

VOLUME 5

Diving Medicine & Recompression Chamber Operations

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U.S. NAVY DIVING MANUAL

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CHAPTER 17

Diagnosis and Treatment of Decompression Sickness and Arterial Gas Embolism

17-1 INTRODUCTION

- 17-1.1 **Purpose.** This chapter describes the diagnosis and treatment of diving disorders with recompression therapy and/or hyperbaric oxygen therapy. Recompression therapy is indicated for treating DCS, AGE, and several other disorders unless the diver is critically ill or has experienced a drowning episode. In those cases where diagnosis or treatment are not clear, direct the patient to the highest level of medical care available and contact the Diving Medical Officers at NEDU or NDSTC for guidance. The recompression procedures described in this chapter are designed to handle most situations that will be encountered operationally. They are applicable to both surface-supplied and open and closed circuit SCUBA diving as well as recompression chamber operations, whether breathing air, nitrogen-oxygen, helium-oxygen, or 100 percent oxygen. Treatment of decompression sickness during saturation dives is covered separately in [Chapter 13](#) of this manual. Periodic evaluation of U.S. Navy recompression treatment procedures has shown they are effective in relieving symptoms over 90 percent of the time when used as published.
- 17-1.2 **Scope.** The procedures outlined in this chapter are to be performed only by trained personnel. Because these procedures are used to treat disorders ranging from mild pain to life-threatening disorders, the degree of medical expertise necessary to carry out proper treatment will vary. Certain procedures, such as starting intravenous (IV) fluid lines and inserting chest tubes, require special training and must not be attempted by untrained individuals. Treatment tables can be initiated without consulting a Dive Medical Officer (DMO), however a DMO should always be contacted at the earliest possible opportunity. A DMO must be contacted prior to releasing the treated individual.

17-2 MANNING REQUIREMENTS

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

the treatment and additional personnel should be obtained as soon as possible. A second team may be required to relieve the initial team during prolonged treatments.

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

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

Notes:

- (a) The Chamber Supervisor and outside tender must perform the essential tasks of all other positions while keeping patient care a priority. The Chamber Supervisor must attempt to obtain additional personnel as soon as possible.
- (b) If the patient has symptoms of serious DCS or AGE where Basic Life Support (BLS) or advanced medical support may be required (e.g., airway management, or thoracic needle decompression), a Diving Medical Technician (DMT) or DMO should accompany the patient inside the chamber in addition to the inside tender. However, recompression treatment must not be delayed while awaiting the arrival of a DMO or DMT.
- (c) The best qualified person available should provide specialized medical care to a patient in the chamber. The best qualified person may be a non-diving surgeon, respiratory therapist, Independent Duty Corpsman (IDC), etc. Since these are emergency exposures, no special medical or physical prerequisites exist. A qualified Inside Tender is required inside the chamber at all times.
- (d) Locking in /out personnel. Inside tenders and additional personnel may be locked in and out during the course of a treatment. Chamber periods should be kept within no-decompression limits if possible. However, decompression may be accomplished in the outerlock utilizing the air decompression schedules in [Table 9-9](#). Once an inside tender exceeds exceptional exposure limits of the applicable schedule they are committed to the entire treatment table.

- 17-2.2 Diving Officer.** The Diving Officer is responsible to the Commanding Officer for the safe conduct of recompression chamber operations and for presenting

recommended changes to treatment protocols to the Commanding Officer. The Diving Officer is responsible for complying with reporting requirements as listed in [Chapter 5](#) and additional duties as defined in the command dive bill.

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

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

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

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

- 17-2.5** **Diving Medical Officer.** The Diving Medical Officer recommends the proper course of treatment, consults with other medical personnel, and prescribes medications and treatment adjuncts. The Diving Medical Officer is the only team member who

can modify recompression treatment tables, with concurrence of the Commanding Officer or Officer-in-Charge.

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

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

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

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

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

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

Non-diving medical personnel (e.g., U.S. Naval Reserve Corpsmen, and nursing personnel) may qualify as an Inside Tender via the Military Diver Inside Tender PQS (NAVEDTRA 43910). Non-diving medical personnel must obtain a current

diving physical exam, conform to Navy physical standards, and pass the diver candidate pressure test.

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

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

The inside tender is also responsible for:

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

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

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

Primary:

Navy Experimental Diving Unit (NEDU)

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

Secondary:

Navy Diving Salvage and Training Center (NDSTC)

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

17-3

ARTERIAL GAS EMBOLISM

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

17-3.1

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

17-4 DECOMPRESSION SICKNESS

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

For purposes of deciding the appropriate treatment, symptoms of decompression sickness are generally divided into two categories, Type I and Type II. Because the treatment of Type I and Type II symptoms may be different, it is important to distinguish between these two types of decompression sickness. The diver may

exhibit certain signs that only trained observers will identify as decompression sickness. Some of the symptoms or signs will be so pronounced that there will be little doubt as to the cause. Others may be subtle and some of the more important signs could be overlooked in a cursory examination. Type I and Type II symptoms may or may not be present at the same time.

17-4.1

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

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

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

17-4.2

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

17-4.2.1

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

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

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

Table 17-2. Rules for Recompression Treatment.

ALWAYS:

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

NEVER:

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

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

17-4.2.1.1 **Differentiating Between Type I Pain and Injury.** The most difficult differentiation is between the pain of Type I decompression sickness and the pain resulting from trauma or other injury such as a muscle strain or bruise. If there is any doubt as to the cause of the pain, assume the diver is suffering from decompression sickness and treat accordingly. Frequently, pain may mask other more significant

symptoms. Pain should not be treated with drugs in an effort to make the patient more comfortable. The pain may be the only way to localize the problem and monitor the progress of treatment.

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

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

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

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

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

17-4.4.1 **Neurological Symptoms.** These symptoms may be the result of involvement of any level of the nervous system. Numbness, paresthesias (a tingling, pricking, creeping, "pins and needles," or "electric" sensation on the skin), decreased sensation to touch, muscle weakness, paralysis, mental status changes, or motor performance alterations are the most common symptoms. Disturbances of higher brain function may result in personality changes, amnesia, bizarre behavior, lightheadedness, lack of coordination, and tremors. Lower spinal cord involvement

can cause disruption of urinary function. Some of these signs may be subtle and can be overlooked or dismissed by the stricken diver as being of no consequence.

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

- 17-4.4.2 **Inner Ear Symptoms (“Staggers”).** The symptoms of inner ear decompression sickness include: tinnitus (ringing in the ears), hearing loss, vertigo, dizziness, nausea, and vomiting. Inner ear decompression sickness has occurred most often in helium-oxygen diving and during decompression when the diver switched from breathing helium-oxygen to air. Inner ear decompression sickness should be differentiated from inner ear barotrauma, since the treatments are different. The “Staggers” has been used as another name for inner ear decompression sickness because of the afflicted diver’s difficulty in walking due to vestibular system dysfunction. However, symptoms of imbalance may also be due to neurological decompression sickness involving the cerebellum. Typically, rapid involuntary eye movement (nystagmus) is not present in cerebellar decompression sickness.
- 17-4.4.3 **Cardiopulmonary Symptoms (“Chokes”).** If profuse intravascular bubbling occurs, symptoms of chokes may develop due to congestion of the lung circulation. Chokes may start as chest pain aggravated by inspiration and/or as an irritating cough. Increased breathing rate is usually observed. Symptoms of increasing lung congestion may progress to complete circulatory collapse, loss of consciousness, and death if recompression is not instituted immediately. Careful examination for signs of pneumothorax should be performed on patients presenting with shortness of breath. Recompression is not indicated for pneumothorax if no other signs of DCS or AGE are present.
- 17-4.4.4 **Differentiating Between Type II DCS and AGE.** Many of the symptoms of Type II decompression sickness are the same as those of arterial gas embolism, although the time course is generally different. (AGE usually occurs within 10 minutes of surfacing.) Since the initial treatment of these two conditions is the same and since subsequent treatment conditions are based on the response of the patient to treatment, treatment should not be delayed unnecessarily in order to make the diagnosis.
- 17-4.5 **Treatment of Type II Decompression Sickness.** Type II Decompression Sickness is treated with initial compression to 60 fsw in accordance with [Figure 17-1](#). If symptoms are improved within the first oxygen breathing period, then treatment is continued on a [Treatment Table 6](#). If severe symptoms (e.g. paralysis, major weakness, memory loss, altered consciousness) are unchanged or worsen within the first 20 minutes at 60 fsw, assess the patient during descent and compress to depth of relief (or significant improvement), not to exceed to 165 fsw. Treat on [Treatment Table 6A](#). To limit recurrence, severe Type II symptoms warrant full

extensions at 60 fsw even if symptoms resolve during the first oxygen breathing period.

- 17-4.6 **Decompression Sickness in the Water.** In rare instances, decompression sickness may develop in the water while the diver is undergoing decompression. The predominant symptom will usually be joint pain, but more serious manifestations such as numbness, weakness, hearing loss, and vertigo may also occur. Decompression sickness is most likely to appear at the shallow decompression stops just prior to surfacing. Some cases, however, have occurred during ascent to the first stop or shortly thereafter. Treatment of decompression sickness in the water will vary depending on the type of diving equipment in use. Specific guidelines are given in [Chapter 9](#) for air dives, [Chapter 12](#) for surface-supplied helium-oxygen dives, and [Chapter 15](#) for EC-UBA dives.
- 17-4.7 **Symptomatic Omitted Decompression.** If a diver has had an uncontrolled ascent and has any symptoms, he should be compressed immediately in a recompression chamber to 60 fsw. Conduct a rapid assessment of the patient and treat accordingly. [Treatment Table 5](#) is not an appropriate treatment for symptomatic omitted decompression. If the diver surfaced from 50 fsw or shallower, compress to 60 fsw and begin [Treatment Table 6](#). If the diver surfaced from a greater depth, compress to 60 fsw or the depth where the symptoms are significantly improved, not to exceed 165 fsw, and begin [Treatment Table 6A](#). Consultation with a Diving Medical Officer should be obtained as soon as possible. For uncontrolled ascent deeper than 165 feet, the diving supervisor may elect to use [Treatment Table 8](#) at the depth of relief, not to exceed 225 fsw.
- Treatment of symptomatic divers who have surfaced unexpectedly is difficult when no recompression chamber is on the dive station. Immediate transportation, while receiving 100% surface oxygen, to a recompression facility is indicated; if this is impossible, the guidelines in [paragraph 17-5.4](#) may be useful.
- 17-4.8 **Altitude Decompression Sickness.** Decompression sickness may also occur with exposure to subatmospheric pressures (altitude exposure), as in an altitude chamber or sudden loss of cabin pressure in an aircraft. Aviators exposed to altitude may experience symptoms of decompression sickness similar to those experienced by divers. The only major difference is that symptoms of spinal cord involvement are less common and symptoms of brain involvement are more frequent in altitude decompression sickness than hyperbaric decompression sickness. Simple pain, however, still accounts for the majority of symptoms.
- 17-4.8.1 **Joint Pain Treatment.** If only joint pain was present but resolved before reaching one ata from altitude, then the individual may be treated with two hours of 100 percent oxygen breathing at the surface followed by 24 hours of observation.
- 17-4.8.2 **Other Symptoms and Persistent Symptoms.** For other symptoms or if joint pain symptoms are present after return to one ata, the stricken individual should be transferred to a recompression facility and treated on the appropriate treatment table, even if the symptoms resolve while in transport. Individuals should be kept on 100 percent oxygen during transfer to the recompression facility.

17-5 RECOMPRESSION TREATMENT FOR DIVING DISORDERS

- 17-5.1 **Primary Objectives.** [Table 17-1](#) gives the basic rules that shall be followed for all recompression treatments. The primary objectives of recompression treatment are:
- Compress gas bubbles to a small volume, thus relieving local pressure and restarting blood flow.
 - Allow sufficient time for bubble resorption.
 - Increase blood oxygen content and thus oxygen delivery to injured tissues.
- 17-5.2 **Guidance on Recompression Treatment.** Certain facets of recompression treatment have been mentioned previously, but are so important that they cannot be stressed too strongly:
- Treat promptly and adequately.
 - The effectiveness of treatment decreases as the length of time between the onset of symptoms and the treatment increases.
 - Do not ignore seemingly minor symptoms. They can quickly become major symptoms.
 - Follow the selected treatment table unless changes are recommended by a Diving Medical Officer.
 - If multiple symptoms occur, treat for the most serious condition.
- 17-5.3 **Recompression Treatment When Chamber Is Available.** Oxygen treatment tables are significantly more effective than air treatment tables. Air treatment tables shall only be used after oxygen system failure or intolerable patient oxygen toxicity problems with DMO recommendation. [Treatment Table 4](#) can be used with or without oxygen but should always be used with oxygen if it is available.
- 17-5.3.1 **Recompression Treatment With Oxygen.** Use [Oxygen Treatment Table 5, 6, 6A, 4, or 7](#), according to the flowcharts in [Figure 17-1](#), [Figure 17-2](#) and [Figure 17-3](#). The descent rate for all these tables is 20 feet per minute. Upon reaching a treatment depth of 60 fsw or shallower place the patient on oxygen. For treatment depths deeper than 60 fsw, use treatment gas if available.
- 17-5.3.2 **Recompression Treatments When Oxygen Is Not Available.** [Air Treatment Tables 1A, 2A, and 3](#) ([Figures 17-11, 17-12](#), and [17-13](#)) are provided for use only as a last resort when oxygen is not available. Use [Air Treatment Table 1A](#) if pain is relieved at a depth less than 66 feet. If pain is relieved at a depth greater than 66 feet, use [Treatment Table 2A](#). [Treatment Table 3](#) is used for treatment of serious symptoms where oxygen cannot be used. Use [Treatment Table 3](#) if symptoms are relieved

within 30 minutes at 165 feet. If symptoms are not relieved in less than 30 minutes at 165 feet, use [Treatment Table 4](#).

17-5.4

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

17-5.4.1

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

17-5.4.1.1

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

17-5.4.1.2

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

17-5.4.1.3

Communications with Chamber. Call ahead to ensure that the chamber will be ready and that qualified medical personnel will be standing by. If two-way

communications can be established, consult with the doctor as the patient is being transported.

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

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

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

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

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

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

17-6 TREATMENT TABLES

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

17-6.2 **Treatment Table 5.** [Treatment Table 5, Figure 17-4](#), may be used for the following:

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

17-6.3 **Treatment Table 6.** [Treatment Table 6](#), [Figure 17-5](#), is used for the following:

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

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

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

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

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

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

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

17-6.6

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

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

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

17-6.6.1

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

Table 17-3. Decompression

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

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

- 17-6.6.2 **Tenders.** When using [Treatment Table 7](#), tenders breathe chamber atmosphere throughout treatment and decompression.
- 17-6.6.3 **Preventing Inadvertent Early Surfacing.** Upon arrival at 4 feet, decompression should be stopped for 4 hours. At the end of 4 hours, decompress to the surface at 1 foot per minute. This procedure prevents inadvertent early surfacing.
- 17-6.6.4 **Oxygen Breathing.** On a [Treatment Table 7](#), patients should begin oxygen breathing periods as soon as possible at 60 feet. Oxygen breathing periods of 25 minutes on 100 percent oxygen, followed by 5 minutes breathing chamber atmosphere, should be used. Normally, four oxygen breathing periods are alternated with 2 hours of continuous air breathing. In conscious patients, this cycle should be continued until a minimum of eight oxygen breathing periods have been administered (previous 100 percent oxygen breathing periods may be counted against these eight periods). Beyond that, oxygen breathing periods should be continued as recommended by the Diving Medical Officer, as long as improvement is noted and the oxygen is tolerated by the patient. If oxygen breathing causes significant pain on inspiration, it should be discontinued unless it is felt that significant benefit from oxygen breathing is being obtained. In unconscious patients, oxygen breathing should be stopped after a maximum of 24 oxygen breathing periods have been administered. The actual number and length of oxygen breathing periods should be adjusted by the Diving Medical Officer to suit the individual patient's clinical condition and development of pulmonary oxygen toxicity.
- 17-6.6.5 **Sleeping, Resting, and Eating.** At least two tenders should be available when using [Treatment Table 7](#), and three may be necessary for severely ill patients. Not all tenders are required to be in the chamber, and they may be locked in and out as required following appropriate decompression tables. The patient may sleep anytime except when breathing oxygen deeper than 30 feet. While asleep, the patient's pulse, respiration, and blood pressure should be monitored and recorded at intervals appropriate to the patient's condition. Food may be taken at any time and fluid intake should be maintained.
- 17-6.6.6 **Ancillary Care.** Patients on [Treatment Table 7](#) requiring intravenous fluid and/or drug therapy should have these administered in accordance with [paragraph 17-12](#) and associated subparagraphs.

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

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

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

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

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

17-7 RECOMPRESSION TREATMENT FOR NON-DIVING DISORDERS

In addition to individuals suffering from diving-related disorders, U.S. Navy recompression chambers are also permitted to conduct emergent hyperbaric oxygen (HBO₂) therapy to treat individuals suffering from cyanide poisoning, carbon monoxide poisoning, gas gangrene, smoke inhalation, necrotizing soft-tissue infections, or arterial gas embolism arising from surgery, diagnostic procedures, or thoracic trauma. If the chamber is to be used for treatment of non-diving related medical conditions other than those listed above, authorization from BUMED Code M95 shall be obtained before treatment begins (BUMEDINST 6320.38 series.) Any treatment of a non-diving related medical condition shall be done under the cognizance of a Diving Medical Officer.

The guidelines given in [Table 17-4](#) for conducting HBO₂ therapy are taken from the Undersea and Hyperbaric Medical Society's Hyperbaric Oxygen (HBO₂) Therapy Committee Report-2014: Approved Indications for Hyperbaric Oxygen Therapy. For each condition, the guidelines prescribe the recommended Treatment Table, the frequency of treatment, and the minimum and maximum number of treatments.

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

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

17-8 RECOMPRESSION CHAMBER LIFE-SUPPORT CONSIDERATIONS

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

- 17-8.1** **Oxygen Control.** All treatment schedules listed in this chapter are usually performed with a chamber atmosphere of air. To accomplish safe decompression, the oxygen percentage should not be allowed to fall below 19 percent. Oxygen may be added to the chamber by ventilating with air or by bleeding in oxygen from an oxygen breathing system. If a portable oxygen analyzer is available, it can be used to determine the adequacy of ventilation and/or addition of oxygen. If no oxygen analyzer is available, ventilation of the chamber in accordance with [paragraph 17-8.4](#) will ensure adequate oxygenation. Chamber oxygen percentages as high as 25 percent are permitted. If the chamber is equipped with a life-support system so that ventilation is not required and an oxygen analyzer is available, the oxygen level should be maintained between 19 percent and 25 percent. If chamber oxygen goes above 25 percent, ventilation with air should be used to bring the oxygen percentage down.
- 17-8.2** **Carbon Dioxide Control.** Ventilation of the chamber in accordance with [paragraph 17-8.4](#) will ensure that carbon dioxide produced metabolically does not cause the chamber carbon dioxide level to exceed 1.5 percent SEV (11.4 mmHg).
- 17-8.2.1** **Carbon Dioxide Monitoring.** Chamber carbon dioxide should be monitored with electronic carbon dioxide monitors. Monitors generally read CO₂ percentage once chamber air has been exhausted to the surface. The CO₂ percent reading at the surface 1 ata must be corrected for depth. To keep chamber CO₂ below 1.5 percent SEV (11.4 mmHg), the surface CO₂ monitor values should remain below 0.78 percent with chamber depth at 30 feet, 0.53 percent with chamber depth at 60 feet, and 0.25 percent with the chamber at 165 feet. If the CO₂ analyzer is within the chamber, no correction to the CO₂ readings is necessary.
- 17-8.2.2** **Carbon Dioxide Scrubbing.** If the chamber is equipped with a carbon dioxide scrubber, the absorbent should be changed when the partial pressure of carbon dioxide in the chamber reaches 1.5 percent SEV (11.4 mmHg). If absorbent cannot be changed, supplemental chamber ventilation will be required to maintain chamber CO₂ at acceptable levels. With multiple or working chamber occupants, supplemental ventilation may be necessary to maintain chamber CO₂ at acceptable levels.
- 17-8.2.3** **Carbon Dioxide Absorbent.** CO₂ absorbent in an opened but resealed bucket may be used until the expiration date on the bucket is reached. Pre-packed, double-bagged canisters shall be labeled with the expiration date from the absorbent bucket. Expired CO₂ absorbent shall not be used in any recompression chamber.
- 17-8.3** **Temperature Control.** Internal chamber temperature should be maintained at a level comfortable to the occupants whenever possible. Cooling can usually be accomplished by chamber ventilation. If the chamber is equipped with a heater/ chiller unit, temperature control can usually be maintained for chamber occupant comfort under any external environmental conditions. Usually, recompression chambers will become hot and must be cooled continuously. Chambers should always be shaded from direct sunlight. The maximum durations for chamber occupants will depend on the internal chamber temperature as listed in [Table 17-5](#). Never commit to a treatment table that will expose the chamber occupants to

greater temperature/time combinations than listed in [Table 17-5](#) unless qualified medical personnel who can evaluate the trade-off between the projected heat stress and the anticipated treatment benefit are consulted. A chamber temperature below 85°F (29°C) is always desirable, no matter which treatment table is used.

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

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

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

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

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

for heavy sweating. A useful indicator of proper hydration is a clear colorless urine.

- 17-8.4 Chamber Ventilation.** Ventilation is the usual means of controlling oxygen level, carbon dioxide level, and temperature. Ventilation using air is required for chambers without carbon dioxide scrubbers and atmospheric analysis. A ventilation rate of two acfm for each resting occupant, and four acfm for each active occupant, should be used. These procedures are designed to assure that the effective concentration of carbon dioxide will not exceed 1.5 percent sev (11.4 mmHg) and that, when oxygen is being used, the percentage of oxygen in the chamber will not exceed 25 percent.
- 17-8.5 Access to Chamber Occupants.** Recompression treatments usually require access to occupants for passing in items such as food, water, and drugs and passing out such items as urine, excrement, and trash. Never attempt a treatment longer than a [Treatment Table 6](#) unless there is access to inside occupants. When doing a [Treatment Table 4, 7, or 8](#), a double-lock chamber is mandatory because additional personnel may have to be locked in and out during treatment.
- 17-8.6 Inside Tender Oxygen Breathing.** During treatments, all chamber occupants may breathe 100 percent oxygen at depths of 45 feet or shallower without locking in additional personnel. Tenders should not fasten the oxygen masks to their heads, but should hold them on their faces. When deeper than 45 feet, at least one chamber occupant must breathe air. Tender oxygen breathing requirements are specified in the figure for each Treatment Table.
- 17-8.7 Tending Frequency.** Normally, tenders should allow a surface interval of at least 18 hours between consecutive treatments on [Treatment Tables 1A, 2A, 3, 5, 6](#), and [6A](#), and at least 48 hours between consecutive treatments on [Tables 4, 7, and 8](#). If necessary, however, tenders may repeat [Treatment Tables 5, 6, or 6A](#) within this 18-hour surface interval if oxygen is breathed at 30 feet and shallower as outlined in [Table 17-7](#). Minimum surface intervals for [Treatment Tables 1A, 2A, 3, 4, 7, and 8](#) shall be strictly observed.
- 17-8.8 Equalizing During Descent.** Descent rates may have to be decreased as necessary to allow the patient to equalize; however, it is vital to attain treatment depth in a timely manner for a suspected arterial gas embolism patient.
- 17-8.9 Use of High Oxygen Mixes.** High oxygen N_2O_2/HeO_2 mixtures may be used to treat patients when recompression deeper than 60 fsw is required. These mixtures offer significant therapeutic advantages over air. Select a treatment gas that will produce a ppO_2 between 1.5 and 3.0 ata at the treatment depth. The standardized gas mixtures shown in [Table 17-6](#) are suitable over the depth range of 61-225 fsw.

Decompression sickness following helium dives can be treated with either nitrogen or helium mixtures. For recompression deeper than 165 fsw, helium mixtures are preferred to avoid narcosis. The situation is less clear for treatment of decompression sickness following air or nitrogen-oxygen dives. Experimental studies have shown both benefit and harm with helium treatment. Until more experience is obtained,

high oxygen mixtures with nitrogen as the diluent gas are preferred if available. High oxygen mixtures may also be substituted for 100% oxygen at 60 fsw and shallower on [Treatment Tables 4, 7, and 8](#) if the patient is unable to tolerate 100% oxygen.

Table 17-6. High Oxygen Treatment Gas Mixtures.

Depth (fsw)	Mix (HeO ₂ or N ₂ O ₂)	pO ₂
0-60	100%	1.00-2.82
61-165	50/50	1.42-3.00
166-225	64/36 (HeO ₂ only)	2.17-2.81

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

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

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

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

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

For Treatment Tables 5, 6, and 6A:

- Remove the mask.

- After all symptoms have completely subsided, decompress 10 feet at a rate of 1 fsw/min. For a convulsion, begin travel when the patient is fully relaxed and breathing normally.
- Resume oxygen breathing at the shallower depth at the point of interruption.
- If another oxygen symptom occurs after ascending 10 fsw, contact a Diving Medical Officer to recommend appropriate modifications to the treatment schedule.

For [Treatment Tables 4, 7, and 8](#):

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

17-8.10.2

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

17-8.11

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

If repair can be completed within 15 minutes:

- Maintain depth until repair is completed.
- After O₂ is restored, resume treatment at point of interruption.

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

- Maintain depth until repair is completed.
- After O₂ is restored: If original table was [Table 5, 6, or 6A](#), complete treatment with maximum number of O₂ extensions.

- 17-8.11.1 **Compensation.** If [Table 4](#), [7](#), or [8](#) is being used, no compensation in decompression is needed if oxygen is lost. If decompression must be stopped because of worsening symptoms in the affected diver, then stop decompression. When oxygen is restored, continue treatment from where it was stopped.
- 17-8.11.2 **Switching to Air Treatment Table.** If O₂ breathing cannot be restored in 2 hours switch to the comparable air treatment table at current depth for decompression if 60 fsw or shallower. Rate of ascent must not exceed 1 fpm between stops. If symptoms worsen and an increase in treatment depth deeper than 60 feet is needed, use [Treatment Table 4](#).
- 17-8.12 **Treatment at Altitude.** Before starting recompression therapy, zero the chamber depth gauges to adjust for altitude. Then use the depths as specified in the treatment table. There is no need to “Cross Correct” the treatment table depths. Divers serving as inside tenders during hyperbaric treatments at altitude are performing a dive at altitude and therefore require more decompression than at sea level. Tenders locking into the chamber for brief periods should be managed according to the Diving At Altitude procedures ([paragraph 9-13](#)). Tenders remaining in the chamber for the full treatment table must breathe oxygen during the terminal portion of the treatment to satisfy their decompression requirement.

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

17-9 POST-TREATMENT CONSIDERATIONS

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

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

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

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

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

Note 1: All tender O₂ breathing times in table are conducted at 30 fsw. In addition, tenders will breathe O₂ on ascent from 30 fsw to the surface.

Note 2: If the tender had a previous hyperbaric exposure within 18 hours, use the following guidance for administering O₂:

- For TT5, add an additional 20 minute O₂ breathing period to the times in the table.
- For TT6 or TT6A, add an additional 60 minute O₂ breathing period to the times in the table.
- For other Treatment tables contact NEDU for guidance.

Note 3: In some instances, tender's oxygen breathing obligation exceeds the table stay time at 30 fsw. Extend the time at 30 fsw to meet these obligations if patient's condition permits. Otherwise, administer O₂ to the tender to the limit allowed by the treatment table and observe the tender on the surface for 1 hour for symptoms of DCS.

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

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

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

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

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

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

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

17-10 NON-STANDARD TREATMENTS

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

17-11 RECOMPRESSION TREATMENT ABORT PROCEDURES

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

17-11.1

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

- If death occurs following initial recompression to 60, 165, or 225 on [Treatment Tables 6, 6A, 4 or 8](#), decompress the tenders on the Air/Oxygen schedule in the Air Decompression Table having a depth exactly equal to or deeper than the maximum depth attained during the treatment and a bottom time equal to or longer than the total elapsed time since treatment began. The Air/Oxygen schedule can be used even if gases other than air (i.e., nitrogen-oxygen or helium-oxygen mixtures) were breathed at depth.
- If death occurs after leaving the initial treatment depth on [Treatment Tables 6 or 6A](#), decompress the tenders at 30 fsw/min to 30 fsw and have them breathe oxygen at 30 fsw for the times indicated in [Table 17-6](#). Following completion of the oxygen breathing time at 30 fsw, decompress the tenders on oxygen from 30 fsw to the surface at 1 fsw/min.
- If death occurs after leaving the initial treatment depth on [Treatment Tables 4 or 8](#), or after beginning treatment on [Treatment Table 7](#) at 60 fsw, have the tenders decompress by continuing on the treatment table as written, or consult NEDU for a decompression schedule customized for the situation at hand. If neither option is possible, follow the original treatment table to 60 fsw. At 60 fsw, have the tenders breathe oxygen for 90 min in three 30-min periods separated by a 5-min air break. Continue decompression at 50, 40 and 30 fsw by breathing oxygen for 60 min at each depth. Ascend between stops at 30 fsw/min. At 50 fsw, breathe oxygen in two 30-min periods separated by a 5-min air

break. At 40 and 30 fsw, breathe oxygen for the full 60-min period followed by a 15-min air break. Ascend to 20 fsw at 30 fsw/min and breathe oxygen for 120 min. Divide the oxygen time at 20 fsw into two 60-min periods separated by a 15 min air break. When oxygen breathing time is complete at 20 fsw, ascend to the surface at 30 fsw/min. Upon surfacing, observe the tenders carefully for the occurrence of decompression sickness.

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

1. If deeper than 60 feet, go immediately to 60 feet.
2. Once the chamber is 60 feet or shallower, put all chamber occupants on continuous 100 percent oxygen. Select the Air/Oxygen schedule in the Air Decompression Table corresponding to the maximum depth attained during treatment and the total elapsed time since treatment began.
3. If at 60 fsw, breathe oxygen for period of time equal to the sum of all the decompression stops 60 fsw and deeper in the Air/Oxygen schedule, then continue decompression on the Air/Oxygen schedule, breathing oxygen continuously. If shallower than 60 fsw, breathe oxygen for a period of time equal to the sum of all the decompression stops deeper than the divers current depth, then continue decompression on the Air/Oxygen schedule, breathing oxygen continuously. Complete as much of the Air/Oxygen schedule as possible.
4. When no more time is available, bring all chamber occupants to the surface (try not to exceed 10 feet per minute) and keep them on 100 percent oxygen during evacuation, if possible.
5. Immediately evacuate all chamber occupants to the nearest recompression facility and treat according to [Figure 17-1](#). If no symptoms occurred after the treatment was aborted, follow [Treatment Table 6](#).

17-12 ANCILLARY CARE AND ADJUNCTIVE TREATMENTS

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

Most U.S. military diving operations have the unique advantage over most other diving operations with the ability to provide rapid recompression for the victims of decompression sickness (DCS) and arterial gas embolism (AGE). When stricken

divers are treated without delay, the success rate of standard recompression therapy is extremely good.

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

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

17-12.1 Decompression Sickness.

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

17-12.1.2 Fluids. Fluids should be administered to all individuals suffering from DCS unless suffering from the chokes (pulmonary DCS). Oral fluids (water, Gatorade-like drinks) are acceptable if the diver is fully conscious, able to tolerate them. If oral fluids cannot be tolerated by the patient, intravenous fluids should be administered. There is no data available that demonstrates a superiority of crystalloids (normal saline or Lactated Ringers solution) over colloids (such as Hetastarch compounds (Hespan or Hextend)) for DCS, but D5W (dextrose in water without electrolytes) should not be used. Since colloids are far more expensive than Lactated Ringers or normal saline, the latter two agents are the most reasonable choices at this time. The optimal amount of crystalloids/colloids is likewise not well-established but treatment should be directed towards reversing any dehydration that may have been induced by the dive (immersion diuresis causes divers to lose 250-500 cc of fluids per hour) or fluid shifts resulting from the DCS. Fluid overloading should be avoided. Urinary output, in the range of 0.5-1.0cc/kg/hour is evidence of adequate intravascular volume.

Chokes (pulmonary DCS) causes abnormal pulmonary function and leakage of fluids into the alveolar spaces. Aggressive fluid therapy may make this condition worse. Consult a DMO (or NEDU) for guidance.

17-12.1.3 **Anticoagulants.** Since some types of DCS may increase the likelihood of hemorrhage into the tissues, anticoagulants should not be used routinely in the treatment of DCS. One exception to this rule is the case of lower extremity weakness. Low molecular weight heparin (LMWH) should be used for all patients with inability to walk due to any degree of lower extremity paralysis caused by neurological DCS or AGE. Enoxaparin 30 mg, or its equivalent, administered subcutaneously every 12 hours, should be started as soon as possible after injury to reduce the risk of deep venous thrombosis (DVT) and pulmonary embolism in any paralyzed patients. Compression stockings or intermittent pneumatic compression are alternatives, although they are less effective at preventing DVT than LMWH.

17-12.1.4 **Aspirin and Other Non-Steroidal Anti-Inflammatory Drugs.** Routine use of anti-platelet agents in patients with neurological DCS is not recommended, due to concern about worsening hemorrhage in spinal cord or inner ear decompression illness. Use of these agents may also be risky in combat divers who may be required to return to action after treatment of an episode of DCS.

17-12.1.5 **Steroids.** Steroids are no longer recommended for the treatment of DCS. No significant reduction in neurological residuals has been found in clinical studies for DCS adjunctively treated with steroids and elevated blood glucose levels associated with steroid administration may actually worsen the outcome of CNS injury.

17-12.1.6 **Lidocaine.** Lidocaine is not currently recommended for the treatment of any type of DCS.

17-12.1.7 **Environmental Temperature.** For patients with evidence of brain or spinal cord damage, the current evidence recommends aggressive treatment of elevated body temperature. When treating victims of neurological DCS, whenever practical, hot environments that may cause elevation of body temperature above normal should be avoided. The patient's body temperature and vital signs should be monitored regularly.

17-12.2 Arterial Gas Embolism.

17-12.2.1 **Surface Oxygen.** Surface oxygen should be used for all cases of AGE as it is for DCS.

17-12.2.2 **Lidocaine.** Lidocaine has been shown to be potentially beneficial in the treatment of AGE. Current recommendations suggests a dosing end-point to achieve serum concentrations producing an anti-arrhythmic effect. An intravenous initial dose of 1 mg/kg followed by a continuous infusion of 2-4 mg/minute, will typically produce therapeutic serum concentrations. If an intravenous infusion is not established, intramuscular administration of 4-5 mg/kg will typically produce a therapeutic plasma concentration 15 minutes after dosing, lasting for around 90

minutes. Doses greater than those noted above may be associated with major side effects, including paresthesias, ataxia, and seizures. Therefore, Lidocaine should only be administered under the supervision of a DMO or other qualified physician.

- 17-12.2.3 **Fluids.** The fluid replacement recommendations for the treatment of AGE differ from those of DCS. Fluid replacement recommendations for AGE differ from DCS because the CNS injury in AGE may be complicated by cerebral edema, which may be worsened by an increased fluid load, thus causing further injury to the diver. If fluid replacement is conducted, colloids are probably the best choice due to their mechanism of action in maintaining intra-vascular volume and minimizing extra-vascular leakage. Particular care must be taken not to fluid overload the injured diver suffering from AGE by adjusting IV rates to maintain just an adequate urine output of 0.5cc/kg/hour. A urinary catheter should be inserted in the unconscious patient and urinary output measured.
- 17-12.2.4 **Anticoagulants.** Anticoagulants should not be used routinely in the treatment of AGE. As noted previously in [paragraph 17-12.1.3](#) on anticoagulants in DCS, Enoxaparin 30 mg, or its equivalent, should be administered subcutaneously every 12 hours, after initial recompression therapy in patients suffering from paralysis to prevent deep venous thrombosis (DVT) and pulmonary embolism.
- 17-12.2.5 **Aspirin and Other Non-Steroidal Anti-Inflammatory Drugs.** Routine use of anti-platelet agents in patients with AGE is not recommended.
- 17-12.2.6 **Steroids.** Steroids are no longer recommended for the treatment of AGE. No significant reduction in neurologic residual has been shown with adjunctive treatment with steroids for AGE and elevated blood glucose levels associated with administration of steroids may worsen the outcome of CNS injury.
- 17-12.2.7 **Environmental Temperature.** For patients with evidence of brain or spinal cord damage, the current evidence recommends aggressive treatment of elevated body temperature. When treating victims of neurological DCS, whenever practical, hot environments that may cause elevation of body temperature above normal should be avoided. The patient's body temperature and vital signs should be monitored regularly.
- 17-12.3 **Sleeping and Eating.** The only time the patient should be kept awake during recompression treatments is during oxygen breathing periods at depths greater than 30 feet. Travel between decompression stops on [Treatment Table 4, 7, and 8](#) is not a contra-indication to sleeping. While asleep, vital signs (pulse, respiratory rate, blood pressure) should be monitored as the patient's condition dictates. Any significant change would be reason to arouse the patient and ascertain the cause.

Food may be taken by chamber occupants at any time. Adequate fluid intake should be maintained as discussed in [paragraph 17-8.3.1](#).

17-13 EMERGENCY MEDICAL EQUIPMENT

Every diving activity shall maintain emergency medical equipment that will be available immediately for use in the event of a diving accident. This equipment is to be in addition to any medical supplies maintained in a medical treatment facility and shall be kept in a kit small enough to carry into the chamber, or in a locker in the immediate vicinity of the chamber.

- 17-13.1 **Primary and Secondary Emergency Kits.** Because some sterile items may become contaminated as a result of a hyperbaric exposure, it is desirable to have a primary kit for immediate use inside the chamber and a secondary kit from which items that may become contaminated can be locked into the chamber only as needed. The primary emergency kit contains diagnostic and therapeutic equipment that is available immediately when required. This kit shall be inside the chamber during all treatments. The secondary emergency kit contains equipment and medicine that does not need to be available immediately, but can be locked-in when required. This kit shall be stored in the vicinity of the chamber.

The contents of the emergency kits presented here are not meant to be restrictive but are considered the minimum requirement. Additional items may be added to suit local medical preferences.

The Primary Emergency Kit is described in [Table 17-8](#). The Secondary Emergency Kit is described in [Table 17-9](#).

- 17-13.2 **Portable Monitor-Defibrillator.** All diving activities/commands shall maintain an automated external defibrillator (AED), preferably with heart rhythm visualization capability, from an approved Authorized Medical Allowance List (AMAL). Diving activities with assigned Diving Medical Officer are recommended to augment with a fully capable monitor defibrillator.

CAUTION **AED's are not currently approved for use under pressure (hyperbaric environment) due to electrical safety concerns.**

Table 17-8. Primary Emergency Kit.

Diagnostic Equipment
Stethoscope
Otoscope (Ophthalmoscope optional) and batteries
Sphygmomanometer (aneroid type only, case vented for hyperbaric use)
Reflex Hammer
Tuning Fork
Pinwheel
Tongue depressors
Thermometer/temperature measurement capability (non-mercury type)
Disposable exam gloves
Skin Marker
Pocket Eye Chart (Snellen)
Emergency Treatment Primary Survey Equipment and Medications
Oropharyngeal airways (#4 and #5 Guedel-type or equivalent)
Nasal airways (#32F and #34F latex rubber)
Lidocaine jelly (2%)
Self-Inflating Bag-Valve Mask (Disposable BVM)
Suction apparatus with appropriate suction tips
Tension pneumothorax relief kit with 3.25 inch, large-bore catheter on a needle
Cricothyrotomy kit
Adhesive tape (2 inch waterproof)
Elastic-Wrap bandage for a pressure bandage (2 and 4 inch)
Pressure dressing
Appropriate Combat Tourniquet
Trauma Scissors
Sterile 4X4s
Cravats

NOTE: One Primary Emergency Kit is required per chamber system, e.g. TRCS requires one. Additional Medical Equipment Authorized for Navy Use (ANU) in a chamber can be found in the Medical Equipment section of the ANU on the NAVSEA website. Contact the Senior Medical Officer at the Navy Experimental Diving Unit for any questions regarding specific pieces of medical equipment for use in the chamber.

Table 17-9. Secondary Emergency Kit.

Emergency Treatment Secondary Survey Equipment and Medications	
Alternative emergency airway device (recommend intubating laryngeal mask airway disposable LMA Fastrach™ kit, size 4 – 5)	
Syringe and sterile water for cuff inflation (10 cc)	
Sterile lubricant	
Qualitative end-tidal CO ₂ detector (colorimetric indicator)	
Chest tube	
BD Bard Parker Heimlich Chest Drain Valve (or other device to provide one-way flow of gas out of the chest)	
#11 knife blade and handle	
Sterile gloves (size 6 – 8)	
Surgical masks (4)	
10% povidone-iodine swabs or wipes	
1% lidocaine solution	
21 gauge. 1 ½ -inch needles on 5 cc syringes (2)	
Curved Kelly forceps	
Intravenous Infusion Therapy	
Catheter on a needle unit, intravenous (16 and 18 gauge - 4 ea)	
Adult interosseous infusion device (IO) for rapid vascular access	
Intravenous infusion sets (2 standard drip and 2 micro-drip)	
Syringes (5, 10 and 30 cc)	
Sterile needles (18, 22 and 25 gauge)	
Normal saline (1 liter bag (4))	
IV Start Kit (10% Povidone-Iodine swabs or wipes, 2 x 2 gauze sponges, Bioclusive dressing, ¾ -inch adhesive tape, phlebotomy tourniquet)	
Band aids	
Sam™ Splint	
Miscellaneous	
Pulse Oximeter (Nonin 9500/8500 series)	
Nasogastric tube	
60 cc Toomey Syringe (Optional)	
Urinary catheterization set with collection bag (appropriate size (12F–14F) Foley-type sterile catheters)	
Assorted suture material (0-silk with and without curved needles)	
Sharps disposable box	
Disposable Minor Surgical Tray can substitute for items listed below:	
Straight and curved hemostats (2 of each)	
Blunt straight surgical scissors	
Needle driver	
Sterile towels	
Sterile gauze pads	
NOTE 1: Whenever possible, preloaded syringe injection sets should be obtained to avoid the need to vent multi-dose vials or prevent implosion of ampules. Sufficient quantities should be maintained to treat one injured diver.	
NOTE 2: One Secondary Emergency Kit is required per chamber system (i.e., TRCS requires one).	
NOTE 3: A portable oxygen supply with an E cylinder (approximately 669 liters of oxygen) with a regulator capable of delivering 12 liters of oxygen per minute by mask/reservoir or 2 liters by nasal canula is recommended whenever possible in the event the patient needs to be transported to another facility.	

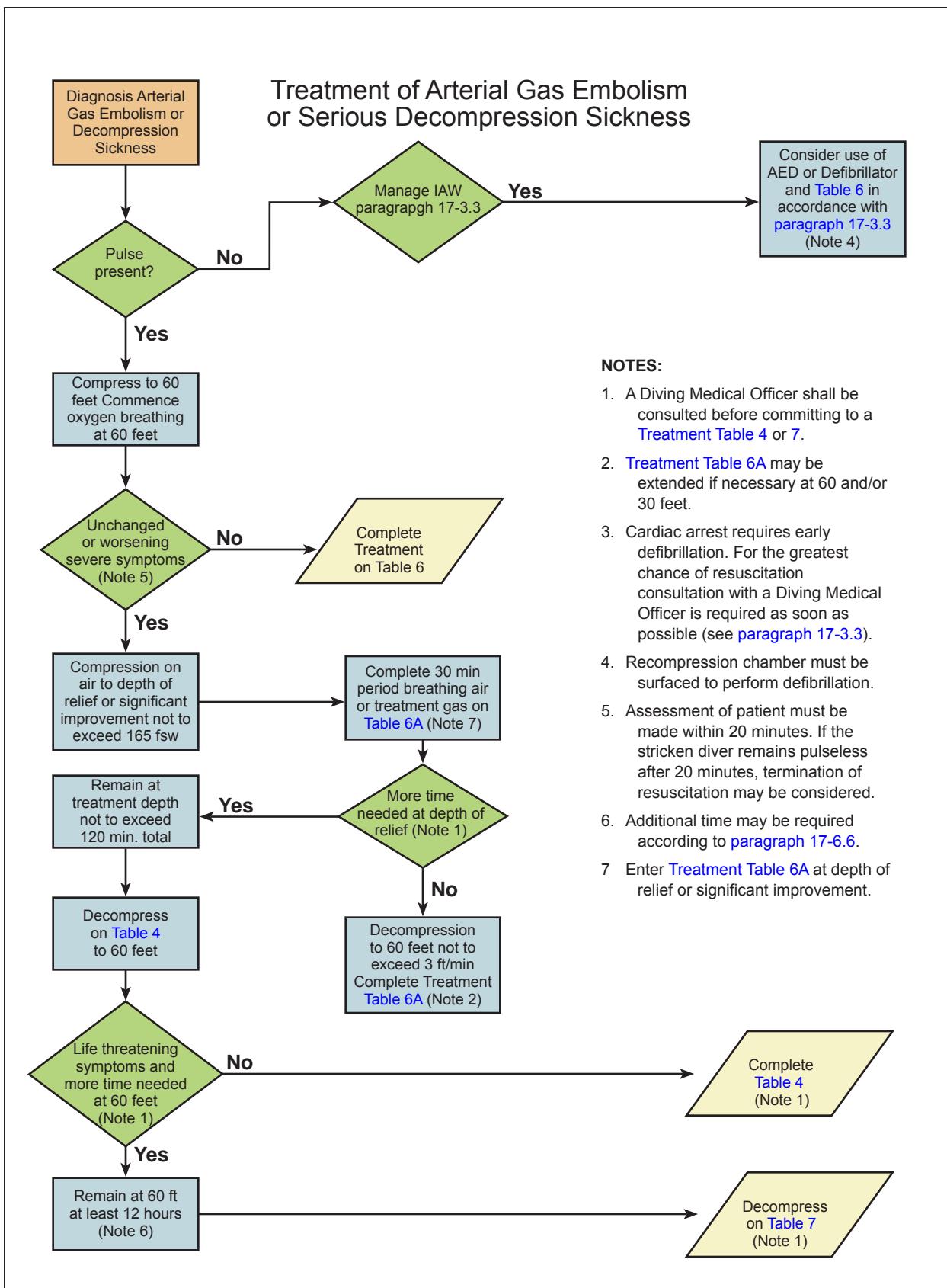
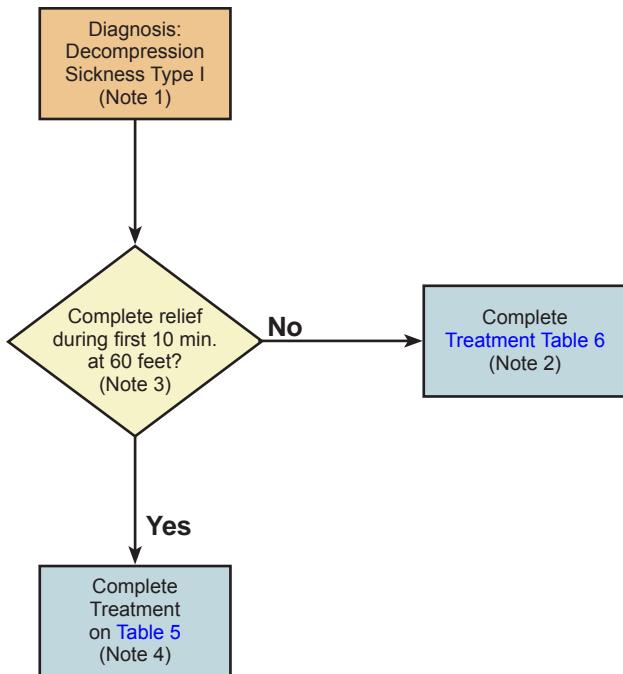


Figure 17-1. Treatment of Arterial Gas Embolism or Serious Decompression Sickness.

Treatment of Type I Decompression Sickness



NOTES:

1. If a complete neurological exam was not completed before recompression, treat as a Type II symptom.
2. [Treatment Table 6](#) may be extended up to four additional oxygen-breathing periods, two at 30 feet and/or two at 60 feet.
3. Diving Supervisor may elect to treat on [Treatment Table 6](#).
4. [Treatment Table 5](#) may be extended two oxygen-breathing periods at 30 fsw.

Figure 17-2. Treatment of Type I Decompression Sickness.

17-13.3 Advanced Cardiac Life Support (ACLS) Drugs and Equipment. All commands with chambers that participate in the local area bends watch shall maintain those drugs recommended by the American Heart Association for ACLS. These drugs need to be in sufficient quantities to support an event requiring Advanced Cardiac Life Support. These drugs are not required to be in every dive kit when multiple chambers/kits are present in a single command. In addition, medications for the treatment of anaphylaxis, which can occur related to marine life envenomation, including Epinephrine 1:1000 solution, Diphenhydramine IM or PO and Hydrocortisone Sodium Succinate IV will be maintained in adequate quantities to treat one patient.

Emergency medical equipment in support of ACLS includes cuffed endotracheal tubes with adapters (7-8 mm), malleable stylet (approx. 12" in length), laryngoscope with blades (McIntosh #3 and #4, Miller #2 and #3). Additional mechanical devices

for verification of endotracheal tube placement are also authorized, but not required (Toomey-type or 50cc catheter tip syringe or equivalent).

NOTE **Some vendors supply pre-packed ACLS kits with automated replenishment programs (examples of which can be found on the Naval Expeditionary Combat Command (NECC) AMAL).**

17-13.4 **Use of Emergency Kits.** Unless adequately sealed against increased atmospheric pressure (i.e., vacuum packed), sterile supplies should be re-sterilized after each pressure exposure; or, if not exposed, to pressure, the sterile supplies should be replaced at package expiration date. Drugs shall be replaced when their expiration date is reached. Not all drug ampules will withstand pressure.

NOTE **Stoppered multi-dose vials with large air volumes may need to be vented with a needle during pressurization and depressurization and then discarded.**

Both kits should be taken to the recompression chamber or scene of the accident. Each kit is to contain a list of contents and have a tamper evident seal. Each time the kit is opened, it shall be inventoried and each item checked for proper working order and then re-sterilized or replaced as necessary. Unopened kits are inventoried quarterly. Concise instructions for administering each drug are to be provided in the kit along with current American Heart Association Advanced Cardiac Life-Support Protocols. In untrained hands, many of the items can be dangerous. Remember that as in all treatments **YOUR FIRST DUTY IS TO DO NO HARM.**

17-13.4.1 **Modification of Emergency Kits.** Because the available facilities may differ on board ship, at land-based diving installations, and at diver training or experimental units, the responsible Diving Medical Officer or Diving Medical Technician are authorized to augment the emergency kits to suit the local needs.

Treatment of Symptom Recurrence

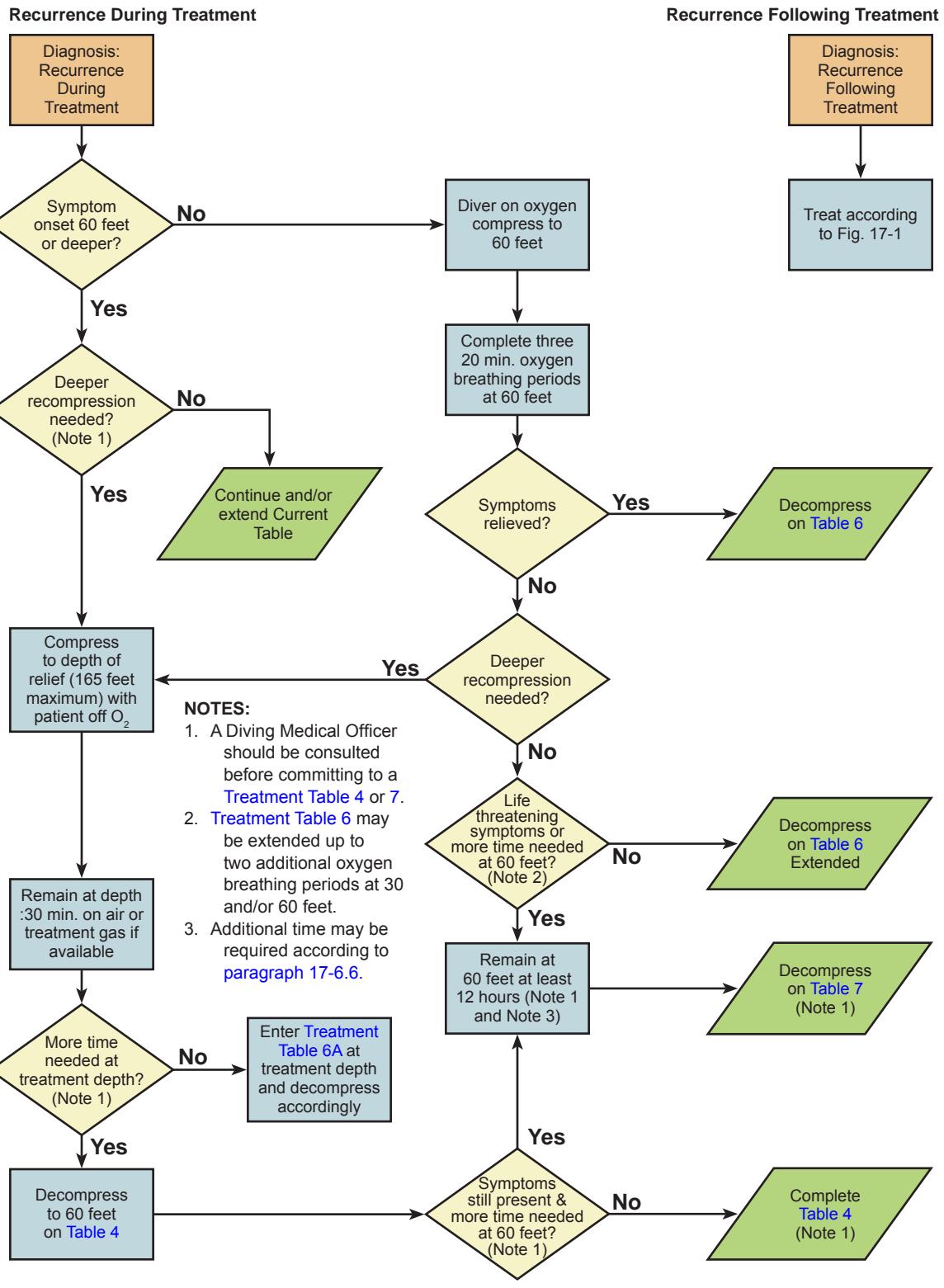


Figure 17-3. Treatment of Symptom Recurrence.

Treatment Table 5

1. Descent rate - 20 ft/min.
2. Ascent rate - Not to exceed 1 ft/min. Do not compensate for slower ascent rates. Compensate for faster rates by halting the ascent.
3. Time on oxygen begins on arrival at 60 feet.
4. If oxygen breathing must be interrupted because of CNS Oxygen Toxicity, allow 15 minutes after the reaction has entirely subsided and resume schedule at point of interruption (see paragraph 17-8.10.1.1)
5. Treatment Table may be extended two oxygen-breathing periods at the 30-foot stop. No air break required between oxygen-breathing periods or prior to ascent.
6. Tender breathes 100 percent O₂ during ascent from the 30-foot stop to the surface. If the tender had a previous hyperbaric exposure in the previous 18 hours, an additional 20 minutes of oxygen breathing is required prior to ascent.

Treatment Table 5 Depth/Time Profile

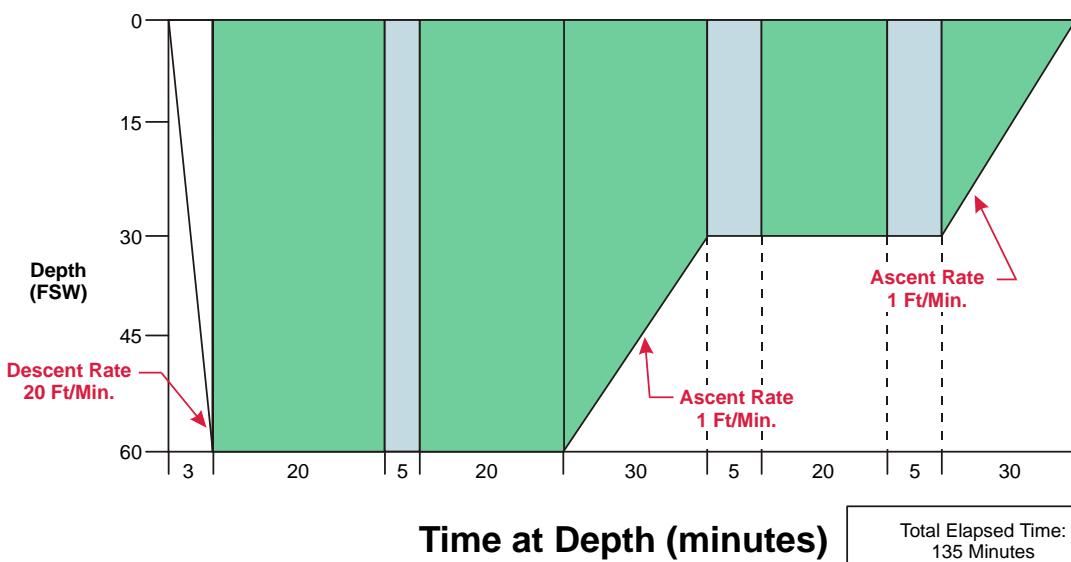


Figure 17-4. Treatment Table 5.

Treatment Table 6

1. Descent rate - 20 ft/min.
2. Ascent rate - Not to exceed 1 ft/min. Do not compensate for slower ascent rates. Compensate for faster rates by halting the ascent.
3. Time on oxygen begins on arrival at 60 feet.
4. If oxygen breathing must be interrupted because of CNS Oxygen Toxicity, allow 15 minutes after the reaction has entirely subsided and resume schedule at point of interruption (see paragraph 17-8.10.1.1).
5. Table 6 can be lengthened up to 2 additional 25-minute periods at 60 feet (20 minutes on oxygen and 5 minutes on air), or up to 2 additional 75-minute periods at 30 feet (15 minutes on air and 60 minutes on oxygen), or both.
6. Tender breathes 100 percent O₂ during the last 30 min. at 30 fsw and during ascent to the surface for an unmodified table or where there has been only a single extension at 30 or 60 feet. If there has been more than one extension, the O₂ breathing at 30 feet is increased to 60 minutes. If the tender had a hyperbaric exposure within the past 18 hours an additional 60-minute O₂ period is taken at 30 feet.

Treatment Table 6 Depth/Time Profile

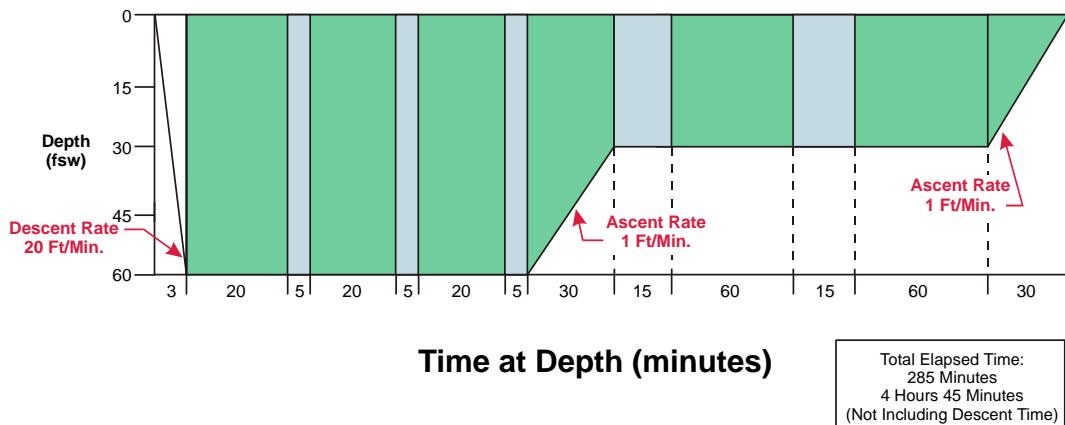


Figure 17-5. Treatment Table 6.

Treatment Table 6A

1. Descent rate - 20 ft/min.
2. Ascent rate - 165 fsw to 60 fsw not to exceed 3 ft/min, 60 fsw and shallower, not to exceed 1 ft/min. Do not compensate for slower ascent rates. Compensate for faster rates by halting the ascent.
3. Time at treatment depth does not include compression time.
4. Table begins with initial compression to depth of 60 fsw. If initial treatment was at 60 feet, up to 20 minutes may be spent at 60 feet before compression to 165 fsw. Contact a Diving Medical Officer.
5. If a chamber is equipped with a high-O₂ treatment gas, it may be administered at 165 fsw and shallower, not to exceed 3.0 ata O₂ in accordance with [paragraph 17-8.9](#). Treatment gas is administered for 25 minutes interrupted by 5 minutes of air. Treatment gas is breathed during ascent from the treatment depth to 60 fsw.
6. Deeper than 60 feet, if treatment gas must be interrupted because of CNS oxygen toxicity, allow 15 minutes after the reaction has entirely subsided before resuming treatment gas. The time off treatment gas is counted as part of the time at treatment depth. If at 60 feet or shallower and oxygen breathing must be interrupted because of CNS oxygen toxicity, allow 15 minutes after the reaction has entirely subsided and resume schedule at point of interruption (see [paragraph 17-8.10.1.1](#)).
7. [Table 6A](#) can be lengthened up to 2 additional 25-minute periods at 60 feet (20 minutes on oxygen and 5 minutes on air), or up to 2 additional 75-minute periods at 30 feet (60 minutes on oxygen and 15 minutes on air), or both.
8. Tender breathes 100 percent O₂ during the last 60 minutes at 30 fsw and during ascent to the surface for an unmodified table or where there has been only a single extension at 30 or 60 fsw. If there has been more than one extension, the O₂ breathing at 30 fsw is increased to 90 minutes. If the tender had a hyperbaric exposure within the past 18 hours, an additional 60 minute O₂ breathing period is taken at 30 fsw.
9. If significant improvement is not obtained within 30 minutes at 165 feet, consult with a Diving Medical Officer before switching to [Treatment Table 4](#).

Treatment Table 6A Depth/Time Profile

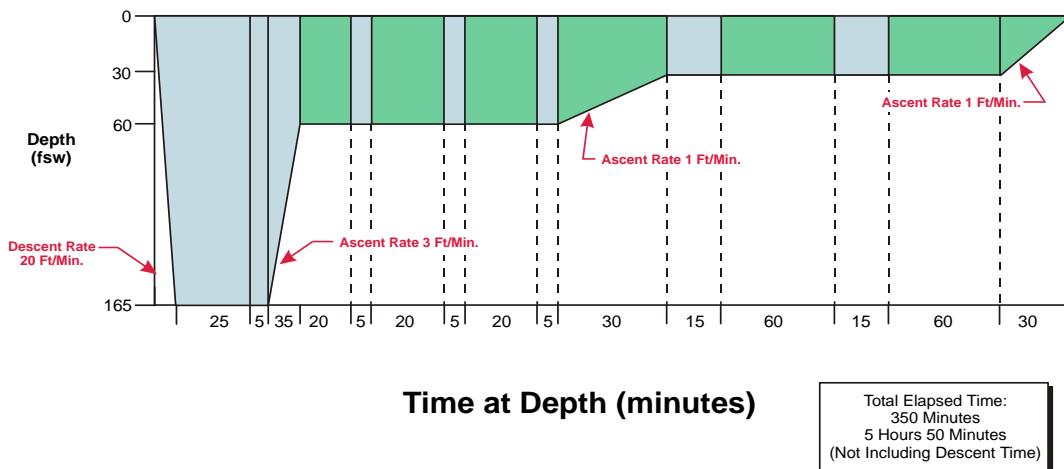


Figure 17-6. Treatment Table 6A.

Treatment Table 4

1. Descent rate - 20 ft/min.
2. Ascent rate - 1 ft/min.
3. Time at 165 feet includes compression.
4. If only air is available, decompress on air. If oxygen is available, patient begins oxygen breathing upon arrival at 60 feet with appropriate air breaks. Both tender and patient breathe oxygen beginning 2 hours before leaving 30 feet. (see paragraph 17-6.5).
5. Ensure life-support considerations can be met before committing to a Table 4. (see paragraph 17-8.10.1.1)
Internal chamber temperature should be below 85° F.
6. If oxygen breathing is interrupted, no compensatory lengthening of the table is required.
7. If switching from Treatment Table 6A or 3 at 165 feet, stay a maximum of 2 hours at 165 feet before decompressing.
8. If the chamber is equipped with a high-O₂ treatment gas, it may be administered at 165 fsw, not to exceed 3.0 ata O₂. Treatment gas is administered for 25 minutes interrupted by 5 minutes of air.

Treatment Table 4 Depth/Time Profile

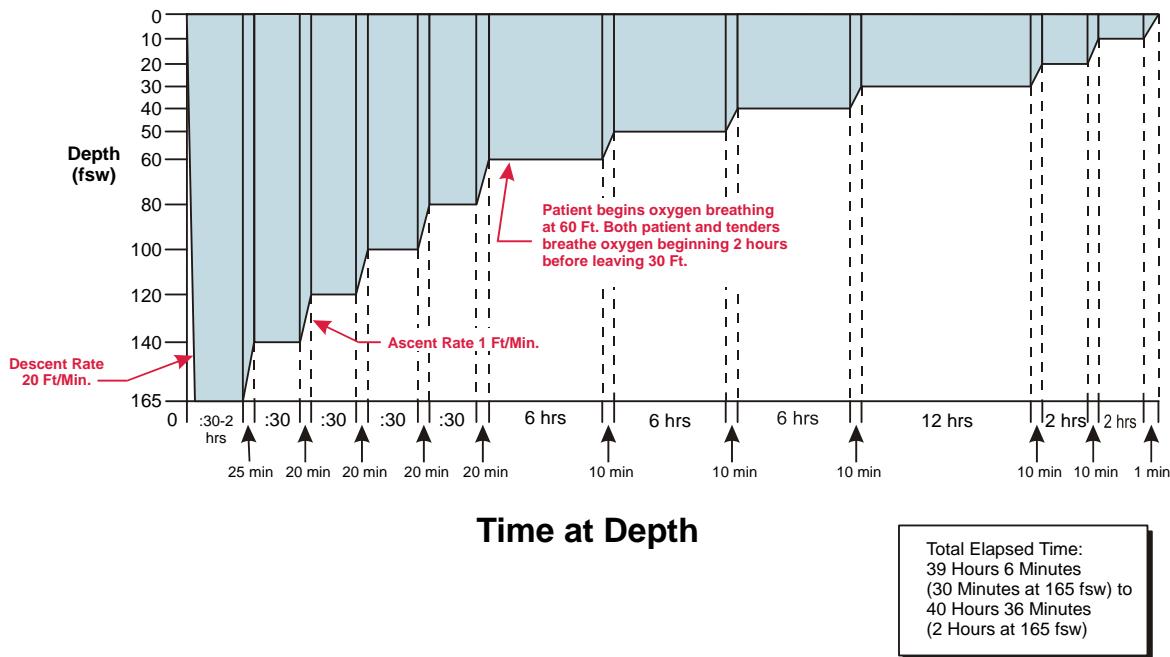


Figure 17-7. Treatment Table 4.

Treatment Table 7

1. Table begins upon arrival at 60 feet. Arrival at 60 feet is accomplished by initial treatment on [Table 6, 6A or 4](#). If initial treatment has progressed to a depth shallower than 60 feet, compress to 60 feet at 20 ft/min to begin Table 7.
2. Maximum duration at 60 feet is unlimited. Remain at 60 feet a minimum of 12 hours unless overriding circumstances dictate earlier decompression.
3. Patient begins oxygen breathing periods at 60 feet. Tender need breathe only chamber atmosphere throughout. If oxygen breathing is interrupted, no lengthening of the table is required.
4. Minimum chamber O₂ concentration is 19 percent. Maximum CO₂ concentration is 1.5 percent SEV (11.4 mmHg). Maximum chamber internal temperature is 85°F ([paragraph 17-6.5](#)).
5. Decompression starts with a 2-foot upward excursion from 60 to 58 feet. Decompress with stops every 2 feet for times shown in profile below. Ascent time between stops is approximately 30 seconds. Stop time begins with ascent from deeper to next shallower step. Stop at 4 feet for 4 hours and then ascend to the surface at 1 ft/min.
6. Ensure chamber life-support requirements can be met before committing to a [Treatment Table 7](#).
7. A Diving Medical Officer should be consulted before committing to this treatment table.

Treatment Table 7 Depth/Time Profile

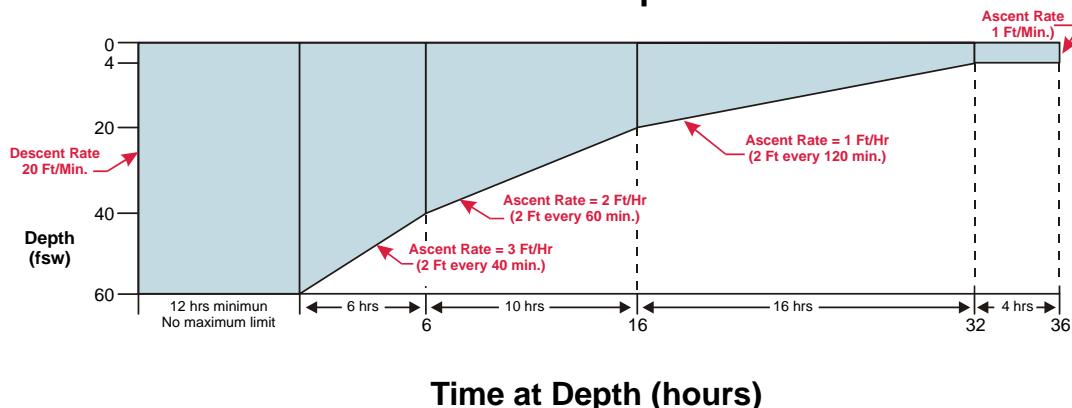


Figure 17-8. Treatment Table 7.

Treatment Table 8

1. Enter the table at the depth which is exactly equal to or next greater than the deepest depth attained in the recompression. The descent rate is as fast as tolerable.
2. The maximum time that can be spent at the deepest depth is shown in the second column. The maximum time for 225 fsw is 30 minutes; for 165 fsw, 3 hours. For an asymptomatic diver, the maximum time at depth is 30 minutes for depths exceeding 165 fsw and 2 hours for depths equal to or shallower than 165 fsw.
3. Decompression is begun with a 2-fsw reduction in pressure if the depth is an even number. Decompression is begun with a 3-fsw reduction in pressure if the depth is an odd number. Subsequent stops are carried out every 2 fsw. Stop times are given in column three. The stop time begins when leaving the previous depth. Ascend to the next stop in approximately 30 seconds.
4. Stop times apply to all stops within the band up to the next quoted depth. For example, for ascent from 165 fsw, stops for 12 minutes are made at 162 fsw and at every two-foot interval to 140 fsw. At 140 fsw, the stop time becomes 15 minutes. When traveling from 225 fsw, the 166-foot stop is 5 minutes; the 164-foot stop is 12 minutes. Once begun, decompression is continuous. For example, when decompressing from 225 feet, ascent is not halted at 165 fsw for 3 hours. However, ascent may be halted at 60 fsw and shallower for any desired period of time.
5. While deeper than 165 fsw, a helium-oxygen mixture with 16-36 percent oxygen may be breathed by mask to reduce narcosis. A 64/36 helium-oxygen mixture is the preferred treatment gas. At 165 fsw and shallower, a HeO₂ or N₂O₂ mix with a ppO₂ not to exceed 3.0 ata may be given to the diver as a treatment gas. At 60 fsw and shallower, pure oxygen may be given to the divers as a treatment gas. For all treatment gases (HeO₂, N₂O₂, and O₂), a schedule of 25 minutes on gas and 5 minutes on chamber air should be followed for a total of four cycles. Additional oxygen may be given at 60 fsw after a 2-hour interval of chamber air. See [Treatment Table 7](#) for guidance. If high O₂ breathing is interrupted, no lengthening of the table is required.
6. To avoid loss of the chamber seal, ascent may be halted at 4 fsw and the total remaining stop time of 240 minutes taken at this depth. Ascend directly to the surface upon completion of the required time.
7. Total ascent time from 225 fsw is 56 hours, 29 minutes. For a 165-fsw recompression, total ascent time is 53 hours, 52 minutes, and for a 60-fsw recompression, 36 hours, 0 minutes.

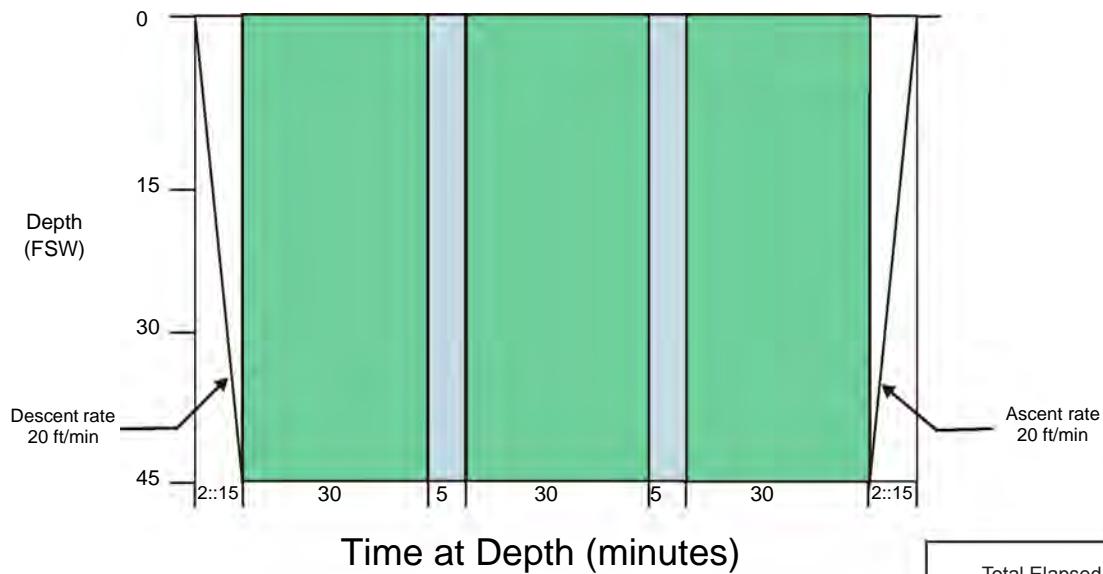
Depth (fsw)	Max Time at Initial Treatment Depth (hours)	2-fsw Stop Times (minutes)
225	0.5	5
165	3	12
140	5	15
120	8	20
100	11	25
80	15	30
60	Unlimited	40
40	Unlimited	60
20	Unlimited	120

Figure 17-9. Treatment Table 8.

Treatment Table 9

1. Descent rate - 20 ft/min.
2. Ascent rate - 20 ft/min. Rate may be slowed to 1 ft/min depending upon the patient's medical condition.
3. Time at 45 feet begins on arrival at 45 feet.
4. If oxygen breathing must be interrupted because of CNS Oxygen Toxicity, oxygen breathing may be restarted 15 minutes after all symptoms have subsided. Resume schedule at point of interruption (see paragraph 17-8.10.1.1).
5. Tender breathes 100 percent O₂ during last 15 minutes at 45 feet and during ascent to the surface regardless of ascent rate used.
6. Patient may breathe air or oxygen during ascent.
7. If patient cannot tolerate oxygen at 45 feet, this table can be modified to allow a treatment depth of 30 feet. The oxygen breathing time can be extended to a maximum of 3 to 4 hours.

Treatment Table 9 Depth/Time Profile



Total Elapsed Time:
102:15
(Not Including Descent Time)

Figure 17-10. Treatment Table 9.

Air Treatment Table 1A

1. Descent rate - 20 ft/min.
2. Ascent rate - 1 ft/min.
3. Time at 100 feet includes time from the surface.

Treatment Table 1A Depth/Time Profile

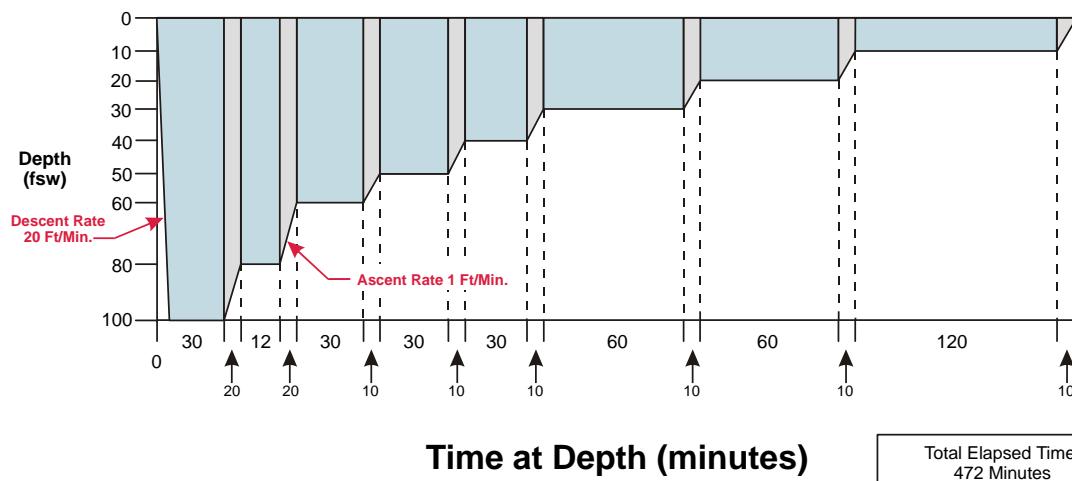


Figure 17-11. Air Treatment Table 1A.

Air Treatment Table 2A

1. Descent rate - 20 ft/min.
2. Ascent rate - 1 ft/min.
3. Time at 165 feet includes time from the surface.

Treatment Table 2A Depth/Time Profile

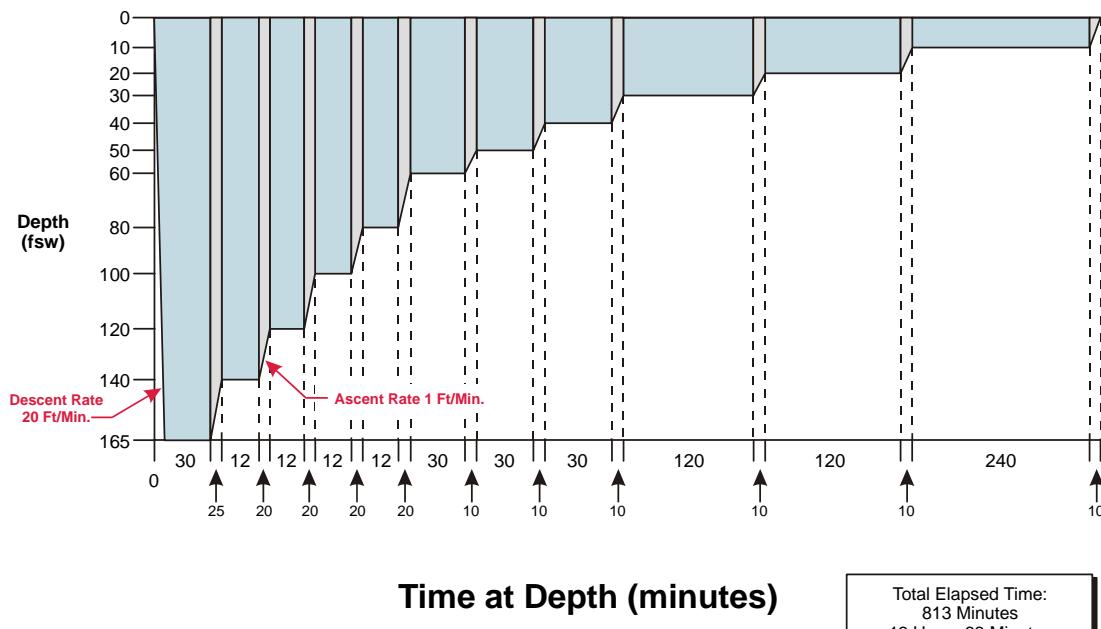


Figure 17-12. Air Treatment Table 2A.

Air Treatment Table 3

1. Descent rate - 20 ft/min.
2. Ascent rate - 1 ft/min.
3. Time at 165 feet-includes time from the surface.

Treatment Table 3 Depth/Time Profile

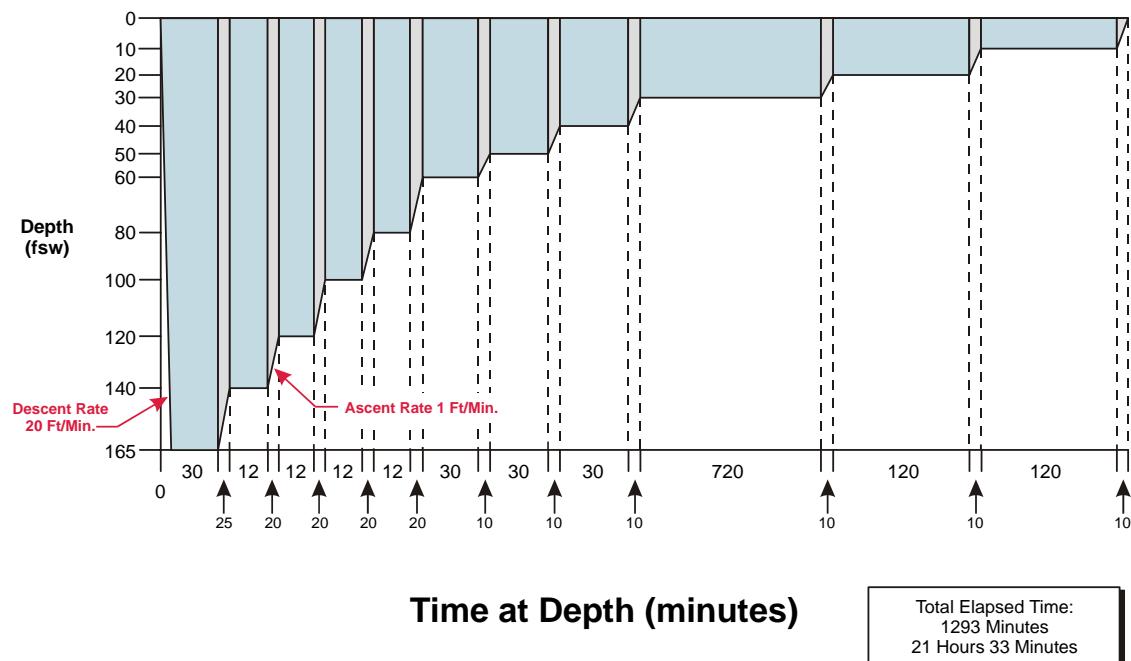


Figure 17-13. Air Treatment Table 3.

Recompression Chamber Operation

18-1 INTRODUCTION

- 18-1.1 **Purpose.** This chapter will familiarize personnel with the maintenance and operational requirements for recompression chambers.
- 18-1.2 **Scope.** Recompression chambers are used for the treatment of decompression sickness and arterial gas embolism, for surface decompression, and for administering pressure tests to prospective divers. Recompression chambers equipped for hyperbaric administration of oxygen are also used in medical facilities for hyperbaric treatment of carbon monoxide poisoning, gas gangrene, and other diseases. Double-lock chambers are used because they permit personnel and supplies to enter and leave the chamber during treatment.
- 18-1.3 **Chamber Requirements.** The requirements for recompression chamber availability are covered in [Chapter 6](#) and repeated below in [Table 18-1](#).

Table 18-1. Navy Recompression Chamber Support Levels

RCC Support Level	Definition
Level I	A U.S. Navy certified recompression chamber close enough to the dive site to support surface decompression with a surface interval of 5 minutes. (Note 1, 2)
Level II	A U.S. Navy certified recompression chamber accessible within one hour of the casualty. (Note 2)
Level III	A U.S. Navy certified recompression chamber accessible within six hours of the casualty. (Note 3, 4)
Note 1: The Commanding Officer may authorize an extension of the surface interval to a maximum of 7 minutes (requirements of paragraph 9-12.6 and 12-5.14 apply) Note 2: A non-Navy chamber may be used if authorized in writing by the first Flag Officer (FO) in the chain of command, and must include a NAVSEA 00C hazard analysis. Note 3: A non-Navy chamber may be used if it is evaluated utilizing the NAVSEA non-Navy recompression chamber check sheet, and authorized in writing by the Commanding Officer. Note 4: During extreme circumstances when a chamber cannot be reached within 6 hours the Commanding Officer (or designated individual) can give authorization to use the nearest recompression facility.	

18-2 DESCRIPTION

Most chamber-equipped U.S. Navy units will have one of seven commonly provided chambers. They are:

1. Double-lock, 200-psig, 425-cubic-foot steel chamber ([Figure 18-1](#)).
2. Recompression Chamber Facility: RCF 6500 ([Figure 18-2](#)).
3. Recompression Chamber Facility: RCF 5000 ([Figure 18-3](#)).
4. Double-lock, 100-psig, 202-cubic-foot steel chamber (ARS 50 class and Modernized) ([Figure 18-4](#) and [Figure 18-5](#)).
5. Standard Navy Double Lock Recompression Chamber System (SNDLRCS) ([Figure 18-6](#)).
6. Transportable Recompression Chamber System (TRCS) ([Figure 18-7](#), [Figure 18-8](#), [Figure 18-9](#)).
7. Fly-Away Recompression Chamber (FARCC) ([Figure 18-10](#), [Figure 18-11](#), [Figure 18-12](#)).

Select U.S. Navy units have a unique treatment option called the Emergency Evacuation Hyperbaric Stretcher (EEHS). The EEHS has a single lock and allows a patient to be administered oxygen at 60 feet while in transport to a recompression chamber. However, it does not provide hands-on access to the patient and therefore does not qualify as a recompression chamber.

18-2.1

Basic Chamber Components. The basic components of a recompression chamber are much the same from one model to another. The basic components consist of the pressure vessel itself, an air supply and exhaust system, a pressure gauge, and a built-in breathing system (BIBS) to supply oxygen to the patient. Additional components may include oxygen, carbon dioxide, temperature and humidity monitors, carbon dioxide scrubbers, additional BIBS systems for air and treatment gases other than oxygen, a BIBS overboard dump system, and a heating/cooling system. Collectively these systems must be able to impose and maintain a pressure equivalent to a depth of 165 fsw (6 ata) on the diver. Double-lock chambers are used because they permit tending personnel and supplies to enter and leave the chamber during treatment.

The piping and valving on some chambers is arranged to permit control of the air supply and the exhaust from either the inside or the outside of the chamber. Controls on the outside must be able to override the inside controls in the event of a problem inside the chamber. The usual method for providing this dual-control capability is through the use of two separate systems. The first, consisting of a supply line and an exhaust line, can only be controlled by valves that are outside of the chamber. The second air supply/exhaust system has a double set of valves, one inside and one outside the chamber. This arrangement permits the tender to

regulate descent or ascent from within the chamber, but always subject to final control by outside personnel.

18-2.2 Fleet Modernized Double-Lock Recompression Chamber. Modernized chambers ([Figure 18-5](#)) have carbon dioxide and oxygen monitors, a CO₂ scrubber system, a Built-In Breathing System (BIBS), and an oxygen dump system which together reduce the ventilation requirements. These chambers also include a chamber environment control system that regulates humidity and temperature.

18-2.3 Recompression Chamber Facility (RCF). The RCF series 6500 and 5000 ([Figures 18-2](#) and [18-3](#)) consists of two sizes of standard double lock steel chambers, each with a medical lock and easy occupant access. The RCF 6500 is capable of treating up to 12 occupants while the RCF 5000 is capable of treating 7 occupants. The systems are installed in a facility to support training, surface decompression, recompression treatment, and medical treatment operations. Each RCF includes primary and secondary air supplies comprised of compressors, purification, and storage for chamber pressurization and ventilation along with oxygen, mix treatment gas, and emergency air supply to the BIBS system. Each RCF has an atmospheric conditioning system that provides internal atmospheric scrubbing and monitoring along with temperature and humidity controls for long term treatment, gas management, and patient comfort. The RCF includes gas supply monitoring, a fire extinguishing system, ground fault interruption and emergency power. The RCF 6500 is equipped with a NATO mating flange. Both series have extra penetrations for auxiliary equipment such as patient treatment monitoring and hoods.

18-2.4 Standard Navy Double Lock Recompression Chamber System (SNDLRCs). The SNDLRCs ([Figure 18-6](#)) consists of a Standard Navy Double Lock (SNDL) recompression chamber and a gas supply system housed within an International Organization for Standards (ISO) container. The system is capable of supporting surface decompression, medical treatment, and training operations. Air is supplied to the system using a Air Flask Rack Assembly (AFRA) which is almost identical to the Air Supply Rack Assembly (ASRA) used in supporting a FADS 3 DLSS. Oxygen is provided by four (4) cylinders that are secured to the interior bulkhead of the ISO container. If an external supply of mixed gas is available it can also be supplied to the chamber BIBS supply.

The SNDL is a 54" diameter, double lock recompression chamber. It is outfitted with a stretcher, BIBS, gas monitoring systems, lights, and an environmental conditioning system. The chamber can comfortably accommodate 4 divers in the inner lock and 3 divers in the outer lock.

The ISO container houses the gas supply systems and the chamber. It also provides a shelter from environmental elements for the Outside Tenders and Diving Supervisor to conduct treatments. The container is both heated and air conditioned as required and also includes a fold-down desktop, a cabinet, lighting, and a vestibule.

18-2.5 Transportable Recompression Chamber System (TRCS). There are three TRCS Mods.

- TRCS Mod 0 ([Figure 18-7](#)) consists of two pressure chambers. One is a conical-shaped chamber ([Figure 18-8](#)) called the Transportable Recompression Chamber (TRC) and the other is a cylindrical shaped vessel ([Figure 18-9](#)) called the Transfer Lock (TL). The two chambers are capable of being connected by means of a freely rotating NATO female flange coupling ([Figure 18-7](#)).
- TRCS Mod 1 consists of just the TRC.
- TRCS Mod 2 is the TRCS Mod 0 which has had the 5000 psi upgrade ECP installed allowing it to be used with an Air Supply Rack Assembly (ASRA).

The TRCS is supplied with a Compressed Air and Oxygen System (CAOS) consisting of lightweight air and oxygen racks of high pressure flasks, as well as a means of reducing oxygen supply pressure. The TRCS Mod 2 can use the TRCS Mod 0 lightweight air racks rated at 3000 psi or an ASRA rated at 5000 psi. The chamber is capable of administering oxygen and mixed gas via BIBS.

An ECP upgrade is available for installing a CO₂ Scrubber in the TL. A TRCS Mod 0 or Mod 2 without a TL CO₂ Scrubber is limited to one patient and one tender.

When a Level I Recompression Chamber is required or Surface Decompression dives are planned, a TRCS Mod 0 or Mod 2 (with TL CO₂ Scrubber installed) can be used.

When a Level I Recompression Chamber is not required, any of the three TRCS Mods can be used.

18-2.6 Fly Away Recompression Chamber (FARCC). This chamber system consists of a 60-inch double lock modernized chamber in a 20' x 8' x 8' milvan ([Figure 18-10](#) and [Figure 18-11](#)). The Fly Away Recompression Chamber (FARCC) also includes a life support skid ([Figure 18-12](#)). In addition, a stand-alone generator is provided for remote site power requirements.

18-2.7 Emergency Evacuation Hyperbaric Stretcher (EEHS). The Emergency Evacuation Hyperbaric Stretcher (EEHS) is a manually-portable single patient hyperbaric tube to be used to transport a diving or disabled submarine casualty from an accident site to a treatment facility while under pressure. The EEHS does not replace a recompression chamber, but is used in conjunction with a chamber. The EEHS is small enough to allow transfer of a patient, under pressure, into or out of many shore based recompression chambers owned by both the DOD, and civilian medical organizations.

18-2.8 Standard Features. Recompression chambers must be equipped with a means for delivering breathing oxygen to the personnel in the chamber. The inner lock should be provided with connections for demand-type oxygen inhalators. Oxygen can be furnished through a pressure reducing manifold connected with supply cylinders outside the chamber.

18-2.8.1 Labeling. All lines should be identified and labeled to indicate function, content and direction of flow. The color coding in [Table 18-2](#) should be used.

- 18-2.8.2 **Inlet and Exhaust Ports.** Optimum chamber ventilation requires separation of the inlet and exhaust ports within the chamber. Exhaust ports must be provided with a guard device to prevent accidental injury when they are open.
- 18-2.8.3 **Pressure Gauges.** Chambers must be fitted with appropriate pressure gauges. These gauges, marked to read in feet of seawater (fsw), must be calibrated or compared as described in the applicable Planned Maintenance System (PMS) to ensure accuracy in accordance with the instructions in [Chapter 4](#).

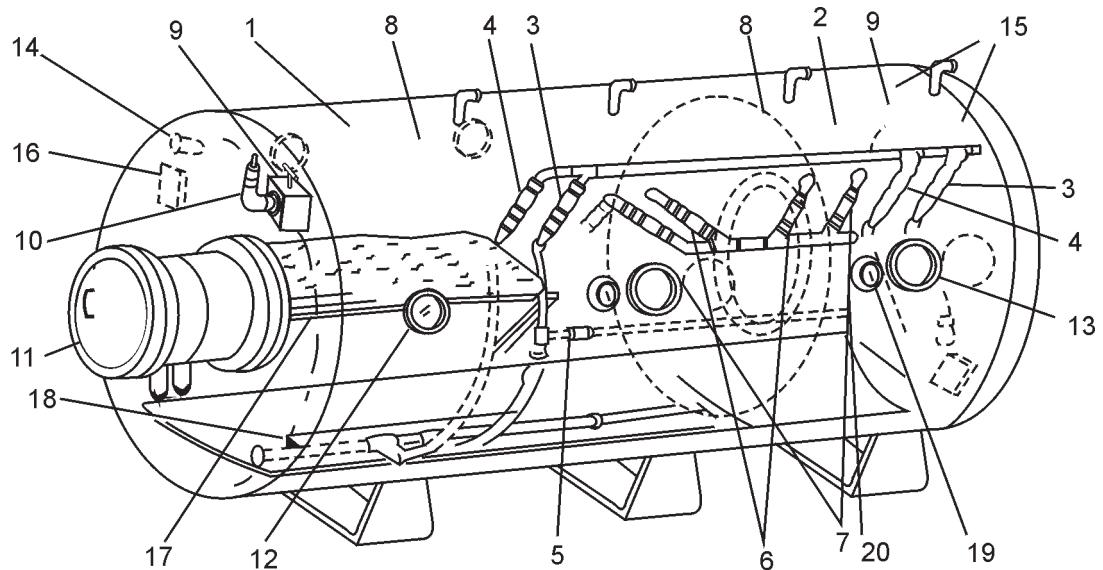
Table 18-2. Recompression Chamber Line Guide.

Function	Designation	Color Code
Helium	HE	Buff
Oxygen	OX	Green
Helium-Oxygen Mix	HE-OX	Buff & Green
Nitrogen	N	Light Gray
Nitrogen Oxygen Mix	N-OX	Light Gray & Green
Exhaust	E	Silver
Air (Low Pressure)	ALP	Black
Air (High Pressure)	AHP	Black
Chilled Water	CW	Blue & White
Hot Water	HW	Red & White
Potable Water	PW	Blue
Fire Fighting Material	FP	Red

- 18-2.8.4 **Relief Valves.** Recompression chambers should be equipped with pressure relief valves in each manned lock. Chambers that do not have latches (dogs) on the doors are not required to have a relief valve on the outer lock. The relief valves shall be set in accordance with PMS. In addition, all chambers shall be equipped with a gag valve, located between the chamber pressure hull and each relief valve. This gag valve shall be a quick acting, ball-type valve, sized to be compatible with the relief valve and its supply piping. The gag valve shall be safety wired in the open position.
- 18-2.8.5 **Communications System.** Chamber communications are provided through a diver's intercommunication system, with the dual microphone/speaker unit in the chamber and the surface unit outside. The communication system should be arranged so that personnel inside the chamber need not interrupt their activities to operate the system. The backup communications system may be provided by a set of standard sound-powered telephones. The press-to-talk button on the set inside the chamber can be taped down, thus keeping the circuit open.
- 18-2.8.6 **Lighting Fixtures.** Consideration should be given to installation of a low-level lighting fixture (on a separate circuit), which can be used to relieve the patient of the heat and glare of the main lights. Emergency lights for both locks and

an external control station are mandatory. No electrical equipment, other than that authorized within the scope of certification or as listed in the NAVSEA Authorization for Navy Use (ANU) List, is allowed inside the chamber. Because of the possibility of fire or explosion when working in an oxygen or compressed air atmosphere, all electrical wiring and equipment used in a chamber shall meet required specifications.

Double-Lock Steel Recompression Chamber

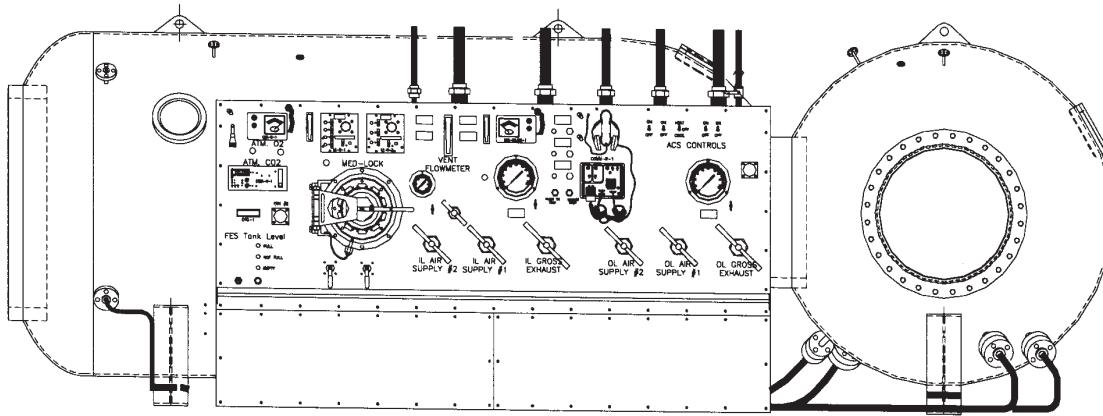


- | | |
|--|--|
| 1. Inner Lock
2. Outer Lock
3. Air Supply – Two-Valve
4. Air Supply – One-Valve
5. Main Lock Pressure Equalizing Valve
6. Exhaust – Two-Valve
7. Exhaust – One-Valve
8. Oxygen Manifold
9. Relief Gag Valve (1 each lock)
10. Relief Valve – 110 psig | 11. Medical Lock 18-Inch Diameter
12. View Port – Inner Lock (4)
13. View Port – Outer Lock (2)
14. Lights – Inner Lock 40 Watt (4)
15. Lights – Outer Lock 40 Watt
16. Transmitter/Receiver
17. Berth – 2'6" x 6'6"
18. Bench
19. Pressure Gauge – Outside (2 each lock)
20. Pressure Gauge – Inside (1 each lock) |
|--|--|

Original Design Pressure – 200 psig
 Original Hydrostatic Test Pressure – 400 psig
 Maximum Operating Pressure – 100 psig

Figure 18-1. Double-Lock Steel Recompression Chamber.

Recompression Chamber Facility: RCF 6500



Design Pressure: 110 psig

Length: 21' 3"

Height: 7' 6"

Internal Volume (OL): 144 ft³

Door Opening (OL): 30"

Design Temperature: 0-125°F

Diameter: 6' 6"

Height: 7' 6"

Internal Volume (IL): 440 ft³

Door Opening (IL): 48"

Viewports: 6 @ 8" diameter Clear Opening (including 1 video port)

Medlock: 18" diameter X 20" long mounted in console with ASME Quick Actuating Enclosure

Mating Flange: NATO per STANAG 1079

Atmospheric Monitoring: Oxygen, Carbon Dioxide, Temperature

Temperature Monitoring: External Heater/Chiller with internal Blower

Scrubber: Magnetically driven, replaceable canister

BIBS: 8 masks in IL, 4 masks in OL, automatic switching with block & bleed for Oxygen/Nitrox or Heliox/Air, overboard dump, and Oxygen analysis of supply gas

Principal Communications: AC Powered Speaker/Headset w/battery backup

Secondary Communications: Sound Powered Phone

Furnishing: Two 7' Bunks, One 5' 6" Bench, One 18" X 18" Bench

Lighting: 4 Lights in IL, 2 Lights in OL

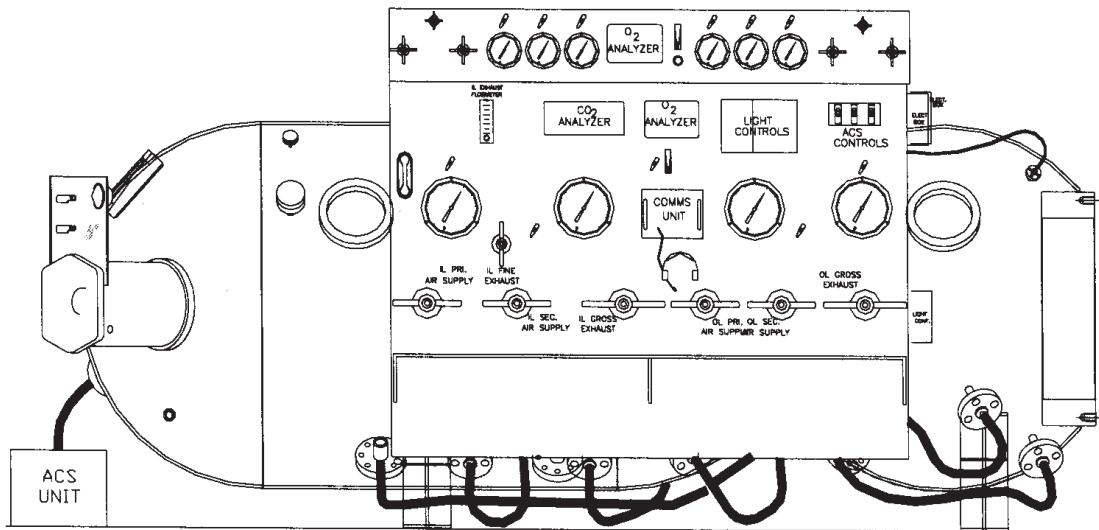
Gas Pressurization Controls: Primary and secondary air

Air Ventilation Controls: Gross vent and fine vent (with flow meter)

Fire Extinguishing System: 2 Hand Held Hoses in IL, 1 in OL

Figure 18-2. Recompression Chamber Facility: RCF 6500.

Recompression Chamber Facility: RCF 5000



Design Pressure: 110 psig

Length: 14' 8"

Height: 5' 7"

Internal Volume (OL): 61 ft³

Door Opening (OL): 30"

Design Temperature: 0-125°F

Diameter: 5'

Weight: 9,300 lbs.

Internal Volume (IL): 162 ft³

Viewports: 6 @ 8" diameter Clear Opening (including 1 video port)

Medlock: 18" diameter X 20" long mounted in console with ASME Quick Actuating Enclosure

Mating Flange: NATO per STANAG 1079

Atmospheric Monitoring: Oxygen, Carbon Dioxide, Temperature

Temperature Monitoring: External Heater/Chiller with internal Blower

Scrubber: Magnetically driven, replaceable canister

BIBS: 4 masks in IL, 3 masks in OL, overboard dump, & Oxygen analysis of supply gas

Principal Communications: AC Powered Speaker/Headset w/battery backup

Secondary Communications: Sound Powered Phone

Furnishing: One Bunks, One Bench

Lighting: 2 Lights in IL, 1 Lights in OL

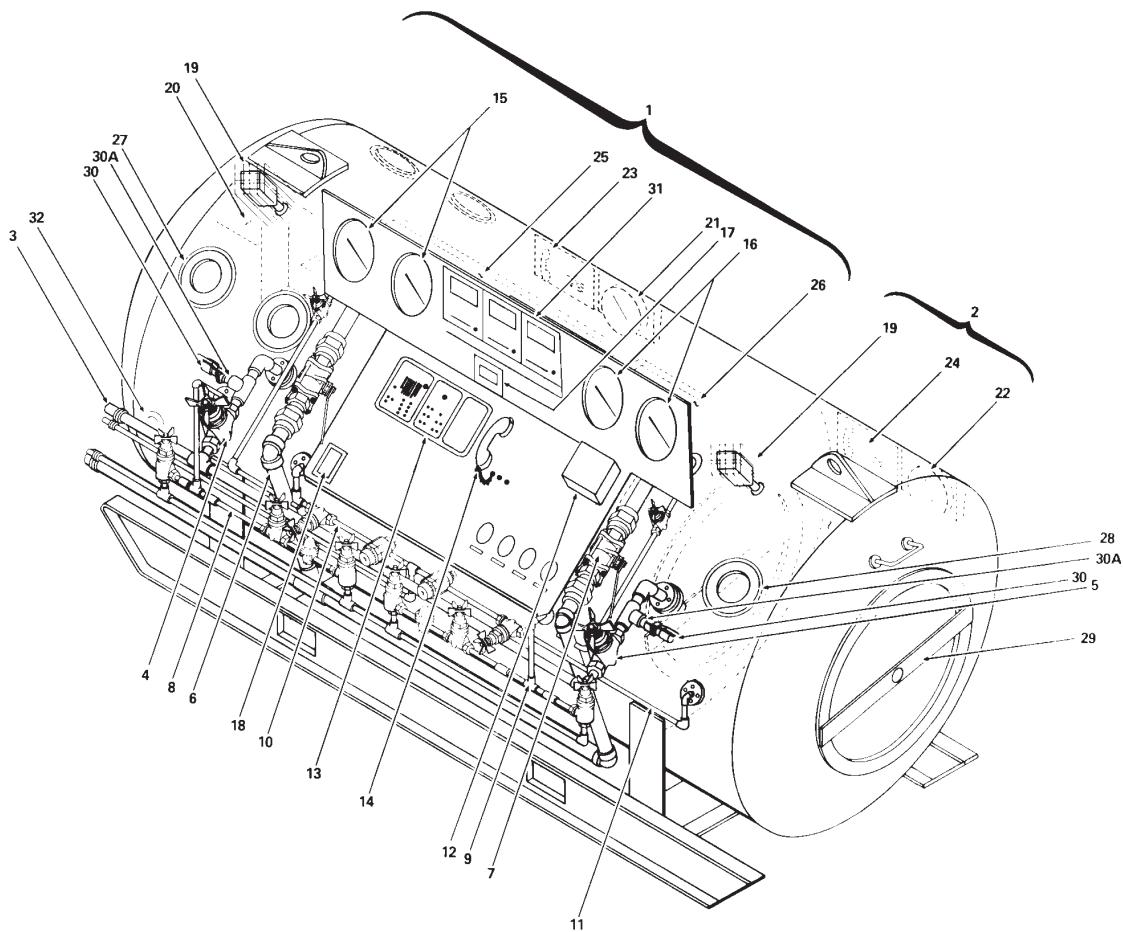
Gas Pressurization Controls: Primary and secondary air

Air Ventilation Controls: Gross vent and fine vent (with flow meter)

Fire Extinguishing System: Hyperbaric extinguisher

Figure 18-3. Recompression Chamber Facility: RCF 5000.

ARS 50 Class Double-Lock Recompression Chamber



- | | |
|--|---------------------------------|
| 1. Inner Lock | 18. Ground Fault Interrupter |
| 2. Outer Lock | 19. Pipe Light Assembly |
| 3. Air Supply Connection | 20. Chiller and Scrubber Panel |
| 4. Air Supply – Inner Lock | 23. Inner Lock Comm Panel |
| 5. Air Supply – Outer Lock | 24. Outer Lock Comm Panel |
| 6. Exhaust – Inner Lock | 25. Bunk Main |
| 7. Exhaust – Outer Lock | 26. Bunk Extension |
| 8. BIBS Supply – Inner Lock | 27. View Ports – Inner Lock (4) |
| 9. BIBS Supply – Outer Lock | 28. View Ports – Outer Lock (2) |
| 10. BIBS Exhaust – Inner Lock | 29. Strongback |
| 11. BIBS Exhaust – Outer Lock | 30. Relief Valve – 100 psig |
| 12. Oxygen Analyzer | 30A. Gag Valve |
| 13. Communications | 31. Pipe Light Controls |
| 14. Sound-Powered Phones | 32. Chiller/Scrubber Penetrator |
| 15. External Depth Gauges – Inner Lock (2) | |
| 16. External Depth Gauges – Outer Lock (2) | |
| 17. Telethermometer | |

Design Pressure – 100 psig

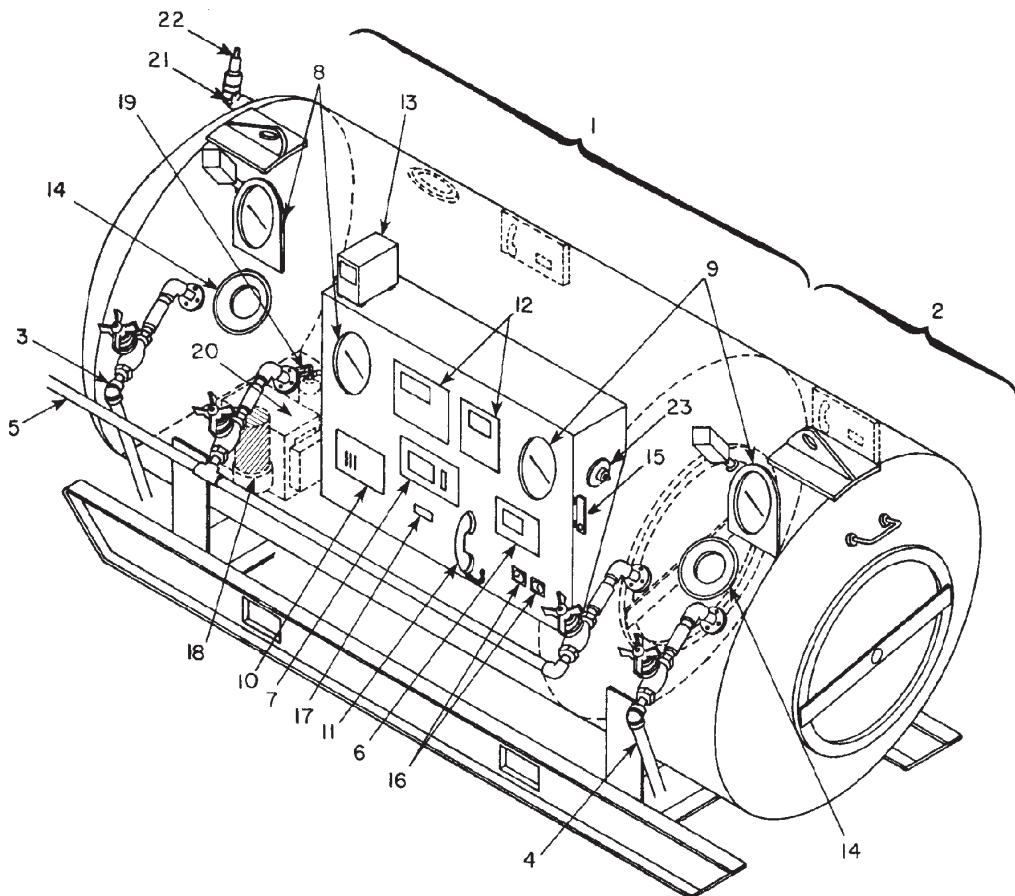
Original Hydrostatic Pressure – 150 psig

Principal Locations – ARS-50 Class Salvage Ships

Volume – Inner Lock = 134 cubic feet
 – Outer Lock = 68 cubic feet
 – Total = 202 cubic feet

Figure 18-4. Double-Lock Steel Recompression Chamber.

Fleet Modernized Double-Lock Recompression Chamber



- | | |
|--------------------------------|--|
| 1. Inner Lock | 13. Ground Fault Interrupter |
| 2. Outer Lock | 14. View Ports (5) |
| 3. Gas Supply – Inner Lock | 15. Flowmeter |
| 4. Gas Supply – Outer Lock | 16. Stopwatch/Timer |
| 5. Gas Exhaust | 17. Telethermometer |
| 6. O ₂ Analyzer | 18. CO ₂ Scrubber |
| 7. CO ₂ Analyzer | 19. Fire Extinguisher |
| 8. Inner-Lock Depth Gauges (2) | 20. Chiller/Conditioner Unit |
| 9. Outer-Lock Depth Gauges (2) | 21. Gag Valve |
| 10. Communications Panel | 22. Relief Valve – 110 psig |
| 11. Sound-Powered Phone | 23. BIBS Overboard Dump Regulator – Outer Lock |
| 12. Pipe Light Control Panel | |

Figure 18-5. Fleet Modernized Double-Lock Recompression Chamber.

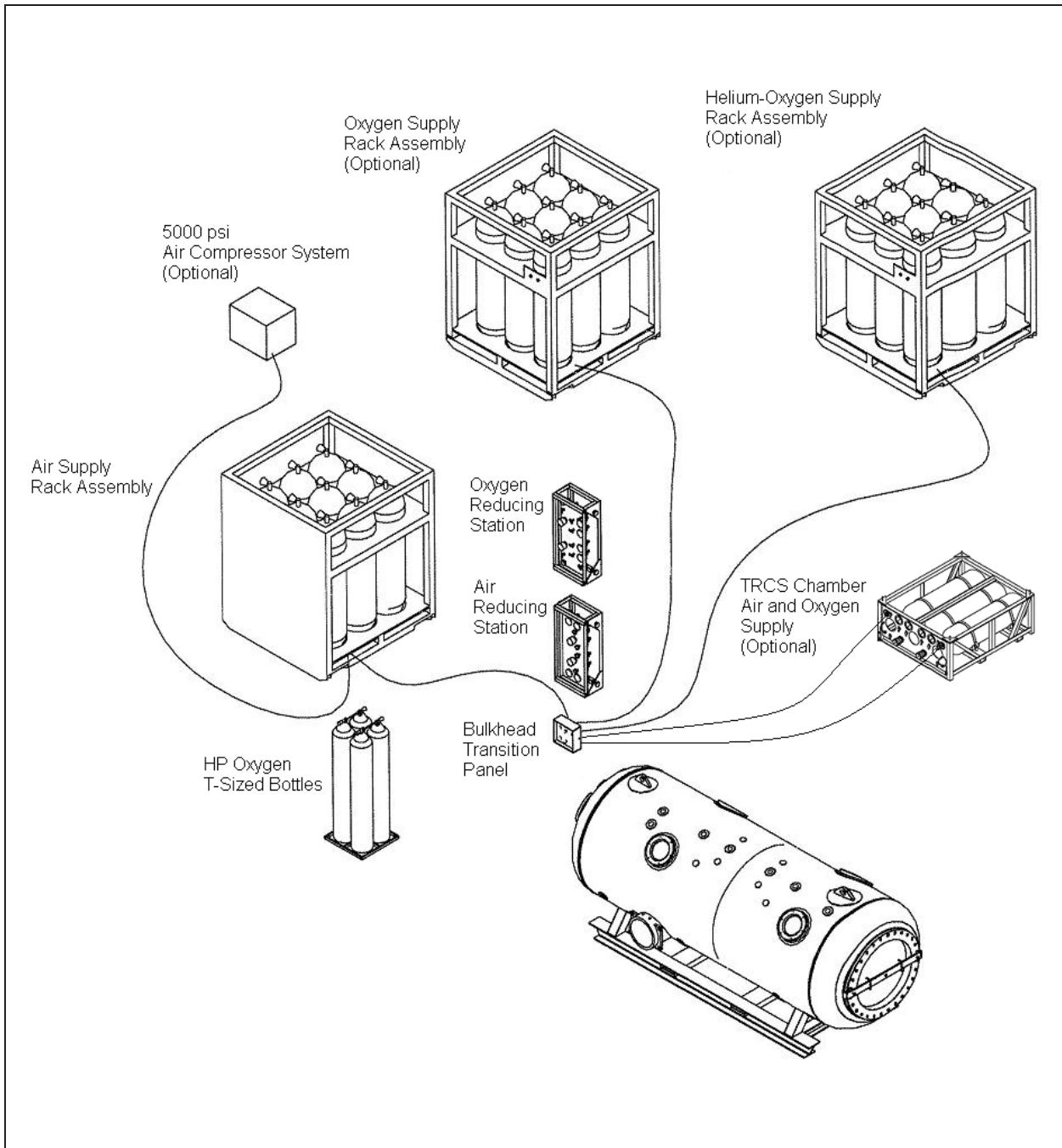


Figure 18-6. Standard Navy Double-Lock Recompression Chamber System.

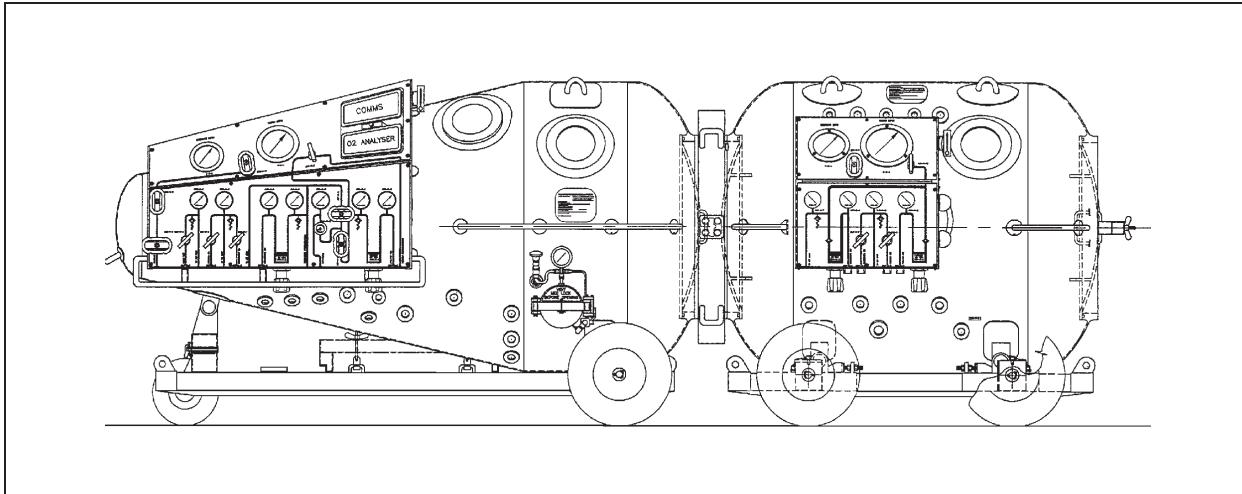
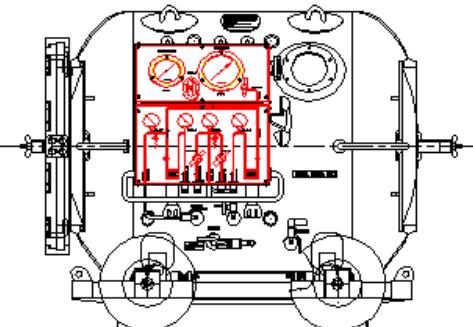


Figure 18-7. Transportable Recompression Chamber System (TRCS).

Design Pressure	110 psig	Height	52" with wheels, 48" without wheels
Design Temperature	0-125°F	Width	50.7"
Length	95.7"	Weight	1,268 lbs.
		Internal Volume	45 cu. ft.
		Door Opening	26"
		View Ports	3 @ 6" dia. Clear Opening
		Medical Lock	5.75" dia. x 11.8" long
		Mating Flange	Male per NATO STANAG 1079
		Life Support Scrubber	Air driven, replaceable scrubber, canister fits in Med Lock
		BIBS	2 masks – oxygen and air supply (with capability for N ₂ O ₂ or HeO ₂) – overboard dump
		Atmospheric Monitoring	Oxygen and Carbon Dioxide Analyzer
		Gas Supply	Primary and secondary air and O ₂
		Communications	Battery-powered speaker/headset phone
		Furnishing	Patient litter, attendants seat

Figure 18-8. Transportable Recompression Chamber (TRC).



Design Pressure	110 psig	Atmospheric Monitoring	Oxygen and Carbon Dioxide Analyzer
Design Temperature	0-125°F	Gas Supply	Primary and secondary air and O ₂
Length	69.9"	Communications	Sound-powered phone
Height		52.9"	
Width		54.8"	
Weight		1,367 lbs.	
Internal Volume		45.5 cu. ft.	
Door Opening		2 doors – 26"	
View Ports		2 @ 6" dia. Clear Opening	
Mating Flange		Rotating Female per NATO STANAG 1079	
Life Support Scrubber		Air-driven, replaceable scrubber, canister fits in TRC Med Lock	
BIBS		2 masks – oxygen and air supply – overboard dump	

Figure 18-9. Transfer Lock (TL).

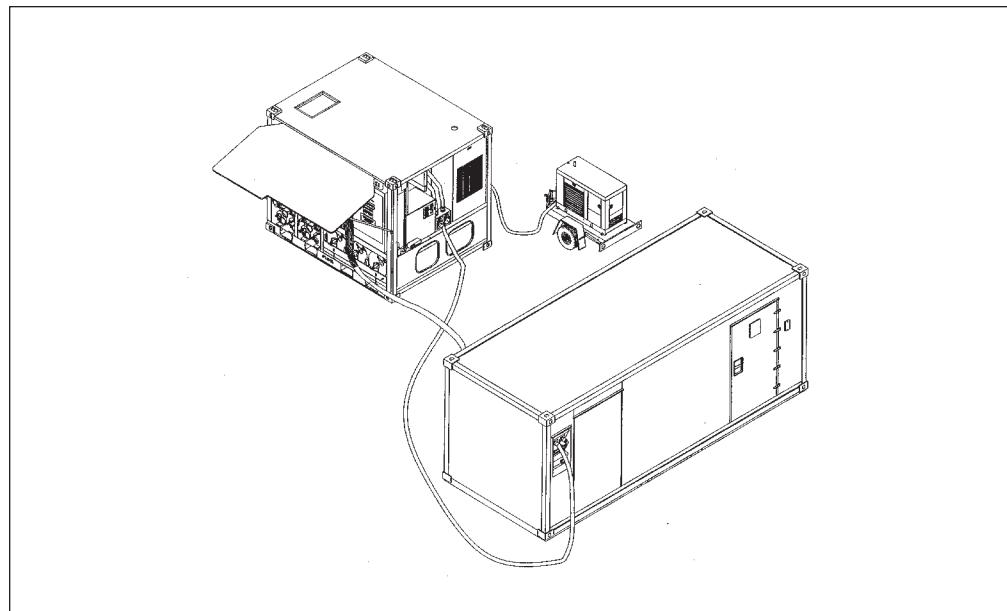


Figure 18-10. Fly Away Recompression Chamber (FARCC).

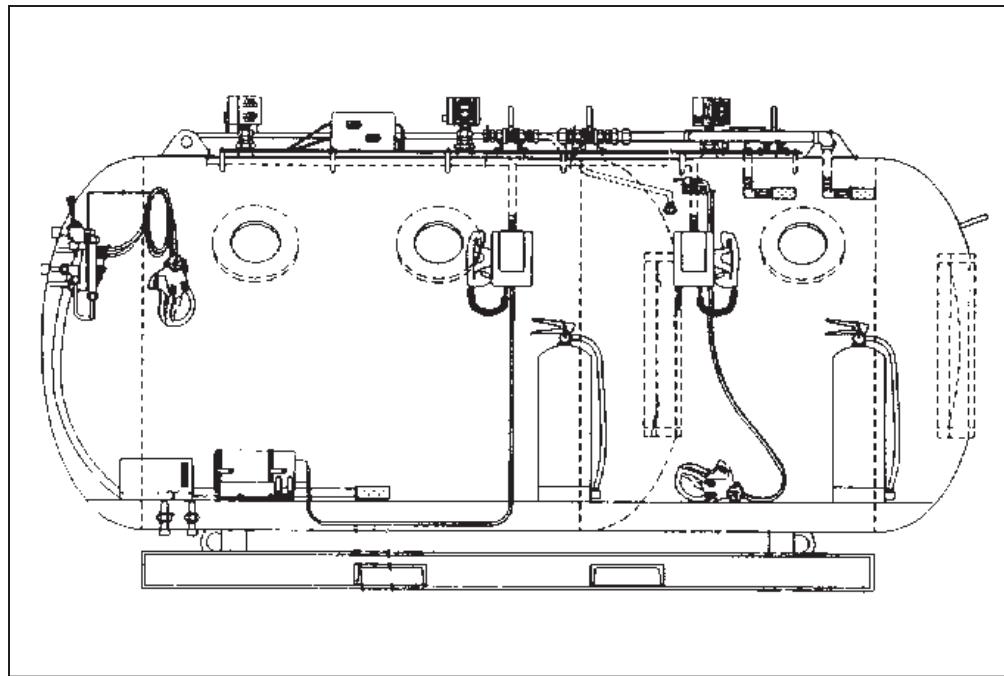


Figure 18-11. Fly Away Recompression Chamber.

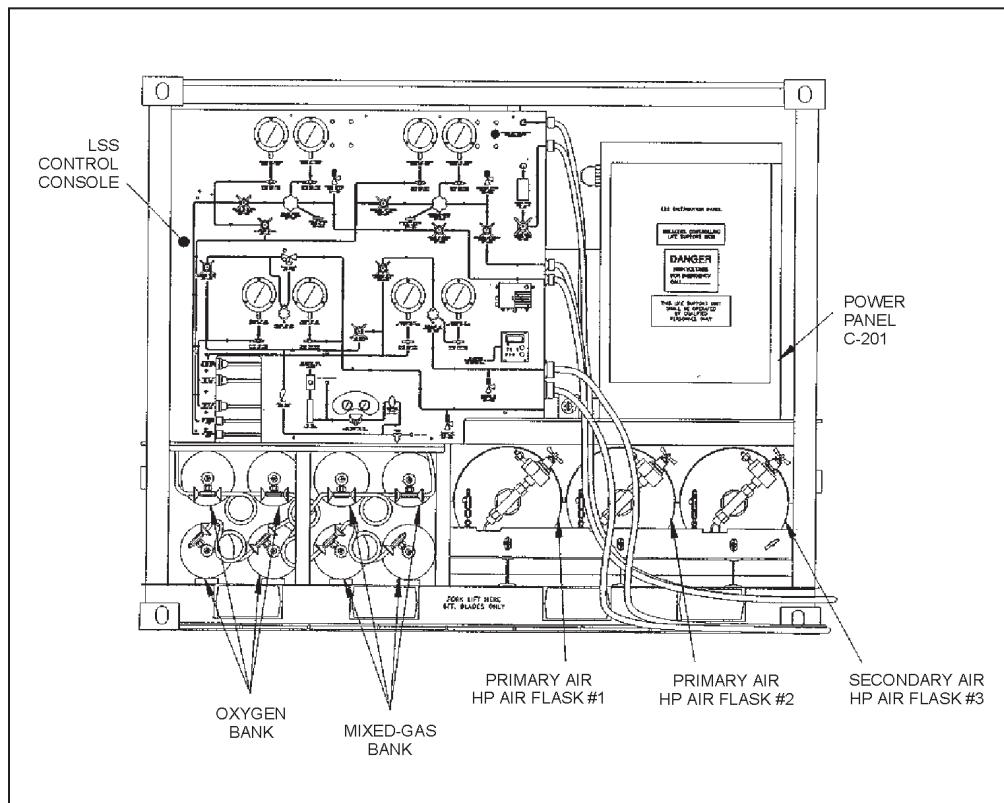


Figure 18-12. Fly Away Recompression Chamber Life Support Skid.

18-3 STATE OF READINESS

Since a recompression chamber is emergency equipment, it must be kept in a state of readiness. The chamber shall be well maintained and equipped with all necessary accessory equipment. A chamber is not to be used as a storage compartment.

The chamber and the air and oxygen supply systems shall be checked prior to each use with the Predive Checklist and in accordance with PMS instructions. All diving personnel shall be trained in the operation of the recompression chamber equipment and should be able to perform any task required during treatment.

18-4 GAS SUPPLY

A recompression chamber system must have a primary and a secondary air supply system that satisfies [Table 18-3](#). The purpose of this requirement is to ensure the recompression chamber system, at a minimum, is capable of conducting a [Treatment Table 6A \(TT6A\)](#).

18-4.1

Capacity. Either system may consist of air banks and/or a suitable compressor. The primary air supply system must have sufficient air to pressurize the inner lock once to 165 fsw and the outer lock twice to 165 fsw and ventilate the chamber as specified in [Table 18-3](#).

■ Primary System Capacity:

$$C_p = (5 \times V_{il}) + (10 \times V_{ol}) + RV$$

Where:

C_p = minimum capacity of primary system in SCF

V_{il} = volume of inner lock

V_{ol} = volume of outer lock

5 = atmospheres equivalent to 165 fsw

10 = twice the atmospheres equivalent to 165 fsw

RV = required ventilation. See [paragraph 18-5.4](#) for Category A and B ventilation requirements. Not used for Category C, D, and E.

The secondary air supply system must have sufficient air to pressurize the inner and outer locks once to 165 fsw plus ventilate the chamber as specified in [Table 18-3](#).

■ Secondary System Requirement:

$$C_s = (5 \times V_{il}) + (5 \times V_{ol}) + RV$$

Where:

C_s = minimum capacity of secondary system in SCF

V_{il} = volume of inner lock

V_{ol} = volume of outer lock

5 = atmospheres equivalent to 165 fsw

RV = required ventilation. For Category A, B, and C, use 4,224 for ventilation rate of 70.4 scfm for one hour. For Category D and E, calculate air or NITROX required for two patients and one tender to breathe BIBS (when not on O₂) during one [TT6A](#) with maximum extensions.

Table 18-3. Recompression Chamber Air Supply Requirements.

Recompression Chamber Configuration	Primary Air Requirement	Secondary Air Requirement
CATEGORY A: No BIBS overboard dump No CO ₂ scrubber No air BIBS No O ₂ and CO ₂ monitor	Sufficient air to press the IL once and the OL twice to 165 fsw and vent during one TT6A for one tender and two patients with maximum extensions.	Sufficient air to press the IL and OL once to 165 fsw and vent for one hour at 70.4 scfm.
CATEGORY B: BIBS overboard dump No CO ₂ scrubber No air BIBS O ₂ and CO ₂ monitors	Sufficient air to press the IL once and the OL twice to 165 fsw and vent for CO ₂ during one TT6A for one tender and two patients with maximum extensions.	Sufficient air to press the IL and OL once to 165 fsw and vent for one hour at 70.4 scfm.
CATEGORY C: BIBS overboard dump CO ₂ scrubber No air BIBS O ₂ and CO ₂ monitors	Sufficient air to press the IL once and the OL twice to 165 fsw.	Sufficient air to press the IL and OL once to 165 fsw and vent for one hour at 70.4 scfm.
CATEGORY D: BIBS overboard dump CO ₂ scrubber Air BIBS O ₂ and CO ₂ monitor	Sufficient air to press the IL once and the OL twice to 165 fsw. (For TRCS, sufficient air to power CO ₂ scrubbers must be included)	Sufficient air to press the IL and OL once to 165 fsw and enough air for one tender and two patients (when not on O ₂) to breathe air BIBS during one TT6A with maximum extensions.
CATEGORY E: BIBS overboard dump CO ₂ scrubber O ₂ and CO ₂ monitor Spare CO ₂ scrubber Secondary power supply NITROX BIBS No Air BIBS	Sufficient air to press the IL once and the OL twice to 165 fsw.	Sufficient air to press the IL and OL once to 165 fsw and enough air/NITROX for one tender and two patients (when not on O ₂) to breathe air/NITROX BIBS during one TT6A with maximum extensions.
Notes:		
1) Additional air source per PSOB will be required for TT4, 7 or 8.		
2) For chambers used to conduct Sur "D" sufficient air is required to conduct a TT6A in addition to any planned Sur "D."		
3) The requirement for BIBS overboard dump can also be satisfied with closed circuit BIBS with CO ₂ scrubbers.		

18-5 OPERATION

18-5.1 **Predive Checklist.** To ensure each item is operational and ready for use, perform the equipment checks listed in the Recompression Chamber Predive Checklist, [Figure 18-13](#).

18-5.2 **Safety Precautions.**

- Do not use oil on any oxygen fitting, air fitting, or piece of equipment.
- Do not allow oxygen supply tanks to be depleted below 100 psig.
- Ensure dogs are in good operating condition and seals are tight.
- Do not leave doors dogged (if applicable) after pressurization.
- Do not allow open flames, smoking materials, or any flammables to be carried into the chamber.
- Do not permit electrical appliances to be used in the chamber unless listed in the Authorization for Navy Use (ANU).
- Do not perform unauthorized repairs or modifications on the chamber support systems.
- Do not permit products in the chamber that may contaminate or off-gas into the chamber atmosphere.

18-5.3 **General Operating Procedures.**

1. Ensure completion of Predive Checklist.
2. Diver and tender enter the chamber together.
3. Diver sits in an uncramped position.
4. Tender closes and dogs (if so equipped) the inner lock door.
5. Pressurize the chamber, at the rate and to the depth specified in the appropriate decompression or recompression table.
6. As soon as a seal is obtained or upon reaching depth, tender releases the dogs (if so equipped).
7. Ventilate chamber according to specified rates and energize CO₂ scrubber and chamber conditioning system.
8. Ensure proper decompression of all personnel.
9. Ensure completion of Postdive Checklist.

RECOMPRESSION CHAMBER PREDIVE CHECKLIST	
Equipment	Initials
Chamber	
System certified	
Cleared of all extraneous equipment	
Clear of noxious odors	
Doors and seals undamaged, seals lubricated	
Pressure gauges calibrated/compared	
Air Supply System	
Primary and secondary air supply adequate	
One-valve supply: Valve closed	
Two-valve supply: Outside valve open, inside valve closed, if applicable	
Equalization valve closed, if applicable	
Supply regulator set at 250 psig or other appropriate pressure	
Fittings tight, filters clean, compressors fueled	
Exhaust System	
One-valve exhaust: Valve closed and calibrated for ventilation	
Two-valve exhaust: Outside valve open, inside valve closed, if applicable	
Oxygen Supply System	
Cylinders full, marked as BREATHING OXYGEN, cylinder valves open	
Replacement cylinders on hand	
Built in breathing system (BIBS) masks installed and tested	
Supply regulator set in accordance with OPs	
Fittings tight, gauges calibrated	
Oxygen manifold valves closed	
BIBS dump functioning	

Figure 18-13. Recompression Chamber Predive Checklist (sheet 1 of 2).

RECOMPRESSION CHAMBER PREDIVE CHECKLIST	
Equipment	Initials
Electrical System	
Lights	
Carbon dioxide analyzer calibrated	
Oxygen analyzer calibrated	
Temperature indicator calibrated	
Carbon dioxide scrubber operational	
Chamber conditioning unit operational	
Direct Current (DC) power supply	
Ground Fault Interrupter (GFI)	
Communication System	
Primary system tested	
Secondary system tested	
Fire Prevention System	
Tank pressurized for chambers with installed fire suppression systems	
Combustible material in metal enclosure	
Fire-retardant clothing worn by all chamber occupants	
Fire-resistant mattresses and blankets in chamber	
Means of extinguishing a fire	
Miscellaneous	
Inside Chamber:	CO ₂ -absorbent canister with fresh absorbent installed
	Urinal
	Primary medical kit
	Ear protection sound attenuators/ear protectors (1 set per person) Must have a 1/16" hole drilled to allow for equalization.
Outside Chamber:	Heater/chiller unit
	Stopwatches for recompression treatment time, decompression time, personnel leaving chamber time, and cumulative time
	Fresh CO ₂ scrubber canister
	<i>U.S. Navy Diving Manual, Volume 5</i>
	Ventilation bill
	Chamber log
	Operating Procedures (OPs) and Emergency Procedures (EPs)
	Secondary medical kit
	Bedpan (to be locked in as required)

Figure 18-13. Recompression Chamber Predive Checklist (sheet 2 of 2).

- 18-5.3.1 **Tender Change-Out.** During extensive treatments, medical personnel may prefer to lock-in to examine the patient and then lock-out, rather than remain inside throughout the treatment. Inside tenders may tire and need relief.
- 18-5.3.2 **Lock-In Operations.** Personnel entering the chamber go into the outer lock and close and dog the door (if applicable). The outer lock should be pressurized at a rate controlled by their ability to equalize, but not to exceed 75 feet per minute. The outside tender shall record the time pressurization begins to determine the decompression schedule for the occupants when they are ready to leave the chamber. When the pressure levels in the outer and inner locks are equal, the inside door (which was undogged at the beginning of the treatment) should open.
- 18-5.3.3 **Lock-Out Operations.** To exit the chamber, the personnel again enter the outer lock and the inside tender closes and dogs the inner door (if so equipped). When ready to ascend, the Diving Supervisor is notified and the required decompression schedule is selected and executed. Constant communications are maintained with the inside tender to ensure that a seal has been made on the inner door. Outer lock depth is controlled throughout decompression by the outside tender.
- 18-5.3.4 **Gag Valves.** The actuating lever of the chamber gag valves shall be maintained in the open position at all times, during both normal chamber operations and when the chamber is secured. The gag valves must be closed only in the event of relief valve failure during chamber operation. Valves are to be lock-wired in the open position with light wire that can be easily broken when required. A WARNING plate, bearing the inscription shown below, shall be affixed to the chamber in the vicinity of each gag valve and shall be readily viewable by operating personnel. The WARNING plates shall measure approximately 4 inches by 6 inches and read as follows:

WARNING
The gag valve must remain open at all times.
Close only if relief valve fails.

- 18-5.4 **Ventilation.** The basic rules for ventilation are presented below. These rules permit rapid computation of the cubic feet of air per minute (acfm) required under different conditions as measured at chamber pressure (the rules are designed to ensure that the effective concentration of carbon dioxide will not exceed 1.5 percent (11.4 mmHg) and that when oxygen is being used, the percentage of oxygen in the chamber will not exceed 25 percent).
1. When air is breathed, provide 2 cubic feet per minute (acfm) for each diver at rest and 4 cubic feet per minute (acfm) for each diver who is not at rest (i.e., a tender actively taking care of a patient).
 2. When oxygen is breathed from the built-in breathing system (BIBS), provide 12.5 acfm for a diver at rest and 25 acfm for a diver who is not at rest. When these ventilation rates are used, no additional ventilation is required for personnel breathing air. These ventilation rates apply only to the number of

people breathing oxygen and are used only when no BIBS dump system is installed.

3. If ventilation must be interrupted for any reason, the time should not exceed 5 minutes in any 30-minute period. When ventilation is resumed, twice the volume of ventilation should be used for the time of interruption and then the basic ventilation rate should be used again.
4. If a BIBS dump system or a closed circuit BIBS is used for oxygen breathing, the ventilation rate for air breathing may be used.
5. If portable or installed oxygen and carbon dioxide monitoring systems are available, ventilation may be adjusted to maintain the oxygen level below 25 percent by volume and the carbon dioxide level below 1.5 percent surface equivalent (sev).

18-5.4.1

Chamber Ventilation Bill. Knowing how much air must be used does not solve the ventilation problem unless there is some way to determine the volume of air actually being used for ventilation. The standard procedure is to open the exhaust valve a given number of turns (or fraction of a turn), which will provide a certain number of cubic feet of ventilation per minute at a specific chamber depth, and to use the supply valve to maintain a constant chamber depth during the ventilation period. Determination of valve settings required for different amounts of ventilation at different depths is accomplished as follows.

WARNING

This procedure is to be performed with an unmanned chamber to avoid exposing occupants to unnecessary risks.

1. Mark the valve handle position so that it is possible to determine accurately the number of turns and fractions of turns.
2. Check the basic ventilation rules above against probable situations to determine the rates of ventilation at various depths (chamber pressure) that may be needed. If the air supply is ample, determination of ventilation rates for a few depths (30, 60, 100, and 165 feet) may be sufficient. It will be convenient to know the valve settings for rates such as 6, 12.5, 25, or 37.5 cubic feet per minute (acfm).
3. Determine the necessary valve settings for the selected flows and depths by using a stopwatch and the chamber as a measuring vessel.
 - a. Calculate how long it will take to change the chamber pressure by 10 feet if the exhaust valve lets air escape at the desired rate close to the depth in question. Use the following formula.

$$T = \frac{V \times 60 \times \Delta P}{R \times (D + 33)}$$

Where:

- T = time in seconds for chamber pressure to change 10 feet
V = internal volume of chamber (or of lock being used for test) in cubic feet (cf)
R = rate of ventilation desired, in cubic feet per minute as measured at chamber pressure (acfm)
 ΔP = Change in chamber pressure in fsw
D = depth in fsw (gauge)

Example: Determine how long it will take the pressure to drop from 170 to 160 feet in a 425-cubic-foot chamber if the exhaust valve is releasing 6 cubic feet of air per minute (measured at chamber pressure of 165 feet).

1. List values from example:

$$\begin{aligned}T &= \text{unknown} \\V &= 425 \text{ cf} \\R &= 6 \text{ acfm} \\ \Delta P &= 10 \text{ fsw} \\D &= 165 \text{ fsw}\end{aligned}$$

2. Substitute values and solve to find how long it will take for the pressure to drop:

$$\begin{aligned}T &= \frac{425 \times 60 \times 10}{6(165 + 33)} \\&= 215 \text{ seconds} \\T &= \frac{215 \text{ seconds}}{60 \text{ seconds / minute}} \\&= 3.6 \text{ minutes}\end{aligned}$$

- b. Increase the empty chamber pressure to 5 feet beyond the depth in question. Open the exhaust valve and determine how long it takes to come up 10 feet (for example, if checking for a depth of 165 fsw, take chamber pressure to 170 feet and clock the time needed to reach 160 feet). Open the valve to different settings until you can determine what setting will approximate the desired time. Record the setting. Calculate the times for other rates and depths and determine the settings for these times in the same way. Make a chart or table of valve setting versus ventilation rate and prepare a ventilation bill, using this information and the ventilation rules.

18-5.4.2 Notes on Chamber Ventilation.

- The basic ventilation rules are not intended to limit ventilation. Generally, if air is reasonably plentiful, more air than specified should be used for comfort. This increase is desirable because it also further lowers the concentrations of carbon dioxide and oxygen.

- There is seldom any danger of having too little oxygen in the chamber. Even with no ventilation and a high carbon dioxide level, the oxygen present would be ample for long periods of time.
- These rules assume that there is good circulation of air in the chamber during ventilation. If circulation is poor, the rules may be inadequate. Locating the inlet near one end of the chamber and the outlet near the other end improves ventilation.
- Coming up to the next stop reduces the standard cubic feet of gas in the chamber and proportionally reduces the quantity (scfm) of air required for ventilation.
- Continuous ventilation is the most efficient method of ventilation in terms of the amount of air required. However, it has the disadvantage of exposing the divers in the chamber to continuous noise. At the very high ventilation rates required for oxygen breathing, this noise can reach the level at which hearing loss becomes a hazard to the divers in the chamber. If high sound levels do occur, especially during exceptionally high ventilation rates, the chamber occupants must wear ear protectors (available as a stock item). A small hole should be drilled into the central cavity of the protector so that they do not produce a seal which can cause ear squeeze.
- The size of the chamber does not influence the rate (acfm) of air required for ventilation.
- Increasing depth increases the actual mass of air required for ventilation; but when the amount of air is expressed in volumes as measured at chamber pressure, increasing depth does not change the number of actual cubic feet (acfm) required.
- If high-pressure air banks are being used for the chamber supply, pressure changes in the cylinders can be used to check the amount of ventilation being provided.

18-6 CHAMBER MAINTENANCE

- 18-6.1 Postdive Checklist.** To ensure equipment receives proper postdive maintenance and is returned to operational readiness, perform the equipment checks listed in the Recompression Chamber Postdive Checklist, [Figure 18-14](#).
- 18-6.2 Scheduled Maintenance.** Every USN recompression chamber shall adhere to PMS requirements and shall be pressure tested when initially installed, at 2-year intervals thereafter, and after a major overhaul or repair. This test shall adhere to PMS requirements and shall be conducted in accordance with [Figure 18-15](#). The completed test form shall be retained until retest is conducted. For a permanently installed chamber, removing and reinstalling constitutes a major overhaul and requires a pressure test. For portable chambers such as the TRCS, SNDLRCS, and FARCC, follow operating procedures after moving the chamber prior to

RECOMPRESSION CHAMBER POSTDIVE CHECKLIST	
Equipment	Initials
Air Supply	
All valves closed	
Air banks recharged, gauged, and pressure recorded	
Compressors fueled and maintained per technical manual/PMS requirements	
View Ports and Doors	
View-ports checked for damage; replaced as necessary	
Door seals checked, replaced as necessary	
Door seals lightly lubricated with approved lubricant	
Door dogs and dogging mechanism checked for proper operation and shaft seals for tightness	
Chamber	
Inside wiped clean with Nonionic Detergent (NID) and warm fresh water	
All unnecessary support items removed from chamber	
Blankets cleaned and replaced	
All flammable material in chamber encased in fire-resistant containers	
Primary medical kit restocked as required	
Chamber aired out	
Outer door closed	
CO ₂ canister packed	
Deckplates lifted, area below deckplates cleaned, deckplates reinstalled	
Support Items	
Stopwatches checked and reset	
<i>U.S. Navy Diving Manual</i> , Operating Procedures (OPs), Emergency Procedures (EPs), ventilation bill and pencil available at control desk	
Secondary medical kit restocked as required and stowed	
Clothing cleaned and stowed	
All entries made in chamber log book	
Chamber log book stowed	

Figure 18-14. Recompression Chamber Postdive Checklist (sheet 1 of 2).

RECOMPRESSION CHAMBER POSTDIVE CHECKLIST	
Equipment	Initials
Oxygen Supply	
BIBS mask removed, cleaned per current PMS procedures, reinstalled	
All valves closed	
System bled	
Breathing oxygen cylinders fully pressurized	
Spare cylinders available	
System free of contamination	
Exhaust System	
One-valve exhaust: valves closed	
Two-valve exhaust: inside valves closed	
Two-valve exhaust: outside valves opened	
Electrical	
All circuits checked	
Light bulbs replaced as necessary	
Pressure-proof housing of lights checked	
All power OFF	
Wiring checked for fraying	

Figure 18-14. Recompression Chamber Postdive Checklist (sheet 2 of 2).

manned use. Chamber relief valves shall be tested in accordance with the Planned Maintenance System to verify setting. Each tested relief valve shall be tagged to indicate the valve set pressure, date of test, and testing activity. After every use or once a month, whichever comes first, the chamber shall receive routine maintenance in accordance with the Postdive Checklist. At this time, minor repairs shall be made and used supplies shall be restocked.

- 18-6.2.1 **Inspections.** At the discretion of the activity, but at least once a year, the chamber shall be inspected, both inside and outside. Any deposits of grease, dust, or other dirt shall be removed and, on steel chambers, the affected areas repainted.
- 18-6.2.2 **Corrosion.** Corrosion is removed best by hand or by using a scraper, being careful not to gouge or otherwise damage the base metal. The corroded area and a small area around it should then be cleaned to remove any remaining paint and/or corrosion.
- 18-6.2.3 **Painting Steel Chambers.** Steel Chambers shall be painted utilizing original paint specifications and in accordance with approved NAVSEA or NAVFAC procedures. The following paints shall be utilized on NAVSEA carbon steel chambers:

PRESSURE TEST FOR USN RECOMPRESSION CHAMBERS

NOTE

All U.S. Navy Standard recompression chambers are restricted to a maximum operating pressure of 100 psig, regardless of design pressure rating.

A pressure test shall be conducted on every USN recompression chamber:

- When initially installed
- After repairs/overhaul
- At two-year intervals at a given location

Performance of the test and the test results are recorded on a standard U.S. Navy Recompression Chamber Air Pressure and Leak Test form ([Figure 18-15](#)).

The test is conducted as follows:

1. Pressurize the innermost lock to 100 fsw (45 psig). Using soapy water or an equivalent solution, leak test all shell penetration fittings, view-ports, dog seals, door dogs (where applicable), valve connections, pipe joints, and shell weldments.
2. Mark all leaks. Depressurize the lock and adjust, repair, or replace components as necessary to eliminate leaks.
 - a. View-Port Leaks. Remove the view-port gasket (replace if necessary), wipe clean.

CAUTION

Acrylic view-ports should not be lubricated or come in contact with any lubricant. Acrylic view-ports should not come in contact with any volatile detergent or leak detector (non-ionic detergent is to be used for leak test). When reinstalling view-port, take up retaining ring bolts until the gasket just compresses evenly about the view-port. Do not overcompress the gasket.

- b. Weldment Leaks. Contact appropriate NAVSEA technical authority for guidance on corrective action.
3. Repeat steps 1 and 2 until all the leaks have been eliminated.
4. Pressurize lock to 225 fsw (100 psig) and hold for 5 minutes.

WARNING

Do not exceed maximum pressure rating for the pressure vessel.

5. Depressurize the lock to 165 fsw (73.4 psig). Hold for 1 hour. If pressure drops below 145 fsw (65 psig), locate and mark leaks. Depressurize chamber and repair leaks in accordance with Step 2 above and repeat this procedure until final pressure is at least 145 fsw (65 psig).
6. Repeat Steps 1 through 5 leaving the inner door open and outer door closed. Leak test only those portions of the chamber not previously tested.

Figure 18-15. Pressure Test for USN Recompression Chambers (sheet 1 of 3).

**STANDARD U.S. NAVY RECOMPRESSION CHAMBER
AIR PRESSURE AND LEAK TEST
(Sheet 2 of 3)**

Ship/Platform/Facility _____

Type of Chamber:

Recompression Chamber Facility - RCF5000	Double-Lock Steel
Recompression Chamber Facility - RCF6500	Standard Navy Double Lock Recompression
Transportable Recompression Chamber (TRC)	Chamber System (SNDLRCs)
Fly-Away Recompression Chamber (FARCC)	Other*

NAME PLATE DATA

Manufacturer _____

Date of Manufacture _____

Contract/Drawing No. _____

Maximum Working Pressure _____

Date of Last Pressure Test

Test Conducted by _____

- #### 1. Conduct visual inspection of chamber to determine if ready for test

Conduct visual inspection of chamber to determine if ready for test
Chamber Satisfactory _____ Initials of Test Conductor _____

Discrepancies from fully inoperative chamber equipment:

2 Close inner door lock. With outer lock door open pressure inner lock to 100 fsw (45 psig) and verify that the following components do not leak:

(Note: If chamber has medical lock, open inner door and close and secure outer door.)

A. Shell penetrations and fittings

Satisfactory

C. Door Seals _____ Satisfactory

D. Door Dog Shaft Seals

E. Value Connections and Stems

Satisfactory

F. Pipe joints Satisfactory

G. Shell Welds

5. Increase inner lock pressure to 225 lsw (100 psig) and hold for 5 minutes.
Record Test Pressure _____ Satisfactory _____

Record Test Pressure _____ Satisfactory _____

(Note. Disregard small leaks at this pressure).

Figure 18-15. Pressure Test for USN Recompression Chambers (sheet 2 of 3).

**STANDARD U.S. NAVY RECOMPRESSION CHAMBER
AIR PRESSURE AND LEAK TEST**
(Sheet 3 of 3)

4. Depressurize lock slowly to 165 fsw (73.4 psig). Secure all supply and exhaust valves and hold for one hour.

Start Time _____ Pressure 165 fsw

End Time _____ Pressure _____ fsw

If pressure drops below 145 fsw (65 psig) locate and mark leaks. Depressurize, repair, and retest inner lock.

Inner Lock Pressure drop test passed _____ Satisfactory Initials of Test Conductor.

5. Depressurize inner lock and open inner lock door. Secure in open position. Close outer door and secure.

(Note: If chamber has medical lock, close and secure inner door and open outer door.)

6. Repeat tests of sections 2, 3, and 4 above when set up in accordance with section 5. Leak test only those portions of the chamber not tested in sections 2, 3, and 4.

A. Shell penetrations and fittings

B. View Ports

8. Deep Sacks

Satisfactory

B. Deer Dog Craft Seals _____ Satisfactory

E. Valve Connections and Stems

F. Pipe Joints

G. Shell Welds

Satisfactory

8. Maximum Chamber Operating Pressure (100 psig) Test (5 minute hold)

Satisfactory _____ Initials of Test Conductor

- #### 9. Inner and Outer Lock Chamber Drop Test

Start Time _____ Pressure 165 fsw

End Time _____ Pressure _____ fsw

Inner and outer lock pressure drop test passed satisfactorily _____ Initials of Test Conductor

10. All above tests have been satisfactorily completed.

Test Director Date

Figure 18-15. Pressure Test for USN Recompression Chambers (sheet 3 of 3).

- Inside:
 - Prime coat NSN 8010-01-302-3608.
 - Finish coat white NSN 8010-01-302-3606.

- Outside:
 - Prime coat NSN 8010-01-302-3608.
 - Exterior coats gray NSN 8010-01-302-6838 or white NSN 8010-01-302-3606.

For original paint specification on NAVFAC steel chambers refer to the Operation and Maintenance Support Information (OMSI) documentation delivered with the system.

18-6.2.4 **Recompression Chamber Paint Process Instruction.** Painting shall be kept to an absolute minimum. Only the coats prescribed above are to be applied. Naval Sea Systems Command will issue a Recompression Chamber Paint Process Instruction (NAVSEA-00C3-PI-001) on request.

18-6.2.5 **Stainless Steel Chambers.** Stainless steel chamber such as the TRCS and SNDLRCS do not require surfaces painted for corrosion resistance, only for cosmetic purposes. Naval Sea Systems Command will provide a Stainless Steel Recompression Chamber Paint Process Instruction on request.

18-6.2.6 **Fire Hazard Prevention.** The greatest single hazard in the use of a recompression chamber is from explosive fire. Fire may spread two to six times faster in a pressurized chamber than at atmospheric conditions because of the high partial pressure of oxygen in the chamber atmosphere. The following precautions shall be taken to minimize fire hazard:

- Maintain the chamber oxygen percentage as close to 21 percent as possible and never allow oxygen percentage to exceed 25 percent.

- Remove any fittings or equipment that do not conform with the standard requirements for the electrical system or that are made of flammable materials. Permit no wooden deck gratings, benches, or shelving in the chamber.

- Use only mattresses designed for hyperbaric chambers. Use Durett Product or submarine mattress (NSN 7210-00-275-5878 or 5874). Other mattresses may cause atmospheric contamination. Mattresses should be enclosed in flame-proof covers. Use 100% cotton sheets and pillow cases. Put no more bedding in a chamber than is necessary for the comfort of the patient. Never use blankets of wool or synthetic fibers because of the possibility of sparks from static electricity.

- Clothing worn by chamber occupants shall be made of 100% cotton, or a flame resistant blend of cotton and polyester for chambers equipped with a fire extinguisher or fixed hand-held or fire suppression system. Diver swim trunks made of 65% polyester 35% cotton material are acceptable.
- Keep oil and volatile materials out of the chamber. If any have been used, ensure that the chamber is thoroughly ventilated before pressurization. Do not put oil on or in any fittings or high-pressure line. If oil is spilled in the chamber or soaked into any chamber surface or equipment, it must be completely removed. If lubricants are required, use only those approved and listed in *Naval Ships Technical Manual* (NSTM) NAVSEA S9086-H7-STM-000, Chapter 262. Regularly inspect and clean air filters and accumulators in the air supply lines to protect against the introduction of oil or other vapors into the chamber. Permit no one to wear oily clothing into the chamber.
- Permit no one to carry smoking materials, matches, lighters or any flammable materials into a chamber. A WARNING sign should be posted outside the chamber. Example:

WARNING

Fire/Explosion Hazard. No matches, lighters, electrical appliances, or flammable materials permitted in chamber.

18-6.2.6.1 **Fire Extinguishing.** All recompression chambers must have a means of extinguishing a fire in the interior. Examples of fire protection include wetted towels, a bucket of water, fire extinguisher, hand-held hose system, or suppression/deluge system. Refer to U.S. Navy General Specification for the Design, Construction, and Repair of Diving and Hyperbaric Equipment (TS500-AU-SPN-010) for specific requirements of fire protection systems. Only fire extinguishers listed on the NAVSEA Authorization for Navy Use (ANU) are to be used.

18-7 DIVER CANDIDATE PRESSURE TEST

All U.S. Navy diver candidates shall be physically qualified in accordance with the *Manual of the Medical Department*, Art. 15-102. Candidates shall also pass a pressure test before they are eligible for diver training. This test may be conducted at any Navy certified recompression chamber, provided it is administered by qualified chamber personnel.

18-7.1 **Candidate Requirements.** The candidate must demonstrate the ability to equalize pressure in both ears to a depth of 60 fsw. The candidate shall have also passed the screening physical readiness test in accordance with MILPERSMAN 1220-100, Exhibit 1.

18-7.1.1 **Aviation Duty Personnel.** In accordance with the Manual of the Medical Department, Art. 15-102, Aviation Duty personnel with documented medical concerns about their ability to safely tolerate barometric changes, may be evaluated with a modified Diver Candidate Pressure Test, which shall be medically

supervised by a UMO. A modified Diver Candidate Pressure Test does not meet the requirement of a standard Diver Candidate Pressure Test.

18-7.2

Procedure.

1. Candidates shall undergo a diving physical examination by a Navy Medical Officer in accordance with the *Manual of the Medical Department*, Art. 15-102, and be qualified to undergo the test.
 - Aviation Duty personnel requiring pressure testing due to medical concerns do not require a Diving Duty physical examination, as per MANMED, Art. 15-102.
2. The candidates and the tender enter the recompression chamber and are pressurized to 60 fsw on air, at a rate of 75 fpm or less as tolerated by the occupants.
 - Descent rates for modified Diver Candidate Pressure Tests administered for Aviation Duty personnel shall be limited to a maximum of 10 fpm. The UMO may modify the descent rate to best achieve the clinical evaluation as long as the modifications are more conservative (i.e. slower) than the standard Diver Candidate Pressure Test.
3. If a candidate cannot complete the descent, the chamber is stopped and the candidate is placed in the outer lock for return to the surface.
4. Stay at 60 fsw for at least 10 minutes.
5. Ascend to the surface following standard air decompression procedures.
6. All candidates shall remain at the immediate chamber site for a minimum of 15 minutes and at the test facility for 1 hour. Candidates or tenders who must return to their command via air travel must proceed in accordance with paragraph 9-14.

18-7.2.1

References.

- *Navy Military Personnel Manual*, Art. 1220-100
- *Manual of the Medical Department*, Art. 15-102

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APPENDIX 5A

Neurological Examination

5A-1 INTRODUCTION

This appendix provides guidance on evaluating diving accidents prior to treatment. [Figure 5A-1a](#) is a guide aimed at non-medical personnel for recording essential details and conducting a neurological examination. Copies of this form should be readily available. While its use is not mandatory, it provides a useful aid for gathering information.

5A-2 INITIAL ASSESSMENT OF DIVING INJURIES

When using the form in [Figure 5A-1a](#), the initial assessment must gather the necessary information for proper evaluation of the accident.

When a diver reports with a medical complaint, a history of the case shall be compiled. This history should include facts ranging from the dive profile to progression of the medical problem. If available, review the diver's Health Record and completed Diving Chart or Diving Log to aid in the examination. A few key questions can help determine a preliminary diagnosis and any immediate treatment needed. If the preliminary diagnosis shows the need for immediate recompression, proceed with recompression. Complete the examination when the patient stabilizes at treatment depth. Typical questions should include the following:

- 1.** What is the problem/symptom? If the only symptom is pain:
 - a.** Describe the pain:
 - Sharp
 - Dull
 - Throbbing
 - b.** Is the pain localized, or hard to pinpoint?
- 2.** Has the patient made a dive recently?
- 3.** What was the dive profile?
 - a.** What was the depth of the dive?
 - b.** What was the bottom time?
 - c.** What dive rig was used?
 - d.** What type of work was performed?
 - e.** Did anything unusual occur during the dive?

4. How many dives has the patient made in the last 24 hours?
 - a. Chart profile(s) of any other dive(s).
5. Were the symptoms first noted before, during, or after the dive? If after the dive, how long after surfacing?
6. If during the dive, did the patient notice the symptom while descending, on the bottom, or during ascent?
7. Has the symptom either increased or decreased in intensity since first noticed?
8. Have any additional symptoms developed since the first one?
9. Has the patient ever had a similar symptom?
10. Has the patient ever suffered from decompression sickness or gas embolism in the past?
 - a. Describe this symptom in relation to the prior incident if applicable.
11. Does the patient have any concurrent medical conditions that might explain the symptoms?

To aid in the evaluation, review the diver's Health Record, including a baseline neurological examination, if available, and completed Diving Chart or Diving Log, if they are readily available.

5A-3 NEUROLOGICAL ASSESSMENT

There are various ways to perform a neurological examination. The quickest information pertinent to the diving injury is obtained by directing the initial examination toward the symptomatic areas of the body. These concentrate on the motor, sensory, and coordination functions. If this examination is normal, the most productive information is obtained by performing a complete examination of the following:

1. Mental status
2. Coordination
3. Motor
4. Cranial nerves
5. Sensory
6. Deep tendon reflexes

The following procedures are adequate for preliminary examination. [Figure 5A-1a](#) can be used to record the results of the examination.

NEUROLOGICAL EXAMINATION CHECKLIST

(Sheet 1 of 2)

(See text of Appendix 5A for examination procedures and definitions of terms.)

Patient's Name: _____ Date/Time: _____

Describe pain/numbness: _____

HISTORY

Type of dive last performed: _____ Depth: _____ How long: _____

Number of dives in last 24 hours: _____

Was symptom noticed before, during or after the dive? _____

If during, was it while descending, on the bottom or ascending? _____

Has symptom increased or decreased since it was first noticed? _____

Have any other symptoms occurred since the first one was noticed? _____

Describe: _____

Has patient ever had a similar symptom before? _____ When: _____

MENTAL STATUS/STATE OF CONSCIOUSNESS

COORDINATION

Walk: _____

Heel-to Toe: _____

Romberg: _____

Finger-to-Nose: _____

Heel Shin Slide: _____

Rapid Movement: _____

STRENGTH (Grade 0 to 5)

UPPER BODY

Deltoids L _____ R _____

Latissimus L _____ R _____

Biceps L _____ R _____

Triceps L _____ R _____

Forearms L _____ R _____

Hand L _____ R _____

CRANIAL NERVES

Sense of Smell (I): _____

Vision/Visual Fld (II): _____

Eye Movements, Pupils (III, IV, VI): _____

Facial Sensation, Chewing (V): _____

Facial Expression Muscles (VII): _____

Hearing (VIII): _____

Upper Mouth, Throat Sensation (IX): _____

Gag & Voice (X): _____

Shoulder Shrug (XI): _____

Tongue (XII): _____

LOWER BODY

HIPS

Flexion L _____ R _____

Extension L _____ R _____

Abduction L _____ R _____

Adduction L _____ R _____

KNEES

Flexion L _____ R _____

Extension L _____ R _____

ANKLES

Dorsiflexion L _____ R _____

Plantarflexion L _____ R _____

TOES

L _____ R _____

Figure 5A-1a. Neurological Examination Checklist (sheet 1 of 2).

NEUROLOGICAL EXAMINATION CHECKLIST

(Sheet 2 of 2)

REFLEXES

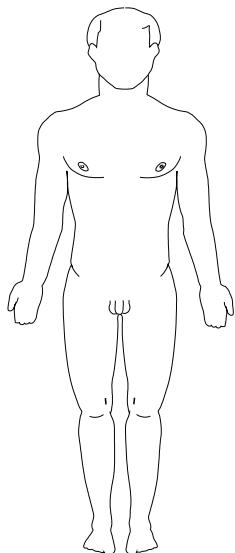
(Grade: Normal, Hypoactive, Hyperactive, Absent)

Biceps	L _____	R _____
Triceps	L _____	R _____
Knees	L _____	R _____
Ankles	L _____	R _____

Sensory Examination for Skin Sensation

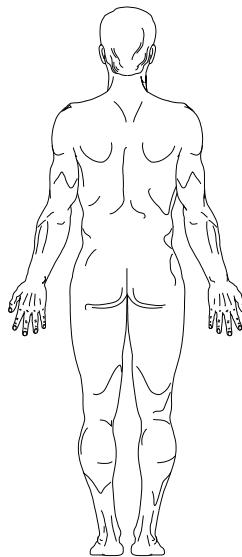
(Use diagram to record location of sensory abnormalities – numbness, tingling, etc.)

LOCATION



Indicate results
as follows:

- |||| Painful Area
- ===== Decreased Sensation



COMMENTS

Examination Performed by: _____

Figure 5A-1b. Neurological Examination Checklist (sheet 2 of 2).

5A-3.1 **Mental Status.** This is best determined when you first see the patient and is characterized by his alertness, orientation, and thought process. Obtain a good history, including the dive profile, present symptoms, and how these symptoms have changed since onset. The patient's response to this questioning and that during the neurological examination will give you a great deal of information about his mental status. It is important to determine if the patient knows the time and place, and can recognize familiar people and understands what is happening. Is the patient's mood appropriate?

Next the examiner may determine if the patient's memory is intact by questioning the patient. The questions asked should be reasonable, and you must know the answer to the questions you ask. Questions such as the following may be helpful:

- What is your commanding officer's name?
- What did you have for lunch?

Finally, if a problem does arise in the mental status evaluation, the examiner may choose to assess the patient's cognitive function more fully. Cognitive function is an intellectual process by which one becomes aware of, perceives, or comprehends ideas and involves all aspects of perception, thinking, reasoning, and remembering. Some suggested methods of assessing this function are:

- The patient should be asked to remember something. An example would be "red ball, green tree, and couch." Inform him that later in the examination you will ask him to repeat this information.
- The patient should be asked to spell a word, such as "world," backwards.
- The patient should be asked to count backwards from 100 by sevens.
- The patient should be asked to recall the information he was asked to remember at the end of the examination.

5A-3.2 **Coordination (Cerebellar/Inner Ear Function).** A good indicator of muscle strength and general coordination is to observe how the patient walks. A normal gait indicates that many muscle groups and general brain functions are normal. More thorough examination involves testing that concentrates on the brain and inner ear. In conducting these tests, both sides of the body shall be tested and the results shall be compared. These tests include:

1. **Heel-to-Toe Test.** The tandem walk is the standard "drunk driver" test. While looking straight ahead, the patient must walk a straight line, placing the heel of one foot directly in front of the toes of the opposite foot. Signs to look for and consider deficits include:
 - a. Does the patient limp?
 - b. Does the patient stagger or fall to one side?

2. **Romberg Test.** With eyes closed, the patient stands with feet together and arms extended to the front, palms up. Note whether the patient can maintain his balance or if he immediately falls to one side. Some examiners recommend giving the patient a small shove from either side with the fingertips.
3. **Finger-to-Nose Test.** The patient stands with eyes closed and head back, arms extended to the side. Bending the arm at the elbow, the patient touches his nose with an extended forefinger, alternating arms. An extension of this test is to have the patient, with eyes open, alternately touch his nose with his fingertip and then touch the fingertip of the examiner. The examiner will change the position of his fingertip each time the patient touches his nose. In this version, speed is not important, but accuracy is.
4. **Heel-Shin Slide Test.** While standing, the patient touches the heel of one foot to the knee of the opposite leg, foot pointing forward. While maintaining this contact, he runs his heel down the shin to the ankle. Each leg should be tested.
5. **Rapid Alternating Movement Test.** The patient slaps one hand on the palm of the other, alternating palm up and then palm down. Any exercise requiring rapidly changing movement, however, will suffice. Again, both sides should be tested.

5A-3.3

Cranial Nerves. The cranial nerves are the 12 pairs of nerves emerging from the cranial cavity through various openings in the skull. Beginning with the most anterior (front) on the brain stem, they are appointed Roman numerals. An isolated cranial nerve lesion is an unusual finding in decompression sickness or gas embolism, but deficits occasionally occur and you should test for abnormalities. The cranial nerves must be quickly assessed as follows:

- I. **Olfactory.** The olfactory nerve, which provides our sense of smell, is usually not tested.
- II. **Optic.** The optic nerve is for vision. It functions in the recognition of light and shade and in the perception of objects. This test should be completed one eye at a time to determine whether the patient can read. Ask the patient if he has any blurring of vision, loss of vision, spots in the visual field, or peripheral vision loss (tunnel vision). More detailed testing can be done by standing in front of the patient and asking him to cover one eye and look straight at you. In a plane midway between yourself and the patient, slowly bring your fingertip in turn from above, below, to the right, and to the left of the direction of gaze until the patient can see it. Compare this with the earliest that you can see it with the equivalent eye. If a deficit is present, roughly map out the positions of the blind spots by passing the finger tip across the visual field.
- III. **Oculomotor, (IV.) Trochlear, (VI.) Abducens.** These three nerves control eye movements. All three nerves can be tested by having the patient's eyes follow the examiner's finger in all four directions (quadrants) and then in towards the tip of the nose (giving a "crossed-eyed" look). The oculomotor nerve can be

further tested by shining a light into one eye at a time. In a normal response, the pupils of both eyes will constrict.

V. Trigeminal. The Trigeminal Nerve governs sensation of the forehead and face and the clenching of the jaw. It also supplies the muscle of the ear (tensor tympani) necessary for normal hearing. Sensation is tested by lightly stroking the forehead, face, and jaw on each side with a finger or wisp of cotton wool.

VII. Facial. The Facial Nerve controls the face muscles. It stimulates the scalp, forehead, eyelids, muscles of facial expression, cheeks, and jaw. It is tested by having the patient smile, show his teeth, whistle, wrinkle his forehead, and close his eyes tightly. The two sides should perform symmetrically. Symmetry of the nasolabial folds (lines from nose to outside corners of the mouth) should be observed.

VIII. Acoustic. The Acoustic Nerve controls hearing and balance. Test this nerve by whispering to the patient, rubbing your fingers together next to the patient's ears, or putting a tuning fork near the patient's ears. Compare this against the other ear.

IX. Glossopharyngeal. The Glossopharyngeal Nerves transmit sensation from the upper mouth and throat area. It supplies the sensory component of the gag reflex and constriction of the pharyngeal wall when saying "aah." Test this nerve by touching the back of the patient's throat with a tongue depressor. This should cause a gagging response. This nerve is normally not tested.

X. Vagus. The Vagus Nerve has many functions, including control of the roof of the mouth and vocal cords. The examiner can test this nerve by having the patient say "aah" while watching for the palate to rise. Note the tone of the voice; hoarseness may also indicate vagus nerve involvement.

XI. Spinal Accessory. The Spinal Accessory Nerve controls the turning of the head from side to side and shoulder shrug against resistance. Test this nerve by having the patient turn his head from side to side. Resistance is provided by placing one hand against the side of the patient's head. The examiner should note that an injury to the nerve on one side will cause an inability to turn the head to the opposite side or weakness/absence of the shoulder shrug on the affected side.

XII. Hypoglossal. The Hypoglossal Nerve governs the muscle activity of the tongue. An injury to one of the hypoglossal nerves causes the tongue to twist to that side when stuck out of the mouth.

5A-3.4 Motor. A diver with decompression sickness may experience disturbances in the muscle system. The range of symptoms can be from a mild twitching of a muscle to weakness and paralysis. No matter how slight the abnormality, symptoms involving the motor system shall be treated.

5A-3.4.1 **Extremity Strength.** It is common for a diver with decompression illness to experience muscle weakness. Extremity strength testing is divided into two parts: upper body and lower body. All muscle groups should be tested and compared with the corresponding group on the other side, as well as with the examiner. [Table 5A-1](#) describes the extremity strength tests in more detail. Muscle strength is graded (0-5) as follows:

- (0) **Paralysis.** No motion possible.
- (1) **Profound Weakness.** Flicker or trace of muscle contraction.
- (2) **Severe Weakness.** Able to contract muscle but cannot move joint against gravity.
- (3) **Moderate Weakness.** Able to overcome the force of gravity but not the resistance of the examiner.
- (4) **Mild Weakness.** Able to resist slight force of examiner.
- (5) **Normal.** Equal strength bilaterally (both sides) and able to resist examiner.

5A-3.4.1.1 **Upper Extremities.** These muscles are tested with resistance provided by the examiner. The patient should overcome force applied by the examiner that is tailored to the patient's strength. [Table 5A-1](#) describes the extremity strength tests. The six muscle groups tested in the upper extremity are:

1. Deltoids.
2. Latissimus.
3. Biceps.
4. Triceps.
5. Forearm muscles.
6. Hand muscles.

5A-3.4.1.2 **Lower Extremities.** The lower extremity strength is assessed by watching the patient walk on his heels for a short distance and then on his toes. The patient should then walk while squatting ("duck walk"). These tests adequately assess lower extremity strength, as well as balance and coordination. If a more detailed examination of the lower extremity strength is desired, testing should be accomplished at each joint as in the upper arm.

5A-3.4.2 **Muscle Size.** Muscles are visually inspected and felt, while at rest, for size and consistency. Look for symmetry of posture and of muscle contours and outlines. Examine for fine muscle twitching.

5A-3.4.3 **Muscle Tone.** Feel the muscles at rest and the resistance to passive movement. Look and feel for abnormalities in tone such as spasticity, rigidity, or no tone.

5A-3.4.4 **Involuntary Movements.** Inspection may reveal slow, irregular, and jerky movements, rapid contractions, tics, or tremors.

5A-3.5 **Sensory Function.** Common presentations of decompression sickness in a diver that may indicate spinal cord dysfunction are:

Table 5A-1. Extremity Strength Tests.

Test	Procedure
Deltoid Muscles	The patient raises his arm to the side at the shoulder joint. The examiner places a hand on the patient's wrist and exerts a downward force that the patient resists.
Latissimus Group	The patient raises his arm to the side. The examiner places a hand on the underside of the patient's wrist and resists the patient's attempt to lower his arm.
Biceps	The patient bends his arm at the elbow, toward his chest. The examiner then grasps the patient's wrist and exerts a force to straighten the patient's arm.
Triceps	The patient bends his arm at the elbow, toward his chest. The examiner then places his hand on the patient's forearm and the patient tries to straighten his arm.
Forearm Muscles	The patient makes a fist. The examiner grips the patient's fist and resists while the patient tries to bend his wrist upward and downward.
Hand Muscles	<ul style="list-style-type: none">• The patient strongly grips the examiner's extended fingers.• The patient extends his hand with the fingers widespread. The examiner grips two of the extended fingers with two of his own fingers and tries to squeeze the patient's two fingers together, noting the patient's strength of resistance.
Lower Extremity Strength	<ul style="list-style-type: none">• The patient walks on his heels for a short distance. The patient then turns around and walks back on his toes.• The patient walks while squatting (duck walk). <p>These tests adequately assesses lower extremity strength as well as balance and coordination. If a more detailed examination of lower extremity strength is desired, testing should be accomplished at each joint as in the upper arm.</p>

In the following tests, the patient sits on a solid surface such as a desk, with feet off the floor.

Hip Flexion	The examiner places his hand on the patient's thigh to resist as the patient tries to raise his thigh.
Hip Extension	The examiner places his hand on the underside of the patient's thigh to resist as the patient tries to lower his thigh.
Hip Abduction	The patients sits as above, with knees together. The examiner places a hand on the outside of each of the patient's knees to provide resistance. The patient tries to open his knees.
Hip Adduction	The patient sits as above, with knees apart. The examiner places a hand on the inside of each of the patient's knees to provide resistance. The patient tries to bring his knees together.
Knee Extension	The examiner places a hand on the patient's shin to resist as the patient tries to straighten his leg.
Knee Flexion	The examiner places a hand on the back of the patient's lower leg to resist as the patient tries to pull his lower leg to the rear by flexing his knee.
Ankle Dorsiflexion (ability to flex the foot toward the rear)	The examiner places a hand on top of the patient's foot to resist as the patient tries to raise his foot by flexing it at the ankle.
Ankle Plantarflexion (ability to flex the foot downward)	The examiner places a hand on the bottom of the patient's foot to resist as the patient tries to lower his foot by flexing it at the ankle.
Toes	<ul style="list-style-type: none">• The patient stands on tiptoes for 15 seconds• The patient flexes his toes with resistance provided by the examiner.

- Pain
- Numbness
- Tingling (“pins-and-needles” feeling; also called paresthesia)

- 5A-3.5.1 **Sensory Examination.** An examination of the patient’s sensory faculties should be performed. [Figures 5A-2a](#) and [5A-2b](#) show the dermatomal (sensory) areas of skin sensations that correlate with each spinal cord segment. Note that the dermatomal areas of the trunk run in a circular pattern around the trunk. The dermatomal areas in the arms and legs run in a more lengthwise pattern. In a complete examination, each spinal segment should be checked for loss of sensation.
- 5A-3.5.2 **Sensations.** Sensations easily recognized by most normal people are sharp/dull discrimination (to perceive as separate) and light touch. It is possible to test pressure, temperature, and vibration in special cases. The likelihood of DCS affecting only one sense, however, is very small.
- 5A-3.5.3 **Instruments.** An ideal instrument for testing changes in sensation is a sharp object, such as the Wartenberg pinwheel or a common safety pin. Either of these objects must be applied at intervals. Avoid scratching or penetrating the skin. It is not the intent of this test to cause pain.
- 5A-3.5.4 **Testing the Trunk.** Move the pinwheel or other sharp object from the top of the shoulder slowly down the front of the torso to the groin area. Another method is to run it down the rear of the torso to just below the buttocks. The patient should be asked if he feels a sharp point and if he felt it all the time. Test each dermatome by going down the trunk on each side of the body. Test the neck area in similar fashion.
- 5A-3.5.5 **Testing Limbs.** In testing the limbs, a circular pattern of testing is best. Test each limb in at least three locations, and note any difference in sensation on each side of the body. On the arms, circle the arm at the deltoid, just below the elbow, and at the wrist. In testing the legs, circle the upper thigh, just below the knee, and the ankle.
- 5A-3.5.6 **Testing the Hands.** The hand is tested by running the sharp object across the back and palm of the hand and then across the fingertips.
- 5A-3.5.7 **Marking Abnormalities.** If an area of abnormality is found, mark the area as a reference point in assessment. Some examiners use a marking pen to trace the area of decreased or increased sensation on the patient’s body. During treatment, these areas are rechecked to determine whether the area is improving. An example of improvement is an area of numbness getting smaller.
- 5A-3.6 **Deep Tendon Reflexes.** The purpose of the deep tendon reflexes is to determine if the patient’s response is normal, nonexistent, hypoactive (deficient), or hyperactive (excessive). The patient’s response should be compared to responses the examiner has observed before. Notation should be made of whether the responses are equal bilaterally (both sides) and if the upper and lower reflexes are similar. If any difference in the reflexes is noticed, the patient should be asked if there is a prior

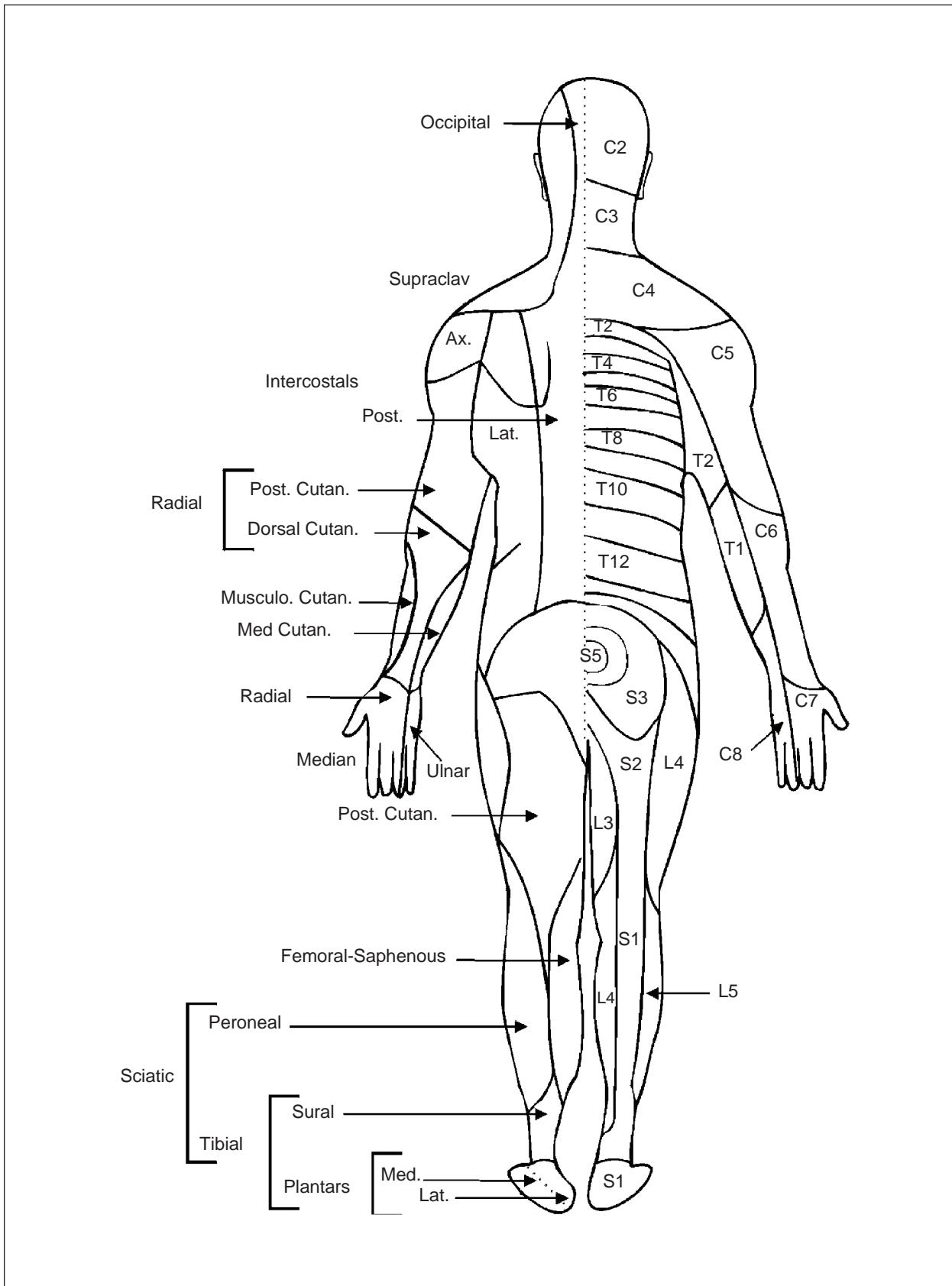


Figure 5A-2a. Dermatomal Areas Correlated to Spinal Cord Segment (sheet 1 of 2).

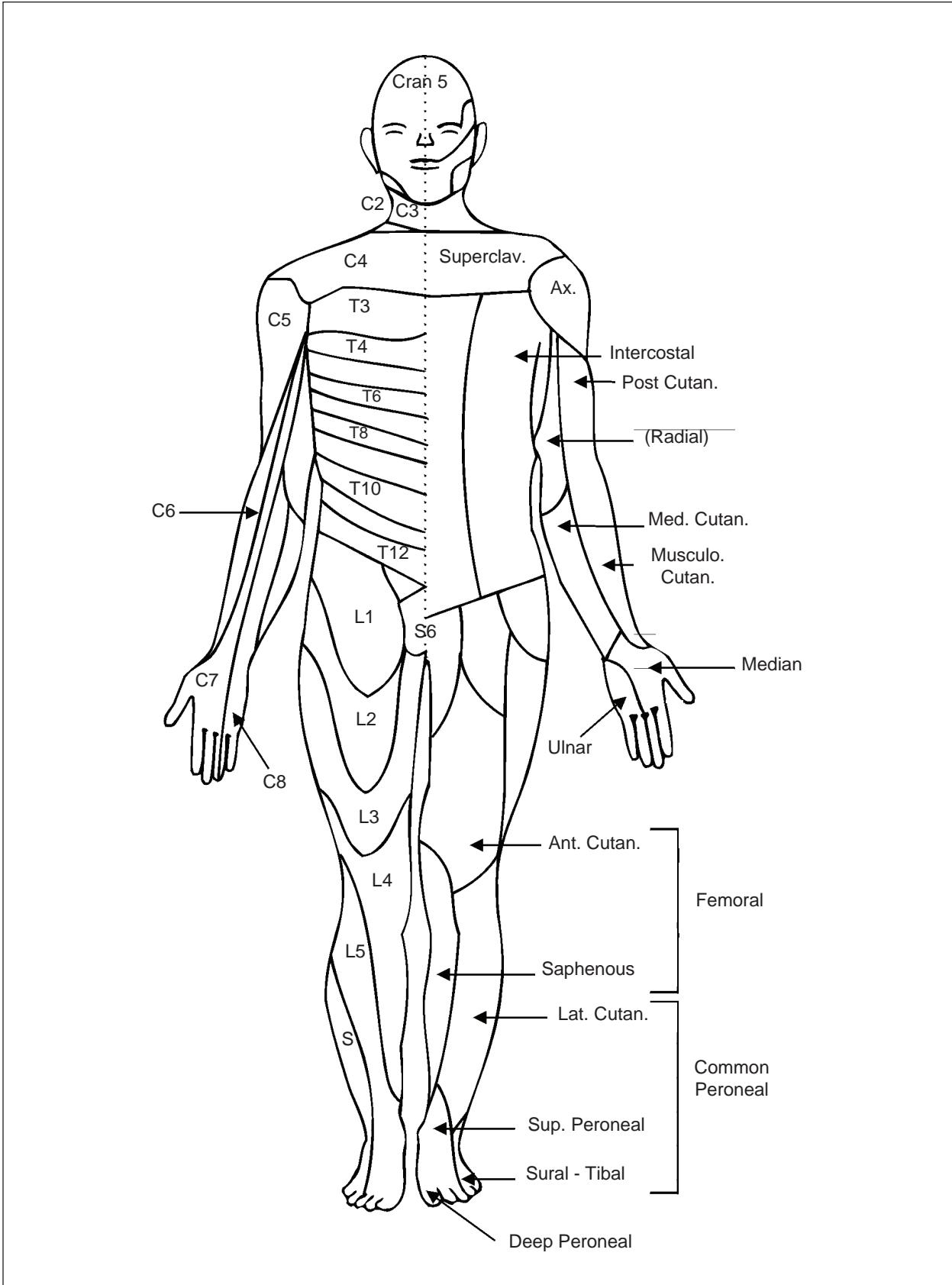


Figure 5A-2b. Dermatomal Areas Correlated to Spinal Cord Segment (sheet 2 of 2).

medical condition or injury that would cause the difference. Isolated differences should not be treated, because it is extremely difficult to get symmetrical responses bilaterally. To get the best response, strike each tendon with an equal, light force, and with sharp, quick taps. Usually, if a deep tendon reflex is abnormal due to decompression sickness, there will be other abnormal signs present. Test the biceps, triceps, knee, and ankle reflexes by striking the tendon as described in [Table 5A-2](#).

Table 5A-2. *Reflexes.*

Test	Procedure
Biceps	The examiner holds the patient's elbow with the patient's hand resting on the examiner's forearm. The patient's elbow should be slightly bent and his arm relaxed. The examiner places his thumb on the patient's biceps tendon, located in the bend of the patient's elbow. The examiner taps his thumb with the percussion hammer, feeling for the patient's muscle to contract.
Triceps	The examiner supports the patient's arm at the biceps. The patient's arm hangs with the elbow bent. The examiner taps the back of the patient's arm just above the elbow with the percussion hammer, feeling for the muscle to contract.
Knee	The patient sits on a table or bench with his feet off the deck. The examiner taps the patient's knee just below the kneecap, on the tendon. The examiner looks for the contraction of the quadriceps (thigh muscle) and movement of the lower leg.
Ankle	The patient sits as above. The examiner places slight pressure on the patient's toes to stretch the Achilles' tendon, feeling for the toes to contract as the Achilles' tendon shortens (contracts).

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APPENDIX 5B

First Aid

5B-1 INTRODUCTION

This appendix, covering one-man cardiopulmonary resuscitation, control of bleeding and shock treatment is intended as a quick reference for individuals trained in first aid and basic life support. Complete descriptions of all basic life support techniques are available through your local branch of the American Heart Association. Further information on the control of bleeding and treatment for shock is in the *Hospital Corpsman 3 & 2 Manual*, NAVEDTRA 10669-C.

5B-2 CARDIOPULMONARY RESUSCITATION

All divers must be qualified in cardiopulmonary resuscitation (CPR) in accordance with the procedures of the American Heart Association. Periodic recertification according to current guidelines in basic life support is mandatory for all Navy divers. Training can be requested through your local medical command or directly through your local branch of the American Heart Association.

5B-3 CONTROL OF MASSIVE BLEEDING

Massive bleeding must be controlled immediately. If the victim also requires resuscitation, the two problems must be handled simultaneously. Bleeding may involve veins or arteries; the urgency and method of treatment will be determined in part by the type and extent of the bleeding.

5B-3.1 External Arterial Hemorrhage. Arterial bleeding can usually be identified by bright red blood, gushing forth in jets or spurts that are synchronous with the pulse. The first measure used to control external arterial hemorrhage is direct pressure on the wound.

5B-3.2 Direct Pressure. Pressure is best applied with sterile compresses, placed directly and firmly over the wound. In a crisis, however, almost any material can be used. If the material used to apply direct pressure soaks through with blood, apply additional material on top; do not remove the original pressure bandage. Elevating the extremity also helps to control bleeding. If direct pressure cannot control bleeding, it should be used in combination with pressure points.

5B-3.3 Pressure Points. Bleeding can often be temporarily controlled by applying hand pressure to the appropriate pressure point. A pressure point is a place where the main artery to the injured part lies near the skin surface and over a bone. Apply pressure at this point with the fingers (digital pressure) or with the heel of the hand; no first aid materials are required. The object of the pressure is to compress the artery against the bone, thus shutting off the flow of blood from the heart to the wound.

- 5B-3.3.1 **Pressure Point Location on Face.** There are 11 principal points on each side of the body where hand or finger pressure can be used to stop hemorrhage. These points are shown in [Figure 5B-1](#). If bleeding occurs on the face below the level of the eyes, apply pressure to the point on the mandible. This is shown in [Figure 5B-1\(A\)](#). To find this pressure point, start at the angle of the jaw and run your finger forward along the lower edge of the mandible until you feel a small notch. The pressure point is in this notch.
- 5B-3.3.2 **Pressure Point Location for Shoulder or Upper Arm.** If bleeding is in the shoulder or in the upper part of the arm, apply pressure with the fingers behind the clavicle. You can press down against the first rib or forward against the clavicle—either kind of pressure will stop the bleeding. This pressure point is shown in [Figure 5B-1\(B\)](#).
- 5B-3.3.3 **Pressure Point Location for Middle Arm and Hand.** Bleeding between the middle of the upper arm and the elbow should be controlled by applying digital pressure in the inner (body) side of the arm, about halfway between the shoulder and the elbow. This compresses the artery against the bone of the arm. The application of pressure at this point is shown in [Figure 5B-1\(C\)](#). Bleeding from the hand can be controlled by pressure at the wrist, as shown in [Figure 5B-1\(D\)](#). If it is possible to hold the arm up in the air, the bleeding will be relatively easy to stop.
- 5B-3.3.4 **Pressure Point Location for Thigh.** [Figure 5B-1\(E\)](#) shows how to apply digital pressure in the middle of the groin to control bleeding from the thigh. The artery at this point lies over a bone and quite close to the surface, so pressure with your fingers may be sufficient to stop the bleeding.
- 5B-3.3.5 **Pressure Point Location for Foot.** [Figure 5B-1\(F\)](#) shows the proper position for controlling bleeding from the foot. As in the case of bleeding from the hand, elevation is helpful in controlling the bleeding.
- 5B-3.3.6 **Pressure Point Location for Temple or Scalp.** If bleeding is in the region of the temple or the scalp, use your finger to compress the main artery to the temple against the skull bone at the pressure point just in front of the ear. [Figure 5B-1\(G\)](#) shows the proper position.
- 5B-3.3.7 **Pressure Point Location for Neck.** If the neck is bleeding, apply pressure below the wound, just in front of the prominent neck muscle. Press inward and slightly backward, compressing the main artery of that side of the neck against the bones of the spinal column. The application of pressure at this point is shown in [Figure 5B-1\(H\)](#). Do not apply pressure at this point unless it is absolutely essential, since there is a great danger of pressing on the windpipe and thus choking the victim.
- 5B-3.3.8 **Pressure Point Location for Lower Arm.** Bleeding from the lower arm can be controlled by applying pressure at the elbow, as shown in [Figure 5B-1\(I\)](#).
- 5B-3.3.9 **Pressure Point Location of the Upper Thigh.** As mentioned before, bleeding in the upper part of the thigh can sometimes be controlled by applying digital pressure in the middle of the groin, as shown in [Figure 5B-1\(E\)](#). Sometimes, however, it

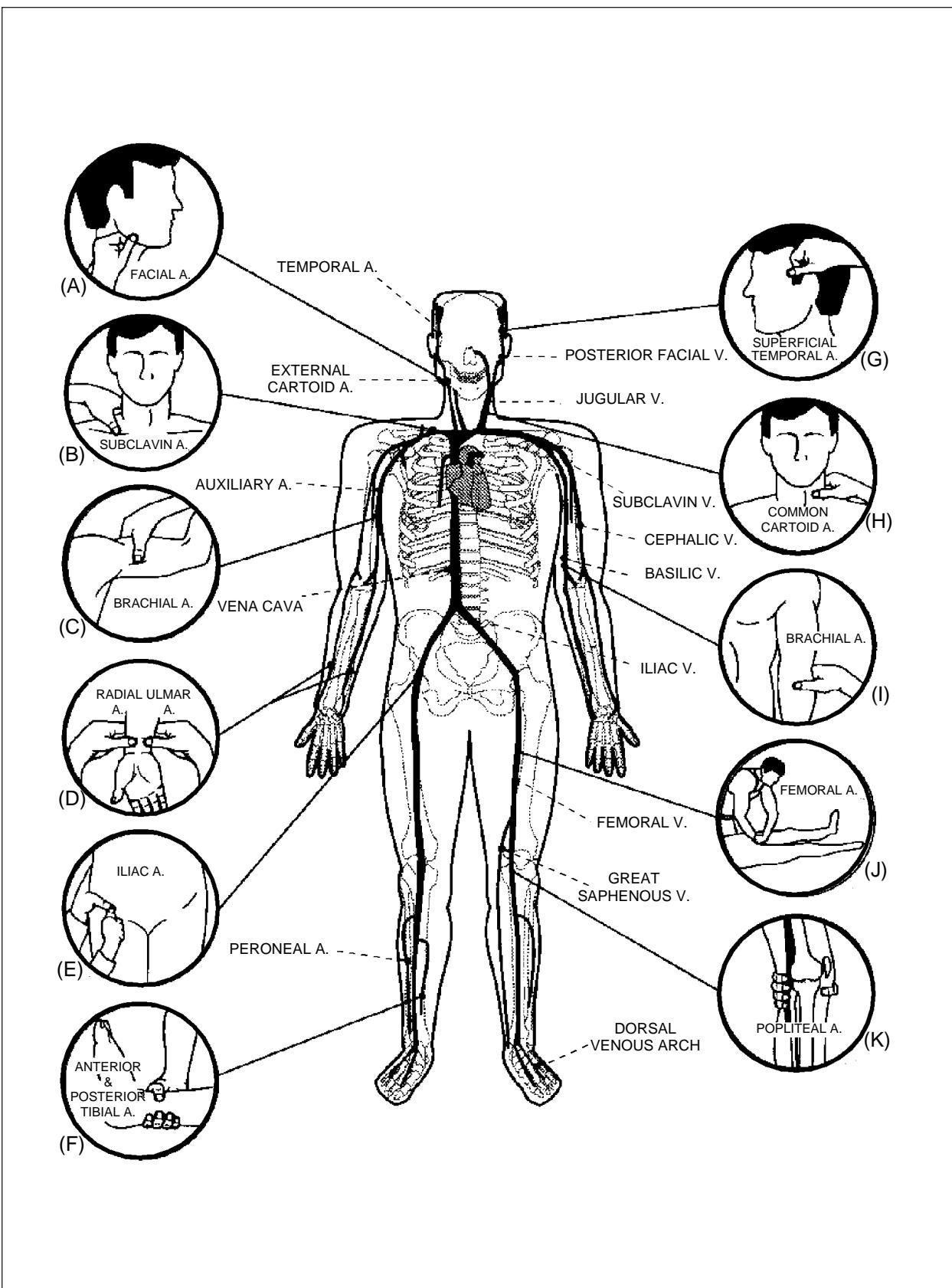


Figure 5B-1. Pressure Points.

is more effective to use the pressure point of the upper thigh as shown in [Figure 5B-1\(J\)](#). If you use this point, apply pressure with the closed fist of one hand and use the other hand to give additional pressure. The artery at this point is deeply buried in some of the heaviest muscle of the body, so a great deal of pressure must be exerted to compress the artery against the bone.

- 5B-3.3.10 **Pressure Point Location Between Knee and Foot.** Bleeding between the knee and the foot may be controlled by firm pressure at the knee. If pressure at the side of the knee does not stop the bleeding, hold the front of the knee with one hand and thrust your fist hard against the artery behind the knee, as shown in [Figure 5B-1\(K\)](#). If necessary, you can place a folded compress or bandage behind the knee, bend the leg back and hold it in place by a firm bandage. This is a most effective way of controlling bleeding, but it is so uncomfortable for the victim that it should be used only as a last resort.
- 5B-3.3.11 **Determining Correct Pressure Point.** You should memorize these pressure points so that you will know immediately which point to use for controlling hemorrhage from a particular part of the body. Remember, the correct pressure point is that which is (1) NEAREST THE WOUND and (2) BETWEEN THE WOUND AND THE MAIN PART OF THE BODY.
- 5B-3.3.12 **When to Use Pressure Points.** It is very tiring to apply digital pressure and it can seldom be maintained for more than 15 minutes. Pressure points are recommended for use while direct pressure is being applied to a serious wound by a second rescuer, or after a compress, bandage, or dressing has been applied to the wound, since it will slow the flow of blood to the area, thus giving the direct pressure technique a better chance to stop the hemorrhage. It is also recommended as a stopgap measure until a pressure dressing or a tourniquet can be applied.
- 5B-3.4 **Tourniquet.** A tourniquet is a constricting band that is used to cut off the supply of blood to an injured limb. Use a tourniquet only if the control of hemorrhage by other means proves to be difficult or impossible. A tourniquet must always be applied ABOVE the wound, i.e., towards the trunk, and it must be applied as close to the wound as practical.
- 5B-3.4.1 **How to Make a Tourniquet.** Basically, a tourniquet consists of a pad, a band and a device for tightening the band so that the blood vessels will be compressed. It is best to use a pad, compress or similar pressure object, if one is available. It goes under the band. It must be placed directly over the artery or it will actually decrease the pressure on the artery and thus allow a greater flow of blood. If a tourniquet placed over a pressure object does not stop the bleeding, there is a good chance that the pressure object is in the wrong place. If this occurs, shift the object around until the tourniquet, when tightened, will control the bleeding. Any long flat material may be used as the band. It is important that the band be flat: belts, stockings, flat strips of rubber or neckerchiefs may be used; but rope, wire, string or very narrow pieces of cloth should not be used because they cut into the flesh. A short stick may be used to twist the band tightening the tourniquet. [Figure 5B-2](#) shows how to apply a tourniquet.

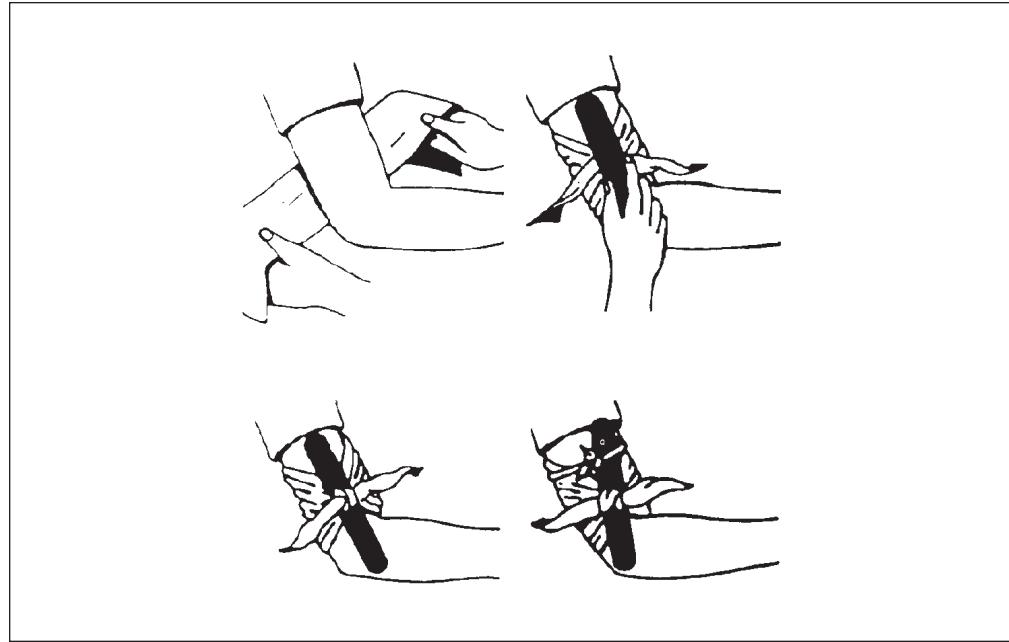


Figure 5B-2. Applying a Tourniquet.

- 5B-3.4.2 **Tightness of Tourniquet.** To be effective, a tourniquet must be tight enough to stop the arterial blood flow to the limb, so be sure to draw the tourniquet tight enough to stop the bleeding. However, do not make it any tighter than necessary.
- 5B-3.4.3 **After Bleeding is Under Control.** After you have brought the bleeding under control with the tourniquet, apply a sterile compress or dressing to the wound and fasten it in position with a bandage.
- 5B-3.4.4 **Points to Remember.** Here are the points to remember about using a tourniquet:
1. Don't use a tourniquet unless you can't control the bleeding by any other means.
 2. Don't use a tourniquet for bleeding from the head, face, neck or trunk. Use it only on the limbs.
 3. Always apply a tourniquet ABOVE THE WOUND and as close to the wound as possible. As a general rule, do not place a tourniquet below the knee or elbow except for complete amputations. In certain distal areas of the extremities, nerves lie close to the skin and may be damaged by the compression. Furthermore, rarely does one encounter bleeding distal to the knee or elbow that requires a tourniquet.
 4. Be sure you draw the tourniquet tight enough to stop the bleeding, but don't make it any tighter than necessary. The pulse beyond the tourniquet should disappear.

5. Don't loosen a tourniquet after it has been applied. Transport the victim to a medical facility that can offer proper care.
6. Don't cover a tourniquet with a dressing. If it is necessary to cover the injured person in some way, MAKE SURE that all the other people concerned with the case know about the tourniquet. Using crayon, skin pencil or blood, mark a large "T" on the victim's forehead or on a medical tag attached to the wrist.

5B-3.5 **External Venous Hemorrhage.** Venous hemorrhage is not as dramatic as severe arterial bleeding, but if left unchecked, it can be equally serious. Venous bleeding is usually controlled by applying direct pressure on the wound.

5B-3.6 **Internal Bleeding.** The signs of external bleeding are obvious, but the first aid team must be alert for the possibility of internal hemorrhage. Victims subjected to crushing injuries, heavy blows or deep puncture wounds should be observed carefully for signs of internal bleeding. Signs usually present include:

- Moist, clammy, pale skin
- Feeble and very rapid pulse rate
- Lowered blood pressure
- Faintness or actual fainting
- Blood in stool, urine, or vomitus

5B-3.6.1 **Treatment of Internal Bleeding.** Internal bleeding can be controlled only by trained medical personnel and often only under hospital conditions. Efforts in the field are generally limited to replacing lost blood volume through intravenous infusion of saline, Ringer's Lactate, or other fluids, and the administration of oxygen. Rapid evacuation to a medical facility is essential.

5B-4 SHOCK

Shock may occur with any injury and will certainly be present to some extent with serious injuries. Shock is caused by a loss of blood flow, resulting in a drop of blood pressure and decreased circulation. If not treated, this drop in the quantity of blood flowing to the tissues can have serious permanent effects, including death.

5B-4.1 **Signs and Symptoms of Shock.** Shock can be recognized from the following signs and symptoms.

- Respiration shallow, irregular, labored
- Eyes vacant (staring), lackluster, tired-looking
- Pupils dilated
- Cyanosis (blue lips/fingernails)
- Skin pale or ashen gray; wet, clammy, cold
- Pulse weak and rapid, or may be normal
- Blood pressure drop
- Possible retching, vomiting, nausea, hiccups
- Thirst

5B-4.2

Treatment. Shock must be treated before any other injuries or conditions except breathing and circulation obstructions and profuse bleeding. Proper treatment involves caring for the whole patient, not limiting attention to only a few of the disorders. The following steps must be taken to treat a patient in shock.

1. Ensure adequate breathing. If the patient is breathing, maintain an adequate airway by tilting the head back properly. If the patient is not breathing, establish an airway and restore breathing through some method of pulmonary resuscitation. If both respiration and circulation have stopped, institute cardiopulmonary resuscitation measures (refer to [paragraph 5B-2](#)).
2. Control bleeding. If the patient has bleeding injuries, use direct pressure points or a tourniquet, as required (refer to [paragraph 5B-3](#)).
3. Administer oxygen. Remember that an oxygen deficiency will be caused by the reduced circulation. Administer 100 percent oxygen.
4. Elevate the lower extremities. Since blood flow to the heart and brain may have been diminished, circulation can be improved by raising the legs slightly. It is not recommended that the entire body be tilted, since the abdominal organs pressing against the diaphragm may interfere with respiration. Exceptions to the rule of raising the feet are cases of head and chest injuries, when it is desirable to lower the pressure in the injured parts; in these cases, the upper part of the body should be elevated slightly. Whenever there is any doubt as to the best position, lay the patient flat.
5. Avoid rough handling. Handle the patient as little and as gently as possible. Body motion has a tendency to aggravate shock conditions.
6. Prevent loss of body heat. Keep the patient warm but guard against overheating, which can aggravate shock. Remember to place a blanket under as well as on top of the patient, to prevent loss of heat into the ground, boat or ship deck.
7. Keep the patient lying down. A prone position avoids taxing the circulatory system. However, some patients, such as those with heart disorders, will have to be transported in a semi-sitting position.
8. Give nothing by mouth.

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Hazardous Marine Creatures

5C-1 INTRODUCTION

- 5C-1.1 **Purpose.** This appendix provides general information on hazardous marine life that may be encountered in diving operations.
- 5C-1.2 **Scope.** It is beyond the scope of this manual to catalog all types of marine life encounters and potential injury. Planners should consult the recommended references listed at the end of this appendix for additional information. Local medical personnel and expert organizations, such as the Divers Alert Network, are often good sources of information and should be consulted prior to operating in unfamiliar waters. A full working knowledge of the marine environment will help to avoid adverse incidents, severe injuries, and lost time.

5C-2 MARINE ANIMALS THAT ATTACK

- 5C-2.1 **Sharks.** Shark attacks on humans are infrequent. The annual recorded number of shark attacks is only 40 to 100 worldwide. Injuries result predominately from bites. Shark skin is covered with abrasive dentine appendages, called denticles, which may cause abrasions if a shark “bumps” a human victim.
- 5C-2.1.1 **Shark Pre-Attack Behavior.** Pre-attack behavior by most sharks is somewhat predictable. A shark that is agitated or preparing to attack may swim erratically, its pectoral fins pointing downward in contrast to the usual flared-out position, sometimes with humped back and upward snout, and sometimes in circles of decreasing radius around its prey. An attack may be heralded by unexpected acceleration or other marked change in behavior, posture, or swim patterns. Sharks are much faster and more powerful than any human swimmer. All sharks should be treated with extreme respect and caution (see [Figure 5C 1](#)). Attacks tend to occur upon persons at the surface, particularly if there is commotion.
- 5C-2.1.2 **First Aid and Treatment.**
1. Bites may result in significant bleeding and tissue loss. Take immediate action to control bleeding using large pressure bandages. Cover wounds with layers of compressive bandages preferably made with gauze, but easily made from shirts or towels, and held in place by wrapping the wound tightly with gauze, torn clothing, towels, or sheets. Direct pressure with elevation or sufficient compression on “pressure points” over major arteries will hopefully control all but the most serious bleeding. These pressure points are the radial artery pulse point for the hand; above the elbow under the biceps muscle for the forearm (brachial artery); and the groin area with deep finger-tip or heel-of-the-hand pressure for bleeding from the leg (femoral artery). When bleeding cannot be immediately controlled by direct pressure and elevation or by compressing pressure points, a tourniquet should be used to save the victim’s life even

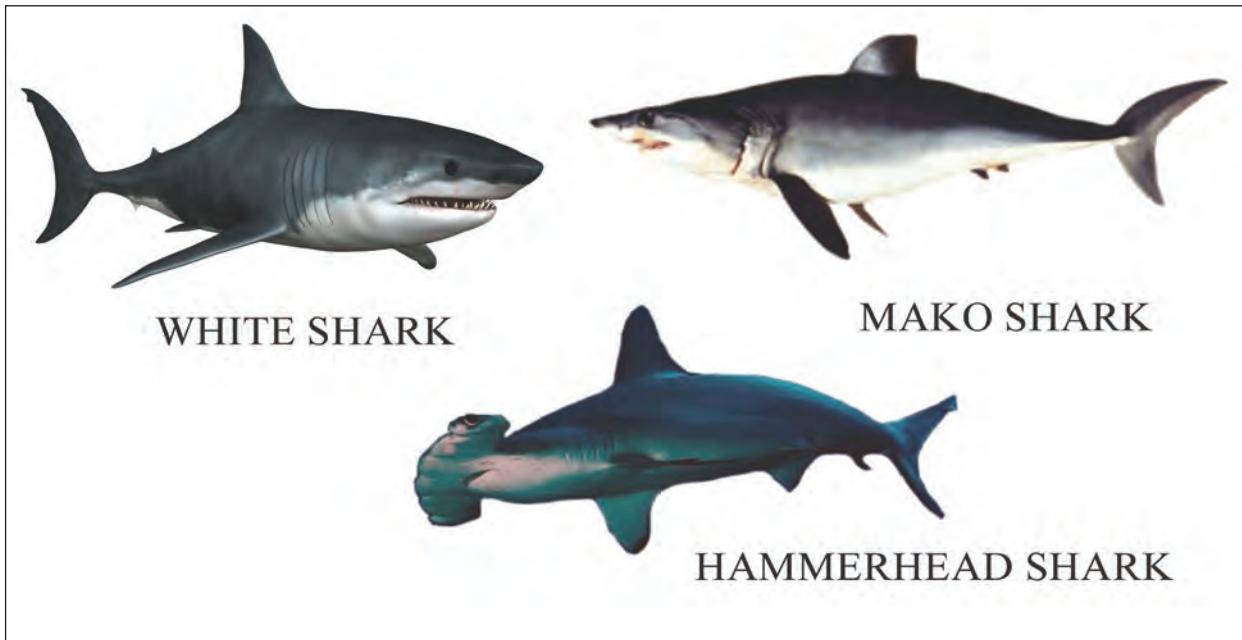


Figure 5C-1. Types of Sharks.

though there is the possibility of loss of the limb if the application exceeds a duration of 2-4 hours. Do not remove the tourniquet. It should be removed only by a physician in a hospital setting. Loosening a tourniquet prematurely may cause further shock by allowing recurrent bleeding.

2. Treat for low blood pressure (in the extreme, for shock) by laying the victim down and elevating his feet.
3. If medical personnel are available, begin intravenous (IV) Ringer's lactate or normal saline solution with a large-bore catheter (16 or 18 gauge). If blood loss has been extensive, several liters should be infused rapidly. The victim's color, pulse, and blood pressure should be used as a guide to the volume of fluid required. Maintain the airway and administer high flow oxygen by face mask. Do not give fluids by mouth. If the victim's cardiovascular state is stable, narcotics may be administered in small incremental doses for pain relief. Observe closely for evidence of depressed respirations due to the use of narcotics.
4. Initial stabilization procedures should include attention to the airway, breathing, and circulation, followed by a complete evaluation of the victim for multiple traumas.
5. Transport the victim to a medical facility as soon as possible. The goal is to treat hemorrhage with blood transfusions. Reassure the victim.
6. Should a severed limb be retrieved, wrap it in bandages, moisten with saline, place in a plastic bag and chill, but do not put the limb in direct contact with ice. Transport the severed limb with the victim.

7. Clean and debride wounds as soon as possible in a hospital or other controlled environment. Since shark teeth are cartilage, not bone, and therefore may not appear on an X-ray, operative exploration should be performed to locate and remove dislodged teeth.
8. Perform X-ray evaluation to evaluate bone damage. Severe crush injury may result in acute renal failure due to myoglobin released from injured muscle. Monitor closely for kidney function and adjust IV fluid therapy appropriately.
9. Administer tetanus prophylaxis: tetanus toxoid, 0.5 ml intramuscular (IM) and tetanus immune globulin, 250 to 400 units IM.
10. Culture infected wounds for both aerobes and anaerobes before instituting broad spectrum antibiotic coverage; infections with Clostridium or Vibrio species have been reported. Consider administering an antibiotic, such as ciprofloxacin, for acute shark bite wounds to prevent Vibrio infection.
11. Acute surgical repair and reconstructive surgery may be necessary.
12. In cases of unexplained decrease in mental status or other neurological signs and symptoms following shark attack while diving, consider arterial gas embolism or decompression sickness as a possible cause.

5C-2.2

Killer Whales. Killer whales live in all oceans, both tropical and polar. These large mammals have blunt, rounded snouts and high black dorsal fins ([Figure 5C-2](#)). The jet black head and back contrast sharply with the white underbelly. Usually, a white patch can be seen behind and above the eye. Killer whales are usually observed in packs of 3 to 40 animals. They have powerful jaws, great weight, speed, and interlocking teeth. Because of their speed and carnivorous habits, these animals should be treated with great respect. There have been no recorded attacks in the wild upon humans.

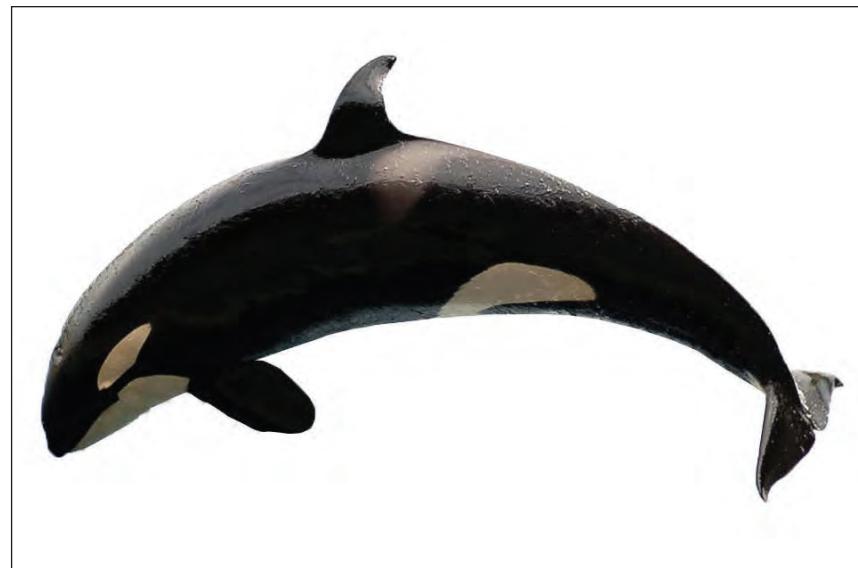


Figure 5C-2. Killer Whale.

- 5C-2.2.1 **Prevention.** When killer whales are spotted, all diving personnel should immediately leave the water. Extreme caution should be observed on shore areas, piers, barges, ice floes, etc., when killer whales are in the area.
- 5C-2.2.2 **First Aid and Treatment.** First aid and treatment would follow the same principles as those used for a shark bites ([paragraph 5C-2.1.2](#)).
- 5C-2.3 **Barracuda.** More than 20 species of barracuda inhabit tropical and subtropical waters from Brazil to Florida and the Indo-Pacific oceans from the Red Sea to the Hawaiian Islands. The barracuda is an elongated fish with prominent jaws and teeth, silver in color, and with a large head and V-shaped tail ([Figure 5C-3](#)). It may grow up to 10 feet long and is a fast swimmer, capable of striking rapidly and fiercely. It will follow swimmers but seldom attacks an underwater swimmer. It is known to attack surface swimmers and limbs dangling in the water, particularly if they are adorned with shiny metallic objects, such as jewelry. Barracuda wounds can be distinguished from those of a shark by the bite pattern. A barracuda leaves straight or V-shaped wounds while those of a shark conform to the shape of the shark jaws. Life threatening attacks by barracuda are very rare.

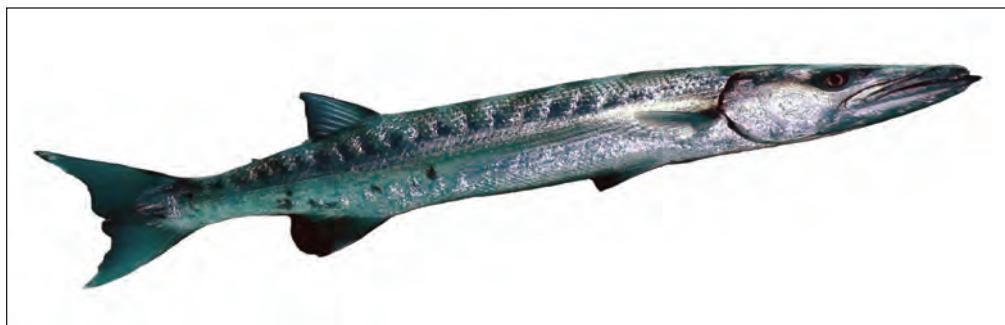


Figure 5C-3. Barracuda.

- 5C-2.3.1 **Prevention.** Barracuda are attracted by shiny objects, such as metallic fishing lures. Avoid wearing shiny equipment or jewelry in the water when barracudas are likely to be present. Avoid carrying speared fish, as barracuda may strike them. Avoid splashing or dangling limbs in barracuda-infested waters.
- 5C-2.3.2 **First Aid and Treatment.** First aid and treatment follow the same principles as those used for shark bites ([paragraph 5C-2.1.2](#)). Injuries are likely to be less severe than shark bite injuries.
- 5C-2.4 **Moray Eels.** While some temperate zone species of moray eels are known, they inhabit primarily tropical and subtropical waters. Moray eels are bottom dwellers commonly found in holes and crevices or under rocks and coral. They are snake-like in appearance and movement and have tough, leathery skin ([Figure 5C-4](#)). Morays can grow to a length of 10 feet and have copious sharp thin teeth. Moray eels are extremely territorial and attack frequently when divers reach into crevices or holes occupied by the animals. They are powerful and vicious biters and may be difficult to dislodge after a bite is initiated. Bites from moray eels range from

multiple small puncture wounds to extensive jagged tears with profuse bleeding if there has been a struggle. Injuries are usually inflicted on the hands or forearms.

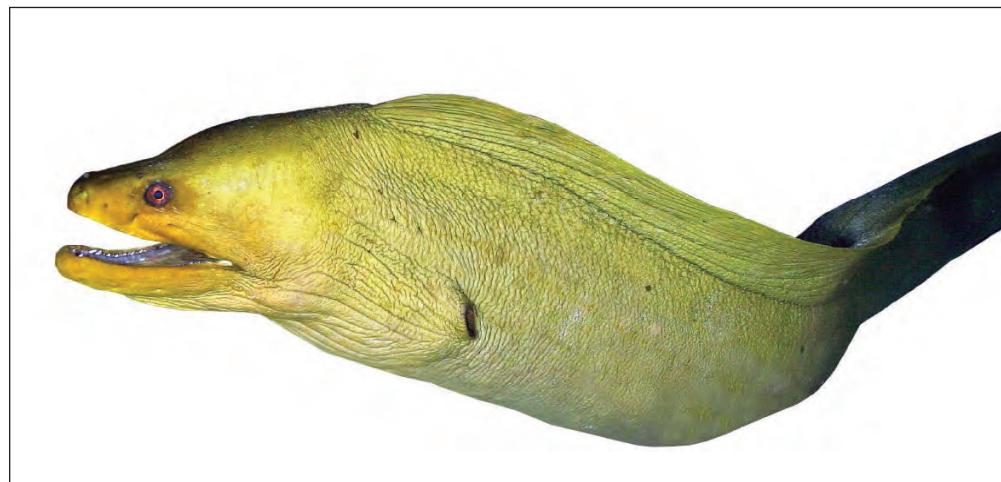


Figure 5C-4. Moray Eel.

5C-2.4.1 **Prevention.** Extreme care should be used when reaching into holes or crevices. Avoid provoking or attempting to dislodge an eel from its hole.

5C-2.4.2 **First Aid and Treatment.** Direct pressure and raising the injured extremity almost always controls bleeding. Arrange for medical follow-up. Severe hand or facial injuries should be evaluated immediately by a physician. Treatment is supportive. Follow principles of wound management and tetanus prophylaxis as in caring for shark bites. Antibiotic therapy should be instituted early. Immediate specialized care by a hand surgeon may be necessary for tendon and/or nerve repair of the hand to prevent permanent loss of function.

5C-2.5 **Sea Lions.** Sea lions inhabit the Pacific Ocean and are numerous on the west coast of the United States. They resemble large seals. Sea lions are normally harmless; however, during the breeding season (October through December) large bull sea lions are quite defensive and will be aggressive towards divers. Attempts by divers to handle these animals may result in bites. The bites are similar in configuration to dog bites and are rarely severe, but may cause unique infections.

5C-2.5.1 **Prevention.** Divers should avoid these mammals when they are in the water, and at any time when they are with their offspring.

5C-2.5.2 **First Aid and Treatment.**

1. Control local bleeding.
2. Clean and debride wound.
3. Administer tetanus prophylaxis as appropriate.

4. Wound infections are common and prophylactic antibiotic therapy is advised. “Seal finger” refers to an infection with Mycoplasma and is amenable to treatment with the antibiotic tetracycline.

5C-3 VENOMOUS MARINE ANIMALS

5C-3.1 **Venomous Fish (excluding Stonefish, Scorpionfish, and Zebrafish).** Identification of a fish following a sting is not always possible; however, symptoms and effects of venoms from stinging fishes do not vary greatly. Venomous fish are rarely aggressive. Contact is usually made by accidentally stepping on or handling the fish. Dead fish spines may remain toxic (Figure 5C-5). Local symptoms following a sting are usually severe pain combined with numbness and/or tingling around the wound. The wound site may become cyanotic with surrounding tissue becoming pale and swollen. General symptoms may include nausea, vomiting, sweating, mild fever, respiratory distress and collapse. Pain may seem disproportionately high for the apparent severity of the injury. Medical personnel should be prepared for serious anaphylactic reactions from apparently minor stings or envenomations. Pain is usually diminished by immersion into hot water (see below).

5C-3.1.1 **Prevention.** Avoid handling venomous fish. Venomous fish are often found in



Figure 5C-5. Weeverfish.

holes or crevices or lying well camouflaged on rocky bottoms. Divers should be alert for their presence and take care to avoid them.

5C-3.1.2 **First Aid and Treatment.**

1. Assist the victim to leave the water; watch for fainting.
2. Lay the victim down and reassure him.
3. Observe for signs of shock.
4. Rinse the wound with sterile saline solution or disinfected water. Surgery may be required to widen the entrance to the puncture wound. Suction is not effective for removing toxin.

5. Soak the wound in hot water for 30 to 90 minutes. This usually provides partial or total pain relief, but may sometimes be ineffective. The water should be as hot as the victim can tolerate but not hotter than 113°F (45°C). Immersion in water above 113°F (45°C) for longer than a brief period may lead to scalding. Use hot compresses if the wound is on the face. Adding magnesium sulfate (Epsom salts) or any other additive to the water offers no benefit. Hot water immersion is a useful technique that may be attempted for any puncture caused by a marine spine, such as that of the crown of thorns starfish (*Acanthaster planci*), the “horns” of the Pacific Lobster, spines of the Pacific Ratfish, and so forth.
6. Infiltration of the wound with 0.5 percent to 2.0 percent lidocaine without epinephrine, or another similar local anesthetic agent, is helpful in reducing pain. Narcotics may also be needed to manage severe pain.
7. Clean and debride the wound. Spines and sheath frequently remain within the wound. Be sure to remove all remnants of the spines or they may continue to release venom.
8. Tourniquets or pressure-immobilization are not advised. Use an antiseptic or antibiotic ointment and sterile dressing. Restrict movement of the extremity with splints and cravats.
9. Administer tetanus immunization as appropriate.
10. Treat prophylactically with topical antiseptic ointment. If more than a few hours to treatment will transpire, administer an antibiotic such as ciprofloxacin.

5C-3.2

Highly Toxic Fish (Stonefish, Scorpionfish, and Zebrafish/Lionfish). Stings by stonefish, scorpionfish, and zebrafish, also known as lionfish, may be quite severe. While many similarities exist between these fish and the venomous fish mentioned in the previous section, this separate section has been included because of the greater toxicity of their venoms and the availability of stonefish antivenin. Local symptoms are similar to those of other fish-induced envenomations except that they are generally more severe and may persist for days. With the sting of a stonefish, pain may be extraordinary and local tissue destruction extensive. Generalized symptoms are often present and may include respiratory failure and cardiovascular collapse. These fish are widely distributed in temperate and tropical seas. Zebrafish/Lionfish are now found in the Gulf of Mexico, Caribbean, and Atlantic Coast of the United States. They are shallow-water bottom dwellers. Stonefish and scorpionfish are less ornate with ruggose or flattened bodies, sometimes dark and mottled. They tend to take on the appearance of their surroundings. Zebrafish are ornate and feathery in appearance with alternating patches of dark and light colors and stripes ([Figure 5C-6](#)).

5C-3.2.1

Prevention. Prevention is the same as for venomous fish ([paragraph 5C-3.1.1](#)).

5C-3.2.2

First Aid and Treatment.

1. Provide the same first aid as that given for venomous fish ([paragraph 5C-3.1.2](#)).

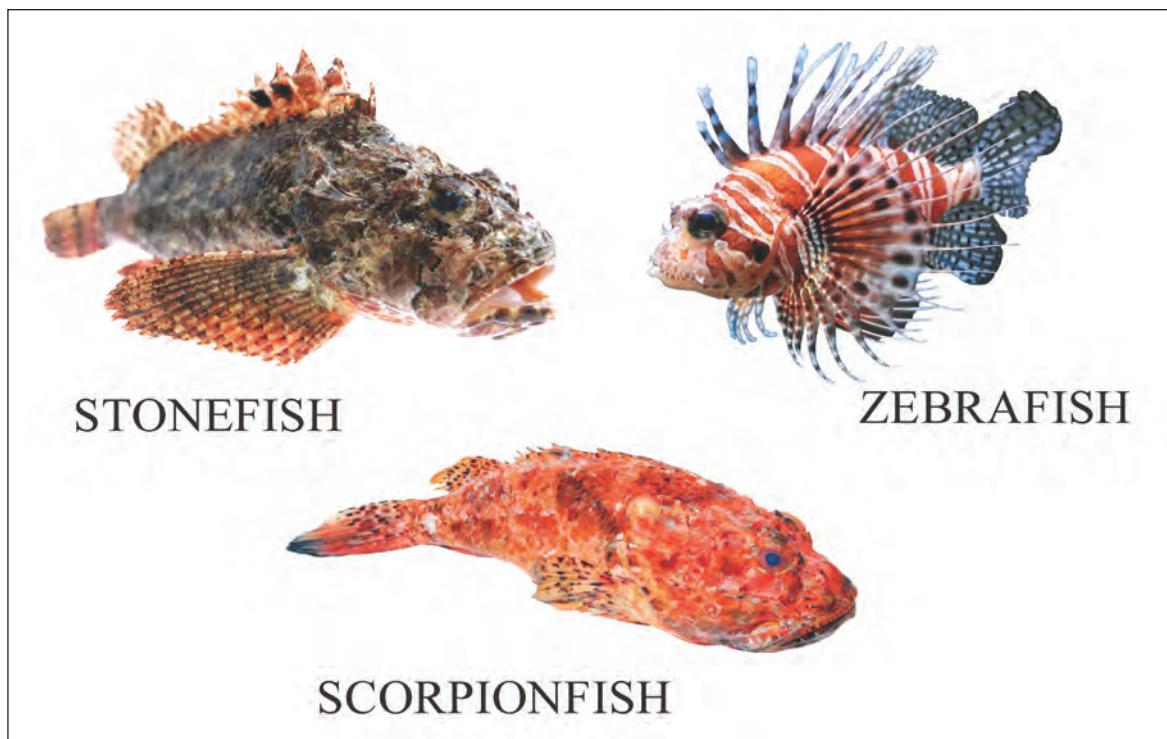


Figure 5C-6. Highly Toxic Fish.

2. Observe the victim carefully for possible development of life-threatening complications. The venoms affect many organ systems, including skeletal, involuntary, and cardiac muscle. This may result in muscular paralysis, respiratory depression, peripheral vasodilation, shock, cardiac dysrhythmias, and cardiac arrest.
3. Clean and debride the wound.
4. Stonefish antivenom is available from Commonwealth Serum Laboratories, Melbourne, Australia (see Reference 1 at end of this appendix for address and phone number). If antivenom is used, the directions regarding dosage and sensitivity testing on the accompanying package insert should be followed and the treating physician must be ready to treat anaphylaxis (severe allergic reaction). In brief, one or two punctures require 2,000 units (one vial); three to four punctures, 4,000 units (two vials); and five to six punctures, 6,000 units (three vials). Antivenin is delivered by slow IV injection while the victim is closely monitored for anaphylaxis.
5. Institute tetanus prophylaxis, analgesic therapy and antibiotics as described for other fish stings.

5C-3.3 Stingrays. Stingrays are common in all tropical, subtropical, warm, and temperate regions. They usually favor sheltered water and burrow into sand with only the eyes and tail exposed. The stingray has a bat-like shape and a long caudal appendage (“tail”) (Figure 5C-7). Most attacks occur when waders inadvertently step on the top surface of a ray, causing it to lash out defensively with its tail. The spine(s)

is located near the base of the tail. Wounds are either punctures or lacerations and are extremely painful. The wound appears swollen and pale with a blue rim. Secondary wound infections are common. Systemic symptoms may include fainting, nausea, vomiting, sweating, respiratory difficulty, and cardiovascular collapse.

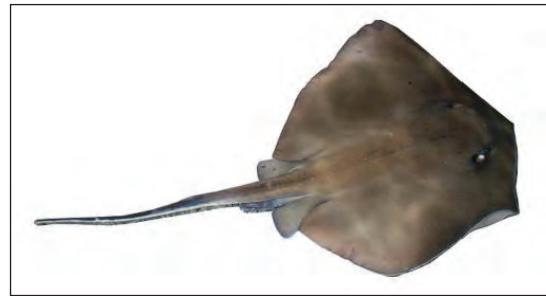


Figure 5C-7. Stingray.

5C-3.3.1 **Prevention.** In shallow waters which favor stingray habitation, shuffle feet on the bottom and probe with a stick to alert the rays and cause them to flee.

5C-3.3.2 **First Aid and Treatment.**

1. Give the same first aid as that given for venomous fish (paragraph 5C-3.1.2). No antivenom is available.
2. Institute hot water therapy as described under fish envenomation.
3. Clean and debride the wound. Remove the spine, if necessary by surgical means. Be sure to remove any remnants of the integumental sheath because it might continue to release toxin.
4. Observe the victim carefully for possible development of life-threatening complications. Symptoms can include cardiac dysrhythmias, hypotension, vomiting, diarrhea, sweating, muscle paralysis, respiratory depression, and cardiac arrest. Fatalities are quite rare. Intrathoracic or intraabdominal penetration may lead to organ puncture and/or serious hemorrhage. If the spine has impaled the victim in the neck or thorax, do not remove it until the victim has been brought to a facility where bleeding control can be promptly obtained in the operating room.
5. Institute tetanus immunization, analgesic therapy, and broad-spectrum antibiotics as described for fish envenomation.

5C-3.4 **Coelenterates.** Hazardous types of coelenterates include: Portuguese man-of-war, box jellyfish, sea nettle, sea wasp, sea blubber, sea anemone, and rosy anemone (Figure 5C-8). Jellyfish vary widely in color (blue, green, pink, red, brown) or may be transparent. They appear as balloon-like floats with tentacles dangling down into the water. The most common marine stinging injury is the jellyfish sting. Jellyfish can come into direct contact with divers in virtually all oceanic regions worldwide. When this happens, the diver is exposed to potentially tens of thousands of minute stinging nematocysts in the tentacles. Most jellyfish stings result only in painful, transient local skin irritation. The box jellyfish and other similar creatures, and Portuguese man-of-war are among the most dangerous types. The sea box jellyfish *Chironex fleckeri* (found in the Indo-Pacific) can

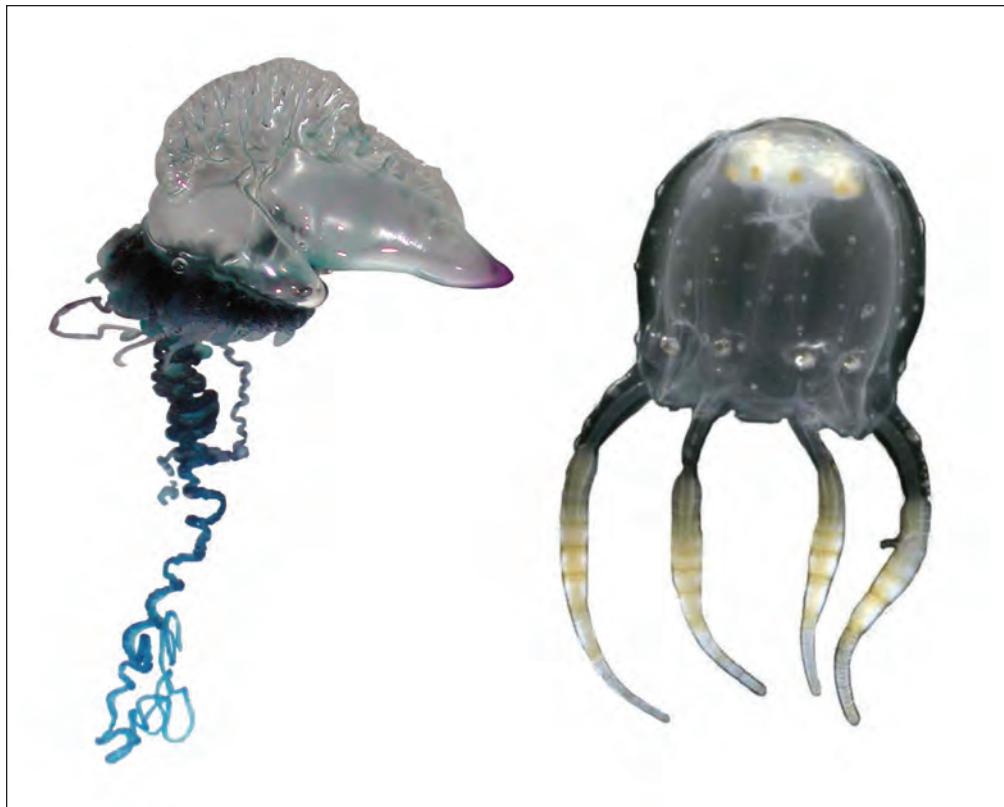


Figure 5C-8. Coelenterates. Hazardous coelenterates include the Portuguese Man-of-War (left) and the sea wasp (right).

induce death within 10 minutes of a sting by cardiovascular collapse, respiratory failure, and muscular paralysis. Deaths from Portuguese man-of-war stings, some of which may be attributed to allergic reactions, have also been reported. Even though intoxication from ingesting poisonous sea anemones is rare, sea anemones must not be eaten.

- 5C-3.4.1 **Prevention.** Do not handle jellyfish. Beached or apparently dead specimens may still be able to sting. Even towels or clothing contaminated with the stinging nematocysts may cause stinging months later.
- 5C-3.4.2 **Avoidance of Tentacles.** In some species of jellyfish, tentacles may trail for great distances horizontally or vertically in the water and are not easily seen by the diver. Swimmers and divers should avoid close proximity to jellyfish to prevent contacting their tentacles, especially when near the surface.
- 5C-3.4.3 **Protection Against Jellyfish.** Wet suits, body shells, or protective clothing should be worn when diving in waters where jellyfish are abundant. Petroleum jelly applied to exposed skin (e.g., around the mouth) helps to prevent stinging, but caution should be used since petroleum jelly can deteriorate rubber products. Safe Sea is a commercial product that functions as a combination jellyfish sting inhibitor and sunscreen.

- 5C-3.4.4 **First Aid and Treatment.** Without rubbing, gently remove any remaining tentacles that can be grasped using a towel or clothing. For preventing further discharge of the stinging nematocysts, copiously apply lidocaine or vinegar (3- to 10-percent solution of acetic acid). Topical isopropyl (rubbing) alcohol is recommended by some experts as an alternative decontaminant. Vinegar is absolutely advised for a box jellyfish sting. Hot water immersion (similar to that used for stonefish – see above – may be beneficial. Methylated spirits or methanol, 100 percent alcohol and alcohol plus seawater mixtures have not been proven to be of benefit. Indeed, these compounds may also worsen the immediate pain. Picric acid, human urine, and fresh water also have been found to either be ineffective or to even discharge nematocysts and should not be used, except for the hot water therapy noted above. Rubbing sand is ineffective and may lead to further nematocyst discharge so should not be used.
- 5C-3.4.5 **Symptomatic Treatment.** Symptomatic treatment for the inflammatory response that occurs from 24 to 72 hours after the initial sting can include topical steroid therapy (not very effective), anesthetic ointment (lidocaine 2 percent), pramoxine lotion, and systemic antihistamines and/or analgesics. Benzocaine topical anesthetic preparations should generally be avoided because they sometimes cause sensitization that leads to later skin reactions.
- 5C-3.4.6 **Anaphylaxis.** Anaphylaxis (a severe allergic reaction) may result from jellyfish stings. It is treated in standard fashion with injected IM epinephrine (such as EpiPen) antihistamines, and systemic corticosteroids.
- 5C-3.4.7 **Antivenin.** Antivenom is available to neutralize the effects of the box jellyfish (*Chironex fleckeri*). Antivenom may be obtained from Commonwealth Serum Laboratories, Melbourne, Australia (See Reference 4 for contact information). Antivenom is preferentially administered slowly through an IV, with a controlled infusion technique if possible. IM injection is safe, but should be used only if the IV method is not feasible. An initial dose of one vial (20,000 units) of sea wasp antivenin should be used by the IV route and three containers if by the IM route. Antivenom should be kept refrigerated, not frozen, at 36 to 50° F (2 to 10° C). Allergic reaction to antivenom should be treated with an IM injection of epinephrine (0.3 cc of 1:1,000 dilution), corticosteroids, and antihistamines. Treat hypotension (severely low blood pressure) with IV volume expanders and pressor medication as necessary.
- 5C-3.5 **Coral.** Coral, a porous, rock-like formation, is usually found in tropical and subtropical waters. Coral edges may be extremely sharp such that the most delicate-appearing coral may be the most hazardous because of its razor-sharp edges. Coral cuts, while usually fairly superficial, take a long time to heal and can cause temporary disability. The smallest cut, if left untreated, can fester and develop into a skin ulcer. Infections often occur and may be recognized by the presence of a red and tender area surrounding the wound. All coral cuts should receive medical attention. Some varieties of coral can actually sting a diver since certain structures termed “coral,” such as “fire coral,” are actually coelenterates with stinging cells.

5C-3.5.1 **Prevention.** Extreme care should be used when working near coral. Coral is often located within a reef formation subjected to heavy surface water action, surface current, and bottom current. Surge sometimes develops in reef areas. For this reason, it is easy for a diver or surface swimmer to be swept or tumbled across coral.

5C-3.5.2 **Protection Against Coral.** Coral should not be handled with bare hands. Feet should be protected with booties, coral shoes or tennis shoes. Wet suits and protective clothing, especially gloves (neoprene or heavy work gloves), should be worn when near coral.

5C-3.5.3 **First Aid and Treatment.**

1. Control local bleeding.
2. Promptly clean with soap and water, and then with medicinal (dilute) hydrogen peroxide or 10-percent povidone-iodine solution. If possible, sharply debride any jagged edges of full thickness skin wound, removing as best possible all foreign particles.
3. Apply antiseptic ointment, such as bacitracin, and cover with a clean dressing.
4. Administer tetanus immunization as appropriate.
5. Topical antiseptic ointment has been proven very effective in preventing infection. In severe cases, restrict the victim to bed rest with elevation of the extremity, wet-to-dry dressings, and systemic antibiotics. Systemic steroids may be needed to manage the inflammatory reaction resulting from a combination of trauma and allergic dermatitis. It may be difficult to differentiate infection from hypersensitivity.

5C-3.6 **Octopuses.** The octopus inhabits tropical and temperate oceans. Species vary depending on region. It is configured as a large head sac surrounded by 8 to 10 tentacles (Figure 5C-9). The head sac houses well-developed eyes, and horny jaws on the mouth. Movement is made by jet action produced by expelling water from the mantle cavity through the siphon. The octopus will hide in caves, crevices and shells. It possesses a well-developed venom apparatus in its salivary glands, and injures its victim by biting. Most species of octopus found in the U.S. are harmless. The blue-ringed octopus common in Australian and Indo-Pacific waters may inflict fatal bites. The venom of the blue-ringed or spotted octopus



Figure 5C-9. Octopus.

is a neuromuscular blocker called tetrodotoxin, which is also found in pufferfish. Envenomation from the bite of such an octopus may lead to muscular paralysis, vomiting, respiratory difficulty, visual disturbances, and cardiovascular collapse. Octopus bites usually consist of two small punctures. The bite may be painless, or a burning or tingling sensation may soon spread. Swelling, redness, and inflammation are common. Local bleeding just after the bite may be brisk because the clotting ability of the blood is sometimes retarded by the anticoagulant action of venom.

- 5C-3.6.1 **Prevention.** Extreme care should be used when reaching into locations, such as caves and crevices that are dark or not well visualized. Regardless of size, an octopus should be handled carefully even while wearing gloves. One should not spear an octopus, especially the large ones found off the coast of the northwestern United States, because of the risk of being entangled within its tentacles. If killing an octopus becomes necessary, stabbing it between the eyes is recommended.

- 5C-3.6.2 **First Aid and Treatment.**
1. Control local bleeding.
 2. Clean the wound and cover it with a clean dressing.
 3. For a suspected blue-ringed octopus bite, apply direct pressure with a pressure bandage and immobilize the extremity in a position that is lower than the heart using splints and elastic bandages.
 4. Be prepared to administer mouth-to-mouth breathing and cardiopulmonary resuscitation if necessary.
 5. Blue-ringed octopus venom is heat stable and acts as a neurotoxin and neuromuscular blocking agent. It is not neutralized by hot water therapy. No antivenom is available.
 6. Medical therapy for blue-ringed octopus bites is directed toward management of paralytic, cardiovascular, and respiratory complications. Respiratory arrest is common, so endotracheal intubation with mechanical ventilation may be required. Duration of paralysis is between 4 and 12 hours. Reassure the victim, who may be comprehending their surroundings even though paralyzed.
 7. Administer tetanus immunization as appropriate.

- 5C-3.7 **Segmented Worms (Annelida) (Examples: Bloodworm, Bristleworm).** This invertebrate type varies according to region and is found in warm, tropical or temperate zones. It is usually found under rocks or coral and is especially common in the tropical Pacific, Bahamas, Florida Keys, and Gulf of Mexico. Annelida have long, segmented bodies with stinging bristle-like structures on each segment. Some species have jaws and can also inflict very painful bites. Venom causes swelling and pain.

5C-3.7.1 **Prevention.** Wear lightweight, cotton gloves to protect against bloodworms, but wear rubber or heavy leather gloves for protection against bristleworms.

5C-3.7.2 **First Aid and Treatment.**

1. Remove bristles with a very sticky tape such as adhesive tape or duct tape. Topical application of vinegar may lessen pain, but this effect is variable.
2. Treatment is directed toward relief of symptoms and may include topical steroid therapy, systemic antihistamines, and analgesics.
3. Wound infection can occur but can be easily prevented by cleaning the skin using an antiseptic solution of 10 percent povidone-iodine and topical antiseptic ointment. Systemic antibiotics may be needed for infections.

5C-3.8 **Sea Urchins.** Sea urchins have worldwide distribution. Each problematic species of sea urchin has a radial shape and penetrating spines or seizing organs, known as globiferous pedicellariae. Penetration by sea urchin spines or the grasp of pedicellariae can cause intense local pain due to venom effects. Numbness, generalized weakness, paresthesias, nausea, vomiting, and cardiac dysrhythmias have been reported.

5C-3.8.1 **Prevention.** Avoid contact with sea urchins. Protective footwear and gloves are recommended. Spines can penetrate wet suits, booties, and tennis shoes.

5C-3.8.2 **First Aid and Treatment.**

1. Remove large spine fragments gently, being very careful not to break them into small fragments that remain in the wound.
2. Soaking the injured body area in nonscalding hot water up to 113° F (45° C) may diminish pain.
3. Clean and debride the wound. Topical antiseptic ointment should be used to prevent infection, but a deep puncture wound(s) may initiate an infection. If feasible, culture the wound before administering systemic antibiotics for established infections.
4. Remove as many of the spines and as much of each spine as possible. Some small fragments may be absorbed by the body. Darkened skin may not indicate retained spines, but rather pigment that has been released from the spine's surface into the wound. Surgical removal, preferably with a dissecting microscope, may be required when spines are near nerves and joints. X-rays or other imaging techniques may be required to locate these spines. Spines can form granulomas months later.
5. Allergic reactions and bronchospasm can be controlled with IM epinephrine (0.3 cc of 1:1,000 aqueous dilution) and by using systemic antihistamines. There are no specific antivenoms available.

6. Administer tetanus immunization as appropriate.

7. Seek medical attention for deep wounds.

5C-3.9

Cone Snails. Cone snails (sometimes called cone “shells”) are widely distributed in all regions and usually found under rocks and coral or crawling along the sandy bottom. The snail’s shell is most often symmetrical in a spiral coil and colorfully patterned on its surface, with a distinct head, one to two pairs of tentacles, two eyes, and a large flattened foot on the body (Figure 5C-10). A cone snail sting should be considered to be as potentially severe as a venomous snake bite. The cone snail has a highly developed venom apparatus: venom is contained in darts inside the proboscis, which extrudes from the narrow end but is able to reach most of the animal. Cone snail punctures are followed by a stinging or burning sensation at the site of the wound. Numbness and tingling begin at the site of the wound and may spread to the rest of the body; involvement of the mouth and lips is severe. Other symptoms may include muscular paralysis, difficulty with swallowing and speech, visual disturbances, and respiratory distress.



Figure 5C-10. Cone Shell.

5C-3.9.1

Prevention. Avoid handling cone snails. Venom can be injected through clothing and gloves.

5C-3.9.2

First Aid and Treatment.

1. Lay the victim down.

2. Apply direct pressure with a pressure bandage and immobilization in a position lower than the level of the heart using splints and elastic bandages.

3. Incision and suction are not recommended.

4. Transport the victim to a medical facility while ensuring that the victim is breathing adequately. Be prepared to administer mouth-to-mouth breathing if necessary.

5. Cone snail venom results in paresis or paralysis of skeletal muscle, with or without myalgias. Symptoms develop within minutes of the sting and effects can last up to 24 hours.

6. No antivenom is available.

7. Respiratory distress may occur due to neuromuscular blockade. Victims should be admitted to medical facilities and monitored closely for respiratory or cardiovascular demise. Treat as symptoms develop.
8. If pain is severe, a local anesthetic without epinephrine may be injected into the wound site or a nerve block may be performed. Analgesics that produce respiratory depression should be used with caution.
9. Management of severe stings is supportive. Breathing may need to be supported with endotracheal intubation and mechanical ventilation.
10. Administer tetanus prophylaxis as appropriate.

5C-3.10 **Sea Snakes.** The sea snake is an air-breathing reptile that has adapted to its aquatic environment by, among other things, developing a paddle-shaped tail. Sea snakes inhabit Indo-Pacific waters and the Red Sea. The most hazardous areas in which to swim are river mouths, where sea snakes sometimes congregate, and the water is more turbid. The sea snake is a true snake, usually 3 to 4 feet in length, but may reach 9 feet. The most commonly encountered species are banded in appearance (Figure 5C-11). The sea snake is curious and while often attracted to divers, usually is not aggressive except during mating season.

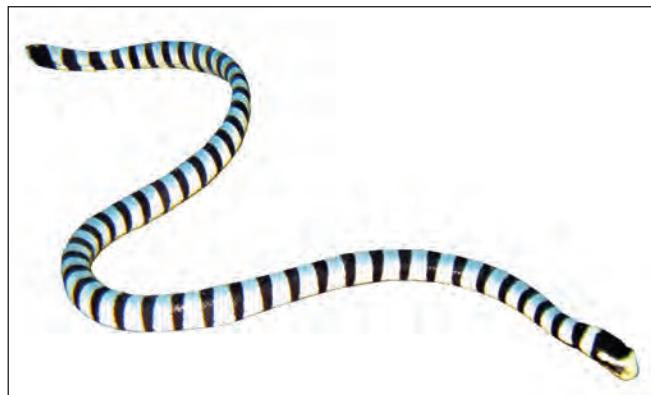


Figure 5C-11. Sea Snake.

5C-3.10.1 **Sea Snake Bite Effects.** Venom of certain sea snakes has toxicity that may exceed that of cobra venom. The bites usually appear as four puncture marks but may range from one to 20 punctures. Teeth may remain in the wound. The predominantly neurotoxic venom is heat-stable, so there is no clinical benefit to hot water immersion of the bitten body part. Due to the small jaws and short fangs of the snake, bites often do not result in envenomation. Sea snake bites characteristically produce little pain, and there is usually a latent period of 10 minutes to several hours before development of generalized symptoms: muscle aching and stiffness, thick tongue sensation, progressive paralysis, nausea, vomiting, difficult speech and swallowing, respiratory distress and failure, and dark-colored urine from myoglobinuria, which may herald incipient kidney failure.

5C-3.10.2 **Prevention.** Wet suits or protective clothing, especially gloves, may provide substantial protection against bites and should be worn when diving in waters where sea snakes are present. Shoes should be worn when walking where sea snakes are known to exist, including in the vicinity of fishing operations. Do not handle sea snakes. Bites often occur to the hands of fishermen attempting to remove snakes from nets.

5C-3.10.3 ***First Aid and Treatment.***

1. Keep the victim still.
2. Apply direct pressure using a compression bandage and immobilize the extremity in the dependent position with splints and elastic bandages.
3. Incision and suction are not useful therapies.
4. Transport all sea snakebite victims to a medical facility as soon as possible, regardless of their current symptoms, as antivenom will likely be necessary.
5. Watch to ensure that the victim is breathing adequately. Be prepared to administer mouth-to-mouth breathing or cardiopulmonary resuscitation.
6. The venom predominately blocks neuromuscular transmission. Myonecrosis with myoglobinuria and renal damage are often seen. Hypotension may develop.
7. Respiratory arrest may result from generalized muscular paralysis; endotracheal intubation and mechanical ventilation may be required.
8. Renal function should be closely monitored because peritoneal or hemodialysis may be needed. Alkalization of urine with sufficient IV fluids will promote myoglobin excretion. Monitor renal function and fluid balance anticipating acute renal failure.
9. Vital signs should be monitored closely. Cardiovascular support plus oxygen and IV fluids may be required.
10. Because of the possibility of delayed onset of symptoms, all sea snakebite victims should be observed for at least 12 hours.
11. If symptoms of envenomation occur within one hour, antivenom should be administered as soon as possible. In a seriously envenomed victim, antivenom therapy may be helpful even after a significant delay. Antivenom is available from Commonwealth Serum Laboratories in Melbourne, Australia and in the United States (see Reference number 1 of this appendix for address and phone number). If antivenom is used, follow the directions regarding dosage and sensitivity testing provided on the accompanying package insert. Be prepared to treat anaphylaxis (severe allergic reaction). Infusion of antivenom by the IV method or closely monitored drip over a period of one hour is recommended.
12. Administer tetanus immunization as appropriate.

5C-3.11 **Sponges.** Sponges induce skin irritation (dermatitis) with chemical irritants and spicules of silica or calcium carbonate embedded in a fibrous skeleton.

5C-3.11.1 **Prevention.** Avoid contact with sponges. Always wear gloves when handling live sponges.

5C-3.11.2 ***First Aid and Treatment.***

1. Adhesive or duct tape can remove some of the sponge spicules.
2. Household vinegar (3- to 10-percent acetic acid solution) should be applied with saturated compresses for 30 to 60 minutes in an initial decontamination as soon as possible after contact with a sponge.
3. Antihistamine (e.g., diphenhydramine) lotion and later a topical steroid (e.g., hydrocortisone) may be applied to reduce the early inflammatory reaction. Severe reactions may require systemic administration (e.g., oral or injection) of a corticosteroid.
4. Antiseptic ointment is utilized if there are signs and symptoms of infection.

5C-4 POISONOUS MARINE ANIMALS

5C-4.1 **Ciguatera Fish Poisoning.** Ciguatera poisoning is caused by eating the flesh of a fish that has eaten a toxin-producing micro-organism, the dinoflagellate *Gambierdiscus toxicus*, or certain other species of dinoflagellates. The poisoning is common in reef fish between latitudes 35°N and 35°S around tropical islands or tropical and semitropical shorelines in south Florida, the Caribbean, the West Indies, and the Pacific and Indian Oceans. Fish and marine animals affected include barracuda, red snapper, grouper, sea bass, amberjack, parrotfish, and the moray eel. Incidence is unpredictable and depends on environmental changes that affect the level of dinoflagellates. The toxin is heat-stable, tasteless, and odorless, and is not destroyed by cooking or gastric acid. Symptoms may begin immediately or within several hours of ingestion and may include nausea, vomiting, diarrhea, itching and muscle weakness, aches and spasms. Neurological symptoms may include pain, ataxia (stumbling gait), paresthesias (tingling), and circumoral parasthesias (numbness around the mouth). Apparent reversal of hot and cold sensation when touching or eating objects of extreme temperatures may occur. In severe cases, respiratory failure and cardiovascular collapse may occur. Pruritus (itching) is characteristically made worse by alcohol ingestion. Gastrointestinal symptoms usually disappear within 24 to 72 hours. Although complete recovery will occur in the majority of cases, neurological symptoms may persist for months or years. Signs and symptoms of ciguatera fish poisoning may be misdiagnosed as decompression sickness or contact dermatitis from presumed contact with fire coral or jellyfish. Because of international transport of fish and rapid modern travel, ciguatera poisoning may occur far from endemic areas and afflict international travelers or unsuspecting restaurant patrons.

5C-4.1.1 **Prevention.** Never eat the liver, viscera, or roe (eggs) of any tropical fish. Unusually large fish of any given species may be more toxic. When traveling, consult natives concerning fish poisoning from local fish, although such information may not be reliable. Although there is a radioimmunoassay to test fish flesh for the presence of the toxin, there is no diagnostic test that can be applied to human victims.

5C-4.1.2 ***First Aid and Treatment.***

1. Treatment is supportive and based upon symptoms.
2. In addition to the symptoms described above, other complications that may require treatment include hypotension and cardiac dysrhythmias.
3. Antiemetics and antidiarrheal agents may be required if gastrointestinal symptoms are severe. Atropine may be needed to control bradycardia. IV fluids may be needed to treat hypotension.
4. Intravenous mannitol infusion has been reported to be useful for severe acute ciguatera poisoning. Amytriptyline has been used successfully to resolve neurological symptoms such as depression.
5. Cool showers may induce pruritus (itching).

5C-4.2 **Scombroid Fish Poisoning.** Scombroid fish poisoning occurs from certain fish that have not been promptly cooled or prepared for immediate consumption. Typical fish causing scombroid poisoning include tuna, skipjack, mackerel, bonito, dolphin fish, mahi mahi (Pacific dolphin), and bluefish. Fish that cause scombroid poisoning are found in tropical and temperate waters. Bacteria in the fish flesh stimulate production of histamine and saurine (a histamine-like compound), which produce the symptoms of a histamine-like reaction: nausea, abdominal pain, vomiting, facial flushing, urticaria (hives), headache, pruritus (itching), bronchospasm, and a burning or itching sensation in the mouth. Symptoms may begin one hour after ingestion and last 8 to 12 hours. Death is rare.

5C-4.2.1 **Prevention.** Immediately clean any fish and preserve by rapid chilling. Do not eat any fish that has been left in the sun or in the heat longer than two hours. Try to place all fish intended for consumption on ice or in a cold refrigerator.

5C-4.2.2 **First Aid and Treatment.** An oral antihistamine, (e.g., diphenhydramine, cimetidine), epinephrine (given subcutaneously), and steroids are given as needed.

5C-4.3 **Pufferfish (Fugu) Poisoning.** An extremely potent neurotoxin called tetrodotoxin is found in the viscera, gonads, liver, and skin of a variety of fish, including the pufferfish, porcupinefish, and ocean sunfish. Pufferfish—also called blowfish, toadfish, and balloonfish, and called “fugu” in Japan—are found primarily in the tropics but also in temperate waters of the coastal U.S., Africa, South America, Asia, and the Mediterranean. Pufferfish is considered a delicacy in Japan, where it is thinly sliced and eaten as sashimi. Licensed chefs are trained to select the pufferfish least likely to be poisonous and also to avoid contact with the visceral organs in which resides concentrated poison. The first sign of poisoning is usually tingling around the mouth, which spreads to the extremities and may lead to body wide numbness. Neurological findings may progress to stumbling gait (ataxia), generalized weakness, and paralysis. The victim, though paralyzed, may remain conscious until death occurs from respiratory arrest.

5C-4.3.1 **Prevention.** Avoid eating pufferfish. Cooking the fish flesh does not destroy the toxin.

5C-4.3.2 **First Aid and Treatment.**

1. Provide supportive care with airway management. Monitor breathing and circulation.
2. Monitor rectal sphincter tone for progression of paralysis.
3. Monitor and treat cardiac dysrhythmias.

5C-4.4 **Paralytic Shellfish Poisoning (PSP) (“Red Tide”).** Paralytic shellfish poisoning (PSP) is due to mollusks (bivalves), such as clams, oysters, and mussels that ingest neurotoxin-containing dinoflagellates. Proliferation of these dinoflagellates in the ocean during certain months of the year produce a characteristic red (or other colored) tide. Some dinoflagellate blooms are colorless, so that poisonous mollusks may unknowingly be consumed. Local public health authorities must monitor seawater and shellfish samples to detect the toxin(s). Poisonous shellfish cannot be detected by appearance, smell, or folk methods (e.g., discoloration of either a silver object or a clove of garlic placed in cooking water). Poisonous shellfish can be found in either low or high tidal zones. Toxic varieties of dinoflagellates are common in the following areas: northwestern U.S. and Canada, Alaska, part of western South America, northeastern U.S., the North Sea European countries, and in the Gulf Coast area of the U.S. One type of dinoflagellate, although not toxic if ingested, may lead to eye and respiratory tract irritation from shoreline exposure when a “bloom” becomes aerosolized by wave action and wind.

5C-4.4.1 **Symptoms.** Symptoms of systemic PSP include circumoral paresthesias (tingling around the mouth), which spreads to the extremities and may progress to muscle weakness, ataxia, salivation, intense thirst, and difficulty swallowing. Gastrointestinal symptoms are not common. Death, although uncommon, can result from respiratory arrest. Symptoms begin 30 minutes after ingestion and may last for many weeks. Gastrointestinal illness occurring several hours after ingestion is most likely due to bacterial contamination of the shellfish (see paragraph 5C 4.5). Allergic reactions such as urticaria (hives), pruritus (itching), dryness or scratching sensation in the throat, swollen tongue and bronchospasm may reflect individual hypersensitivity to a specific shellfish and not be related to PSP.

5C-4.4.2 **Prevention.** The toxins are heat stable, so cooking does not prevent poisoning. Broth or bouillon in which shellfish is boiled is especially dangerous because the toxins are water-soluble and will concentrate in the broth.

5C-4.4.3 **First Aid and Treatment.**

1. No antidote is known. Lavaging the stomach with alkaline fluids (e.g., a solution of baking soda) has been reported to be helpful, but is unlikely to be of great benefit.
2. Provide supportive treatment with close observation and advanced life support as needed until the illness resolves.

- 5C-4.5 **Bacterial and Viral Diseases from Shellfish.** Large outbreaks of typhoid fever and other diarrheal diseases caused by the bacteria genus *Vibrio* have been traced to consuming contaminated raw oysters and inadequately cooked crabs and shrimp. Diarrheal stool samples from victims suspected of having bacterial and viral diseases from shellfish should be placed on a special growth medium (e.g., thiosulfate-citrate-bile salts-sucrose agar) to specifically grow *Vibrio* species, with isolates being sent to reference laboratories for confirmation.
- 5C-4.5.1 **Prevention.** To avoid bacterial or viral disease (e.g., Hepatitis A or Norwalk viral gastroenteritis) associated with oysters, clams, and other shellfish, an individual should eat only thoroughly cooked shellfish. It has been proven that eating raw shellfish (mollusks) definitely presents a risk for contracting gastroenteric disease.
- 5C-4.5.2 **First Aid and Treatment.**
1. Provide supportive care with attention to maintaining fluid intake by mouth or IV.
 2. Consult medical personnel for treatment of the various *Vibrio* species that may be suspected.
- 5C-4.6 **Sea Cucumbers.** The sea cucumber is frequently eaten in some parts of the world, where it is sold as “trepang” or “beche-de-mer.” It is boiled and then dried in the sun or smoked. Contact with the liquid ejected from the visceral cavity of some sea cucumber species may result in a severe skin reaction (dermatitis) or even blindness. Intoxication from sea cucumber ingestion is rare.
- 5C-4.6.1 **Prevention.** Local inhabitants can advise about the edibility of sea cucumbers in that region. However, this information may not be reliable. Avoid contact with visceral juices.
- 5C-4.6.2 **First Aid and Treatment.** Because no antidote is known, treatment is symptomatic. Skin irritation may be treated as are jellyfish stings ([paragraph 5C 3.4.4](#)).
- 5C-4.7 **Parasitic Infestation.** Parasitic infestations of fish can be of two types: superficial and within the flesh. Superficial parasites burrow into the surface of fish and are easily seen and removed. These may include fish lice, anchor worms, and leeches. Parasites embedded into flesh can become encysted or remain free in the muscle, entrails, and gills of the fish. These parasites may include roundworms, tapeworms, and flukes. If the fish is inadequately cooked, these parasites can be passed on to humans.
- 5C-4.7.1 **Prevention.** Avoid eating raw fish. Prepare all fish by thorough cooking or hot-smoking. When cleaning fish, look for mealy or encysted areas in the flesh; cut out and discard any cyst or suspicious areas. Remove all superficial parasites. Never eat the entrails or viscera of any fish.

5C-5 REFERENCES FOR ADDITIONAL INFORMATION

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