatigue, often disproportional to the physical exertion expended, may be experienced following deep dives or a series of repetitive dives. The onset of fatigue may occur 2 to 5 hours after the diver surfaces and is characterized by an overwhelming desire to sleep.

Most central nervous system (CNS) lesions occur in the spinal cord, particularly in the lower segment; cerebral damage is relatively rare. Quadriplegia, paraplegia, and paralysis of a single or several extremities in every combination have been reported. Early vasomotor collapse and severe clinical shock are associated with more serious manifestations. Various body functions may be affected. Initial and permanent residual damage may result in loss of bladder, bowel, and sexual function.

First Aid For Suspected Air Embolism or Decompression Sickness

The first responder(s) must provide immediate and proper care for possible victims of air embolism or decompression sickness at the scene of the accident. Furthermore, arrangements must be made to enter the victim into the hyperbaric trauma system as soon as possible. All symptoms of air embolism and decompression sickness are generally considered together in the early management of a diving accident. It is more important to use proper early first aid than to attempt to distinguish between the two conditions because the initial management of both conditions is essentially the same until hyperbaric therapy is started. The first aid procedures recommended below are in accord with those published by the Divers Alert Network (DAN) and the Undersea Medical Society (UMS) [16, 36].

The most important initial factor in managing a diving accident is to recognize that a diver has sustained injury. In most situations this is obvious, however, occasionally mild symptoms may be dismissed or not recognized. As previously discussed, both symptoms/signs and circumstances are important in diagnosis. The following are obvious indicators of serious complications and air embolism and/or decompression sickness must be suspected until proven otherwise by a physician:

* Diver loses consciousness underwater or shortly after surfacing (cause unknown);

* Diver exhibits symptoms of neurological abnormality following ascent from a shallow dive (pulmonary barotrauma/air embolism can occur when ascending from a depth as shallow as four feet);

* Diver exhibits symptoms of pain or neurological abnormality following ascent from no-decompression dives deeper than 30 feet or even shallower depths for repetitive dives (decompression sickness); and

* Diver exhibits symptoms of pain or neurological abnormality following ascent from deep dives and dives near or beyond no-decompression limits.

An injured diver may fail to recognize **mild symptoms.** Severe fatigue or unusual tiredness and itching are considered mild symptoms and may respond to oxygen breathing. If a diver experiences mild symptoms on surfacing, place the diver on his/her left side with head down and give 100% oxygen. The oxygen may relieve the symptoms or prevent them from getting worse. If the symptoms are relieved after an interval of oxygen breathing, do not discontinue oxygen breathing immediately as the symptoms may recur. Continue oxygen breathing for at least 30 minutes. If symptoms are relieved, consult a physician for further instructions and monitor the diver for recurring or new symptoms. If symptoms are not relieved, proceed with first aid protocol given below [36].

The first aid procedures for management of a suspected air embolism or decompression sickness are given and discussed below. A simplified flow chart reprinted from the DAN Underwater Diving Accident Manual summarizes the procedure (Figure 2) [36].

Perform Life-Saving Procedures. Administer CPR if required and protect the diver from further injury.

Victim Position. Place the victim on left side in a head down position, especially if air embolism is suspected (Figure 3). In this modified Trendelenburg position the entire body is maintained at an angle up to about 30 degrees [36].

This position is for breathing victims only. It is intended to encourage a bubble in the brain circulation to dislodge itself and migrate to a less damaging area. This phenomenon has been demonstrated in the laboratory on animals but not on human subjects. Subjective observations and case history review of a limited number of air embolism patients suggest that it may be beneficial (personal experience).

A properly strapped backboard is almost a necessity for maintaining this body position. The backboard may not be immediately available at an accident scene and it may be difficult to contrive an appropriate system. Using natural beach slope and shaping sand may be possible for immediate on-site positioning. In a motel room, a bed may be tilted by blocking one end and using pillows to support the body on its left side. If the left side position can not be maintained, the head down position may still be achievable and beneficial. Transportation in some aircraft and emergency vehicles may preclude maintaining this position. Consequently, DAN suggests that this modified Trendelenburg position should not be viewed as absolutely necessary [36].

Airway Management. It is important to insure that the airway is open and to prevent aspiration of vomitus. Placing a distressed diver in a head down position may induce some respiratory impairment through airway obstruction (tongue falling back into the oropharynx portion of the throat) and vomiting. Continously monitor the victim and make adjustments as necessary in order to prevent/manage these conditions. If trained emergency medical personnel and/or a physician is available, the placement of an endotracheal tube can be used to correct these problems.

Administer Oxygen. Administer as high a concentration of oxygen as possible by tight-fitting mask (100%). Continuous 100% oxygen administration and maintenance of intravascular volume is considered the most important feature of immediate management, and should be continued until the victim reaches the hyperbaric chamber [16, 36]. Do not remove the oxygen except to clear the airway, administer fluids (when applicable), or if the victim shows signs of convulsions [36].

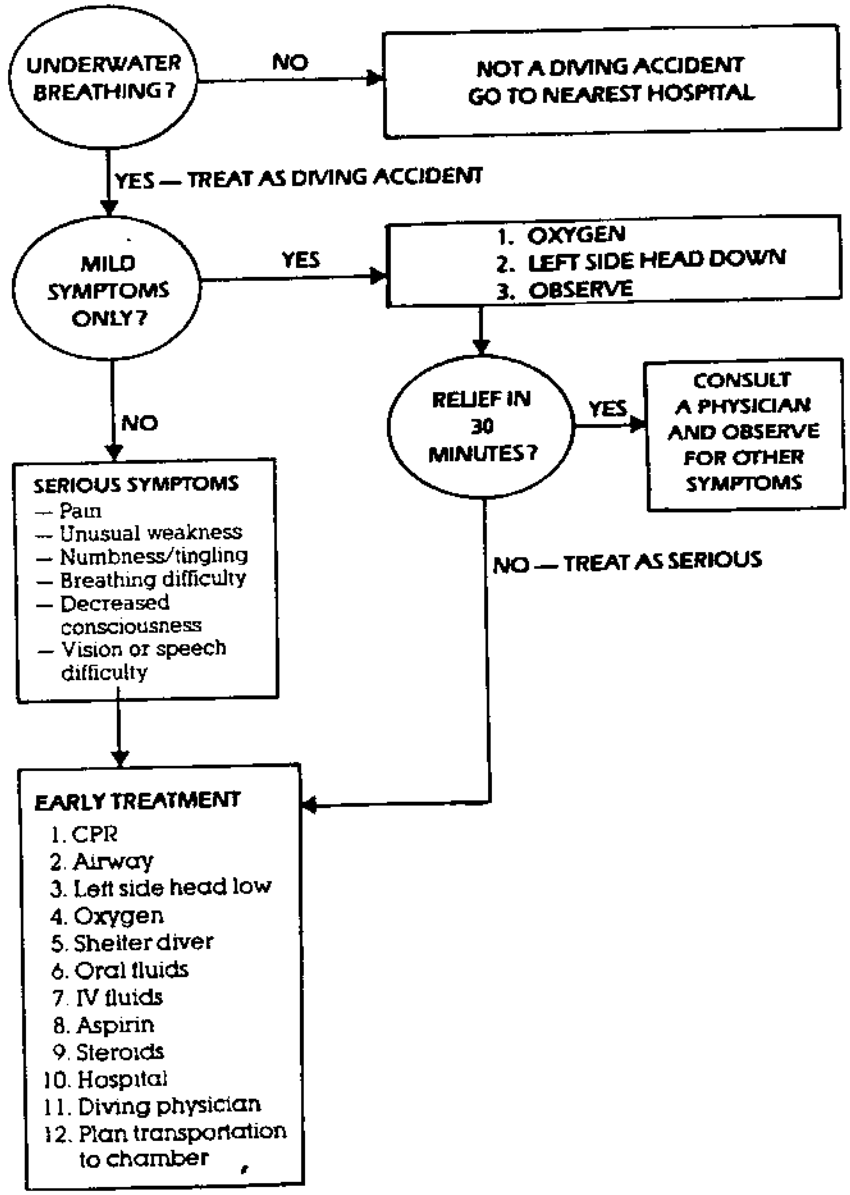

FIGURE 2. Diving Accident Management Flow Chart [36].

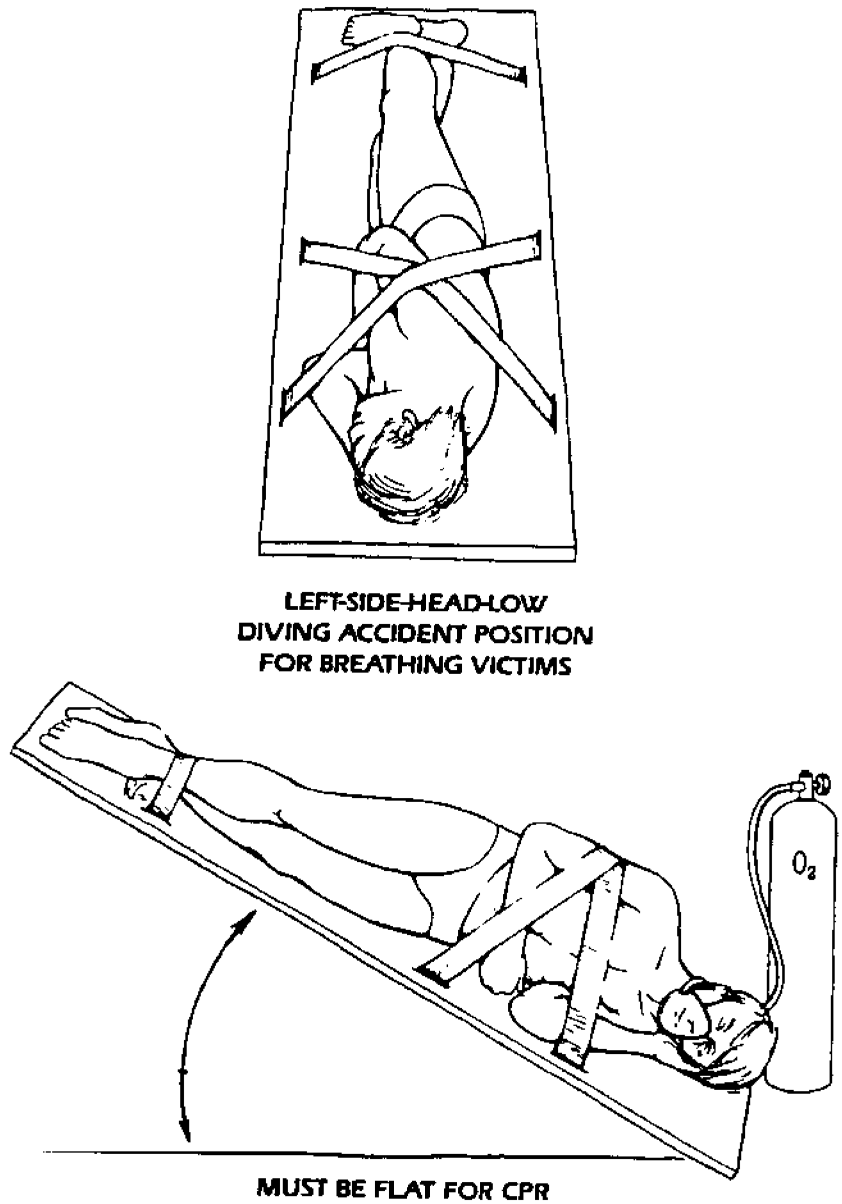

FIGURE 3. Modified Trendelenburg Position [36].

Diving accident victims who receive oxygen immediately after their injury have a better recovery than if no oxygen is used. The crucial value of early oxygen breathing must always be emphasized, particularly for sport diving injuries not occurring near hyperbaric chambers [36]. The use of oxygen and oxygen breathing equipment has been previously discussed.

Management of a Convulsion. If convulsions occur, do not use forceful restraint. Turn the victim on side (supporting head and neck), maintain airway, and remove vomitus. Hold the victim loosely to prevent self-injury and do not force airway or tongue blade. Resume oxygen breathing when convulsions subside.

Protect Victim. Protect the injured diver from excessive heat, cold, wetness, or noxious fumes.

Liquids. For a conscious victim, give oral non-alcoholic liquids such as fruit juice or balanced electrolyte beverage (such as Gatorade). Give one liter in the first hour. If the delay in hyperbaric treatment is to be extensive, continue sufficient fluid intake to maintain a urine output of 1 or 2 ml/kg/hr (kg means kilograms body weight) or approximately 1/3 to 2/3 fluid ounces per 22 pounds of body weight per hour [16]. If possible, consult with a physician by radio/telephone when long delay is anticipated and adjust fluid intake per physician instructions. Fluid level maintenance is considered very important in the management of decompression sickness.

Aspirin. Most authorities approve of the use of 2 aspirin (5 grains each) as an anti-platelet agent. They conclude that it can do little harm and may do some good.

Local Medical Care. Evaluate and stabilize the patient at the nearest hospital emergency room prior to transfer to a hyperbaric chamber facility (if needed) [36]. Several factors must be considered. First, serious and potentially life-threatening conditions such as heart failure, kidney failure, severe shock, etc., require immediate attention. Failure to properly stabilize the patient could result in serious complications or even death enroute to the hyperbaric chamber. In serious cases, an aggressive intravenous fluid replacement procedure may be started, a urinary catheter inserted, and drugs administered. Secondly, through proper medical evaluation and consultation with DAN it may be determined that the patient has not experienced air embolism or decompression sickness and that hyperbaric therapy is not required.

Consultation. Physicians not familiar with the management and treatment of diving related injuries must be encouraged to consult with a diving physician and/or DAN. The National Divers Alert Network located at the Duke University Medical Center provides 24 hour telephone consultation at **(919) 684-8111.** This number may be called collect in an emergency. For medical problems, the caller is connected with a physician experienced in diving medicine. The DAN physicians can assist with diagnosis and initial treatment of an injured diver and supervise referral to appropriate hyperbaric chamber facilities while working with regional coordinators throughout the nation [36].

Hyperbaric Chamber Facility Contact. It is necessary to contact the hyperbaric chamber facility to which the patient is to be transported **prior to initiating transport procedures** in order to assure that the chamber is available and that a treatment team is assembled and prepared to receive the patient. Hyperbaric chambers may be occupied, out of service for maintenance, or closed.

Transporting the Patient. A major determinant of the successful outcome of a treatment is the expedience with which the patient can receive proper hyperbaric therapy. If the distance is too great for suface transportation, air evacuation must be used. It is critically important that the patient not be exposed to significantly decreased barometric pressure at altitude. Flight crews must maintain cabin pressure at sea level or fly at the lowest safe altitude in unpressurized aircraft. If a patient is moved by helicopter, the pilots must be instructed to keep the flight as low as possible but not greater than 500 to 800 feet above ground level. One hundred percent oxygen breathing and fluid therapy must be maintained during flight [16]. If the patient is experiencing obvious distress (equalization problems or otherwise), suggest that the helicopter pilot select an appropriate safe altitude that can be maintained for a level flight instead of attempting to follow the ground terrain.

The DAN Manual. The DAN Manual is intended to serve as a guide for the diver, paramedic, and physician in the recognition and initial management of a diving accident victim [36]. The diver should keep a copy of the DAN Manual in his/her dive kit so that it is always available. In the event of an accident, record the details of the accident and initial first aid management in the back of the injured diver's DAN Manual and assure that the manual remains with the diver as he/she moves through the emergency medical system.

Fluid Therapy and Drugs. In unconscious patients and in patients with manifestations more serious than limb pain bends, intravenous fluid replacement is preferred. Ringer's lactate, normal saline solution, or 5% dextrose in saline solution should be given [36] to maintain urine output at 1 to 2 ml/kg/hr (or approximately 1/3 to 2/3 fluid ounces per 22 pounds body weight per hour) [16]. Do not use 5% dextrose in water.

If there is evidence of neurologic involvement, give steroids, hydrocortisone sodium succinate, 1.0 gm. i.v. or dexamethasone, 20-30 mgm. i.v. [16, 36].

With spinal cord involvement, an in-dwelling urinary catheter should be considered [16].

The use of intravenous fluids, drugs, and catheter is only applicable for qualified medical personnel.

Fructus reports on the benefits of a first aid/enroute protocol for management of decompression sickness [28]. This protocol with minor clarification by Anderson [9] includes:

1. 100% oxygen by mask;

2. Steroids, i.v., single administration (1000 mg hydrocortisone hemisuccinate or 30 mg dextamethasone or 160 mg methylprednisolone);

3. Aspirin, 10 grains orally if patient is conscious; and

4. Fluid volume replacement, i.v. infusion, 1 liter per hour for three to four hours (i.e., Ringer's lactate, normal saline, or dextrose 5% in saline) +/- plasma expanders (i.e., dextran 40, 500 ml)

Fructus reported on 67 cases of decompression sickness of which 14 were transported without first aid and 53 received first aid management which included oxygen, aspirin, and/or fluids [28]. Of the 53 victims receiving first aid, 38 (or 72%) showed improvement or were asymptomatic by the time they arrived at a treatment facility. All of these cases involved neurologic decompression sickness with delays of 3 to 24 hours between onset of symptoms and beginning of hyperbaric therapy (mean delay of about 10 hours).

COLD INJURY

If a victim is cold and has **any** of the following signs or symptoms, consider that person to have severe hypothermia:

* Depressed vital signs.

* Altered level of consciousness, including slurred speech, staggering gait, and decreased mental skills.

* Core temperature of 90° F. or less.

* No shivering in spite of being very cold.

* Associated significant illness or injury that is present or that may have permitted the hypothermia to develop.

If the victim is cold and does not have any of these signs or symptoms, he/she is considered to have mild hypothermia.

The basic treatment for a hypothermic victim is as follows:

* Treat very gently.

* Remove wet clothing/diving suits. Replace with dry clothing or dry coverings of some kind.

* Insulate from the cold.

* Add heat to the head, neck, chest, and groin externally, or internally if a system for breathing warm moist air is available. Avoid attempts to warm the extremities.

  The first responder must prevent further heat loss at the core. This can only be done by insulating the entire patient, plus adding heat to the core area.

  Application of heat can be accomplished by placing warm objects such as hot water bottles, chemical heat packs (wrapped in a towel), warmed rocks (wrapped in a towel), human bodies, etc. Monitor closely and be certain to protect patient's skin from burns.

* Do not rub or manipulate the extremities.

* Do not give coffee or alcohol.

* Do not put the patient in a shower or bath.

* Warm liquids may be given only after uncontrollable shivering stops and the victim has a clear level of consciousness, the ability to swallow, and evidence of rewarming already.

* If **severe** hypothermia is present, treat as above and transport to a medical facility.

Treatment for severe hypothermia with no life signs is as follows:

* Provide the basic treatment as indicated above.

* Carefully assess the presence or absence of pulse or respiration for one to two minutes.

* If no pulse or respiration, start CPR.

* Obtain a rectal temperature if possible.

* If you are less than 15 minutes from a medical facility, do not bother trying to add heat.

* If you are greater than 15 minutes from a medical facility, add heat gradually and gently.

* Reassess the physical status periodically.

* Transfer to a medical facility in all cases.

The above procedures were taken from a booklet titled, "State of Alaska Hypothermia and Cold Water Near Drowning Guidelines" [6]. For additional information consult this booklet or Forgey [27]. At present there is some degree of controversy within the medical community regarding administering CPR to a hypothermic individual. Some authorities specifically state that a hypothermic person should not be given CPR in the field [5]. In a recent discussion Martin J. Nemiroff, M. D. indicated that the Alaska Guidelines [6] remain as the most acceptable alternative for the first responder to follow. The general management of cold-related injuries is also discussed by Somers [43] and Lentz, et. al. [33].

RESPIRATORY PROBLEMS

Diver maladies involving respiration include asphyxia, carbon dioxide excess, carbon monoxide poisoning, oil-vapor inhalation, and near-drowning. Low level contamination of a diver's air supply during scuba cylinder filling is possible, but uncommon. Carbon monoxide (CO) contamination is probably the most serious potential problem. A diver breathing air containing CO may lose consciousness without warning or experience severe headache, dizziness, weakness, nausea, confusion, clumsiness, or a feeling of tightness in the head. There may be an abnormal blueness or redness of lips, fingernails, and skin. However, the classic "cherry red" sign may or may not be evident and is, therefore, not a reliable diagnostic aid. Unlike carbon monoxide which is difficult, if not impossible, to detect without special testing equipment, the presence of oil in an air supply is generally quite evident by taste or odor. If oil presence is suspected, immediately discontinue use of the air supply.

Carbon dioxide may be rarely introduced during filling of the scuba cylinder. It is more frequently retained in the body through abnormal breathing patterns (skip-breathing). Occasionally a diver will lose consciousness without respiratory warning. On the other hand, there may be headache, dizziness, confusion, slowing of response, and/or nausea.

Open circuit scuba divers have lost consciousness from anoxia (lack of oxygen). Moisture accidentally introduced into a steel scuba cylinder can combine with oxygen in the air to form rust. This oxidation process consumes the oxygen in the cylinder. If a diver uses this air cylinder, he/she may breathe the remaining gas, primarily nitrogen, and lose consciousness from anoxia or lack of oxygen. Drowning is one of the major causes of diving fatalities and is usually caused by hypoxia (insufficient oxygen), followed by asphyxia, as a result of loss of air supply or submergence without an air supply.

The primary first aid procedure for respiratory problems is breathing fresh air. If breathing has ceased, start artificial respiration or CPR immediately. All victims must receive first aid for prevention/management of shock, and must receive medical attention even if revived without medical assistance. Carbon monoxide poisoning victims must be treated with oxygen, preferably under hyperbaric conditions. Oil-vapor inhalation victims may be retained for medical observation and managed similiarly to pneumonia cases depending upon the severity of dosage.

EAR AND SINUS BAROTRAUMA

Damage to ears and sinuses can result from attempting to dive with a cold or allergy or simply failing to equalize pressure during descent/ascent. Such barotrauma is evident by pain at the time of injury and discharge of bloody mucus during/following ascent. Spitting blood generally indicates middle ear barotrauma and discharge from the nose is characteristic of sinus injury. Most diving authorities concur that a "hands-off" policy for first aiders results in fewer complications and more rapid healing. Do not attempt to clean damaged ears and do not resume diving until the injury has healed. Seek medical attention if discharge, tenderness, or infection persist.

OTHER PHYSIOLOGICAL PROBLEMS

Nitrogen narcosis and oxygen toxicity are avoidable problems in recreational scuba diving. By limiting depths to less than 100 feet, the recreational diver can avoid the potential problems associated with breathing nitrogen under high pressure. The responses of a diver under the influence of nitrogen narcosis are not dissimilar to those associated with alcohol intoxication. Simply ascending to a shallower depth, preferably to the surface, with a controlled ascent relieves the problem.

Oxygen toxicity is generally associated with breathing **pure** oxygen at depths in excess of 25 feet. This condition is preventable by assuring that a scuba cylinder is **not** filled with pure oxygen and by not using closed-circuit oxygen/mixed gas scuba without proper training and maintenance. Consult the U.S. Navy Diving Manual or NOAA Diving Manual for further information [37, 47, 48].

MARINE LIFE INJURIES

The first aid procedures given below are for those animals commonly encountered by divers in the tropical Western Atlantic Ocean (including the Bahamian, Caribbean, and Florida waters) and on the Pacific Coast of the United States. Additional information on the nature and management of injuries caused by marine animals and on first aid procedures for injuries caused by marine animals of the South Pacific Ocean, Red Sea, and other regions can be obtained from Somers [44] and selected medical textbooks [10, 21. 32].

Marine Life Stings

The first aid procedures recommended for **commom jellyfish and hydrozoan (Portugese man-of-war) stings** that are considered non-life-threatening in healthy individuals vary with author and geographic area. Many authorities suggest immediate liberal use of a solution with high alcohol content (e.g., isopropyl rubbing alcohol) or vinegar since they **allegedly** inactivate the nematocysts. If these rinsing solutions are unavailable, the injured area should immediately be flushed with **sea water** and carefully cleaned of debris. Other inactivating solutions cited in various publications include formalin, household ammonia, urine, petroleum products (gasoline, kerosene, etc.), and beer. However, recent studies suggest that these solutions may be ineffective [22].

Never rinse the sting area with fresh water to remove tentacles. Fresh water has an osmotic effect on the nematocysts causing them to discharge. Beer apparently has the same effect as fresh water. Also, never rub the area with sand since this procedure will cause discharge of more nematocysts. Most authorities also discourage the use of petroleum products.

Recent research at James Cook University (Australia) and by the Royal Australian Navy School of Underwater Medicine has revealed that application of methylated spirits, 100% alcohol, and alcohol mixtures with seawater **produced dramatic, instantaneous discharge of the nematocysts, and this was associated with increased clinical sensitivity** [22]. The James Cook University group found that the application of 3% to 10% acetic acid (or vinegar) was most effective in preventing the massive discharge of nematocysts associated with the application of alcohol and other common solutions tested. Further studies by Carl Edmonds, M.D., of the Diving Medical Center in Australia (one of the foremost world authorities on marine life injuries) concluded that **vinegar** and Xylocaine (lidocaine) will prevent further nematocysts discharge. Surprisingly, Edmonds also found that selected commercial preparations, anti-sting lotions, and the enzymatic product, Adolf's meat tenderizer, were **clinically ineffective** [22]. The same was found for other common solutions such as urine, household ammonia, and so on.

Next, the tentacles that didn't rinse off must be carefully removed with a towel, stick, knife blade, etc. These residual tentacles may also be removed by coalescing them with a drying agent (e.g., flour, baking soda, talc, etc.) and then scraping them from the skin with a thin knife blade. **Avoid** personal contact with the tentacles.

After tentacles have been removed, some authors recommend neutralizing the toxins by applying one of the compounds/solutions mentioned above and thoroughly scrubbing with an antibacterial soap and water. The sting site is dried and an analgesic-antihistamine ointment applied. To the contrary, Australian authorities specifically state that the affected area must **not** be washed with soap and water for 24 hours [4, 50].

Local anesthetic ointments (lidocaine HCl) or sprays (Benzocaine, 14%), antihistaminic creams, or mild steroid lotions (hydrocortisone, 1%) may be soothing [10]. They are used after the toxin is inactivated. A lidocaine spray (Clinicaine by Johnson and Johnson) may be beneficial as an initial inactivating agent as well as a soothing solution [personal experience].

Observe the victim for general reactions and shock. It is advisable to lay the victim down and keep him as quiet as possible. The symptoms of **shock** include glassy eyes with dilated pupils; wet and clammy skin; weak and rapid pulse; pale or ashen skin tone; increased breathing rate (shallow or deep and irregular); and sensations of coldness [1]. First aid measures for prevention and management of shock [1] include keeping the victim lying down and covered **only** enough to prevent loss of body heat. No attempt should be made to add heat since raising the surface temperature of the body can be harmful. Elevate the feet or end of stretcher 8 to 12 inches. Giving fluids by mouth has value in shock; however, fluids should only be given when medical assistance is not available within a reasonable amount of time (delay of more than one hour). Fluids **should not be given** when the victim is unconscious, vomiting/likely to vomit, or experiencing seizures, since such states may result in aspiration of fluids into the lungs. Water that is neither hot nor cold (preferably a salt-soda solution, 1 level teaspoon of salt and 1/2 level teaspoon of baking soda per quart of water) is given at about 4 ounces every 15 minutes. Do not give the victim sea water. Discontinue fluids if the victim becomes nauseated or vomits. Obtain medical assistance as soon as possible. **Keep in mind that physiologically or emotionally induced shock may be associated with any marine life injury.**

Simple pain relief measures (e.g., aspirin tablets, or equivalent, in accord with dosage instructions on container) are considered acceptable. Do not attempt to administer medications if the victim is unconscious or nauseated/vomiting.

Naturally, all stings will not result in severe reaction or shock and require such aggressive first aid measures. For example, fire coral encounters do not involve tentacle removal, and some small jellyfish stings give only minor, momentary irritation. After minor encounters the diver may continue to dive. However, the victim and his buddies must maintain an **awareness** for more serious reactions. In rare cases, respiratory or cardiac arrest may occur and require immediate life saving action.

Sponges

The **fire sponge** (Tedania ignis), found off Hawaii and the Florida Keys, and the **"Do-Not-Touch-Me" sponge** (Neofibularia nolitangere), common to the Caribbean, are typical offenders. Reactions are characterized by itching and burning, which may progress to local joint swelling, blisters, and stiffness. Soaks in dilute (5%) acetic acid (vinegar) are considered beneficial [10].

Coral

Wounds inflicted by contact with stony coral are an ever-present annoyance to divers in the tropics. The sharp calcareous edges produce wounds which are generally superficial but notoriously slow to heal. Coral cuts, if left untreated, may become ulcerous. Sting cells may further complicate conditions. The initial effects of coral poisoning are pain and an itching sensation in and around the wound, accompanied by reddening and welt formation in the surrounding areas. Secondary infection is common.

First aid involves prompt removal of visible debris and cleansing of the wound with hot water and antibacterial soap. It is occasionally helpful to use hydrogen peroxide to bubble out coral "dust." Promote free bleeding; however, keep in mind that excessive probing can cause unnecessary tissue damage. Deeply embedded materials may require removal by a physician. Elevation of the involved limb is strongly recommended. The use of antiseptic creams is a matter of personal preference. Monitor the wound closely and cleanse/change dressings as soon as possible upon return from subsequent dives. Even minor wounds can become seriously infected. Current tetanus immunization is recommended for all divers. For severe wounds, or if complications appear, seek immediate medical attention.

Sea Urchin

The sea urchin most familiar to the United States diver is the genus Diadema, which includes the long-spined or black sea urchin common to the Bahamas, Florida Keys, and West Indies. These sea urchins with long, brittle spines are not considered to be a serious hazard by most divers; however, they may produce a painful puncture wound with redness and swelling. The fragments of the spine will produce a purple discoloration in the area of the wound. In minor injuries, the spines of some species will dissolve with few complications besides localized discomfort.

However, deeply embedded spines will cause irritating discomfort of long duration if not removed. These should be removed with a fine tweezer or small needle (sterilized), the area thoroughly scrubbed with hot water and antibacterial soap, and a sterile dressing applied. Medication to control pain, inflammation, and infection may be required. Consult a physician immediately if symptoms of infection or other complications appear. Surgical removal of deeply embedded spines may be necessary.

Venomous Fish

First aid for venomous fish wounds (such as scorpion fish) includes alleviating pain, combating shock and the effects of the venom, and preventing infection. Since unconsciousness is common, the victim should be removed from the water promptly. Pain will be severe. Have the victim lie down and apply measures to prevent/combat shock. Keep the affected limb level with the body and as still as possible to minimize the spread of venom. Carefully wash out or irrigate the wound with cold salt water or with sterile saline. Although the use of a tourniquet is indicated in some manuals, the practice is considered to be of limited value [21, 32]. However, Auerbach and Halstead do indicate that the application of a "loose tourniquet" which occludes only superficial venous and lymphatic return may be of some value [10]. This "loose tourniquet" should be released for 90 seconds every 10 minutes in order to preserve circulation. Considering the inherent risk associated with the use of tourniquets, this practice is generally discouraged for first aiders. Attempt to remove any remaining portions of the spine sheath.

Soak in plain water, as hot as can be tolerated (up to 50° C/122°F), for at least 30 minutes. Use hot compresses on areas that cannot be immersed. Heat may produce rapid pain relief and is believed to destroy the venom. Be careful not to scald the tissue. Immersion in hot water appears to be the **most important** first aid procedure for venomous fish injuries universally agreed upon by authorities.

Although some diving manuals recommend that the first aider make a small incision at the site to encourage bleeding and facilitate irrigation, Halstead [32] indicates that the incision may be of limited value, and Edmonds [21] indicates that a small incision can be made across the wound and parallel to the axis of the limb, to encourage mild bleeding and pain relief **if other methods are not available.** In light of modern trends in first aid and the potentially limited value of the incision method indicated by physicians, this author is inclined to not recommend this procedure unless future evidence supports its benefit.

Visible foreign material should be removed. Auerbach and Halstead suggest that local suction may be of some value; however, they do not indicate the use of incision [10]. Medical attention will be needed for further treatment of the wound and prevention of infection.

Bites

Injuries inflicted by moray eels, barracuda, and sharks are generally severe lacerations with profuse bleeding. First aid procedures for controlling bleeding and subsequent shock should be started immediately [1]. Prompt medical attention will usually be required.

Octopus

The bite is similar for all species and usually consists of two small puncture wounds. A burning sensation with localized discomfort may later spread from the bite. Bleeding is usually profuse, and swelling and redness are common in the immediate area. First-aid measures include scrubbing the bite with antibacterial soap. Measures to combat shock should be taken, and medical attention may be required.

Annelid Worms

The segmented marine bristleworm, *Eurythoe complanata*, possesses tufted, silky, chitinous bristles in a row along each side. Upon contact or stimulation of any kind, the bristles rise on edge as a defensive mechanism. The fine bristles penetrate the skin and are very difficult to remove. This results in a burning sensation, inflammation, and possibly local swelling and numbness. Bristleworms are found in the Bahamas, Florida Keys, Gulf of Mexico, and throughout the tropical Pacific.

HELICOPTER EVACUATION PROCEDURES

Helicopters are becoming a major means of transporting seriously injured persons. Most major medical centers have helicopters and/or landing areas. Each helicopter evacuation is different. In some situations, helicopter personnel will give directions by radio. In others, ground support personnel such as law enforcement officers and emergency rescue persons who are familiar with helicopters will take charge of the landing area. Knowledge of basic procedures and what to expect will improve the safety and efficiency of a helicopter evacuation. The following procedures for evacuating a patient from a boat have been modified from the NOAA Diving Accident Manual [41]:

1. Try to establish communications with the helicopter. If your boat is unable to furnish the necessary frequency, try to work through another boat.

2. Maintain speed of 10 to 15 knots; do not slow down or stop.

3. Maintain course into the wind about 20 degrees on port bow.

4. Put all antennas down, if possible, without losing communications.

5. Secure all loose objects on or around the deck.

6. Always let the lifting device (stretcher) touch the boat before handling it to prevent electric shock.

7. Place the patient in a lifejacket.

8. Tie/strap the patient in the basket face up.

9. If the patient cannot communicate, secure to the patient or place in the basket written information about the patient and the accident situation including name, age, address, description of the accident or circumstances preceding the injury/illness, first aid provided and so on.

10. If the patient is a diving accident victim, insure that the flight crew has a copy of, or instructions on, medical/first aid procedures for diving accidents. A copy of the DAN manual is beneficial.

11. If diving accident victim, insure that the flight crew will deliver the victim to an appropriate medical facility with a hyperbaric chamber if possible.

12. If the patient dies prior to pick-up, inform the fight crew so that they do not take unnecessary risk.

If the helicopter is making a pick-up on land, clear the area of loose debris if possible, devise a signal that will enable the pilot to determine wind direction (smoke flare), and be sure that the landing area is clear of people. Do not approach the helicopter until directed by the flight crew. Be especially careful of the tail rotor.

CONCLUSIONS

The actions of the **first responder** are the key elements in the successful management of a diving accident victim. Failure to take immediate and appropriate steps to deal with the injured diver's condition can cost a life or contribute to serious disability. Remember, when you approach an injured diver, "You are part of the beginning of the rest of that diver's life!"

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