

Diving Disorders Not Requiring Recompression Therapy

19-1 INTRODUCTION

19-1.1 Purpose. This chapter covers diagnosis and treatment of diving disorders for which recompression therapy usually is not required. It is important to realize that this chapter is a working document. While you should adhere to the procedures as closely as possible, any mistakes or discrepancies shall be brought to the attention of NAVSEA immediately. There are instances where clear direction cannot be given; in these cases, contact the diving medical experts at NEDU or NDSTC for clarification.

19-1.2 Scope. This chapter is a reference for individuals trained in diving procedures. It is also directed to users with a wide range in medical expertise, from the fleet diver to the Diving Medical Officer. Certain treatment procedures require consultation with a Diving Medical Officer for safe and effective use. In preparing for any diving operation, it is mandatory that the dive team have a medical evacuation plan and know the location of the nearest or most accessible Diving Medical Officer and recompression chamber. Diving Medical Personnel should be involved in pre-dive planning and in training to deal with medical emergencies. Even if operators feel they know how to handle medical emergencies, a Diving Medical Officer should be consulted whenever possible.

19-2 BREATHING GAS DISORDERS

All members of the dive team shall be constantly alert for signs and symptoms of oxygen deficiency (hypoxia), carbon monoxide poisoning, carbon dioxide toxicity (hypercapnia), oxygen toxicity, nitrogen narcosis, labored breathing (dyspnea), and hyperventilation.

19-2.1 Oxygen Deficiency (Hypoxia). Oxygen deficiency, or *hypoxia*, if not corrected promptly, leads to loss of judgment, unconsciousness, and even death. There is no reliable warning of the onset of hypoxia. If hypoxia develops gradually, symptoms of interference with brain function will appear. Symptoms of hypoxia include:

- Lack of concentration
- Lack of muscle control
- Inability to perform delicate or skill-requiring tasks
- Drowsiness
- Weakness
- Agitation
- Euphoria
- Loss of consciousness

19-2.1.1 **Causes of Hypoxia.** The most common cause of hypoxia is an interruption of the breathing gas supply. This situation is obvious, and is treated by immediately reestablishing the gas supply, or shifting to an alternate gas supply. Shifting the diver to a gas with insufficient oxygen can also cause hypoxia. Analysis of diving accidents caused by divers breathing insufficient oxygen indicates that the first sign of trouble is an unresponsive diver. The immediate cause of the problem usually is not obvious. Always know the oxygen content of the diver's breathing gas! If a diver becomes unresponsive during a mixed-gas dive, hypoxia should be assumed until it is ruled out.

19-2.1.2 **Treating Hypoxia.** To begin immediate treatment for hypoxia:

1. If the diver is in the water, shift to an alternate gas supply containing sufficient oxygen.
2. Administer 100 percent oxygen at the surface.
3. If the diver has lost consciousness or appears abnormal in any way, seek medical advice immediately.

19-2.1.3 **Unconsciousness Due to Hypoxia.** Because the first sign of hypoxia may be unconsciousness, it may be difficult to differentiate hypoxia from arterial gas embolism in an ascending diver. However, recompression treatment for arterial gas embolism should also correct the hypoxia.

19-2.1.4 **Treating Hypoxia in Specific Operational Environments.** Refer to Volume 4 for information on treatment of hypoxia arising in specific operational environments for MK 16 dives and diving involving closed-circuit oxygen rebreathers.

19-2.2 **Carbon Monoxide Poisoning.** Carbon monoxide poisoning can result from an air supply contaminated by exhaust fumes. It is treated the same way as low oxygen content of breathing gas. The early signs of carbon monoxide poisoning are:

- Headache
- Nausea
- Vomiting

Divers with these symptoms can be treated with 100 percent oxygen at the surface. Divers with symptoms (i.e. severe headache, mental status changes, any neurological symptoms, rapid heart rate) should be treated at 60 fsw on oxygen. When carbon monoxide poisoning is suspected, isolate the suspect breathing gas source, and forward gas samples for analysis as soon as possible.

19-2.3 **Carbon Dioxide Toxicity (Hypercapnia).** Carbon dioxide toxicity, or *hypercapnia*, may occur with or without a deficiency of oxygen. The diver may have no warning of hypercapnia and may become confused and even slightly euphoric before losing consciousness. The inspired carbon dioxide itself does not usually cause permanent injury. Injury from hypercapnia is usually due to secondary effects such as drowning or injury caused by decreased mental function or uncon-

sciousness. Because the first sign of hypercapnia may be unconsciousness and it may not be readily apparent whether the cause is hypoxia or hypercapnia, rule out hypoxia first.

19-2.3.1 **Causes of Carbon Dioxide Buildup.** Carbon dioxide buildup can be caused by:

- Inadequate ventilation of UBAs
- Controlled or skip-breathing
- Excessive breathing resistance
- Excessive dead space in equipment such as a failure of mushroom valves in scuba mouthpiece
- Failure or expenditure of the carbon dioxide absorbent material in a closed-circuit or semiclosed-circuit UBA

19-2.3.2 **Treating Hypercapnia.** To treat hypercapnia, lower the inspired carbon dioxide level by:

1. Increasing helmet ventilation
2. Decreasing the level of exertion
3. Shifting to an alternate breathing source
4. Aborting the dive if defective equipment is the cause

Divers surfacing unconscious should be treated for suspected arterial gas embolism.

19-2.3.3 **Treating Hypercapnia in Specific Operational Environments.** Refer to Volume 4 for information on treatment of hypercapnia in specific operational environments for MK 16 diving operations and diving involving closed-circuit oxygen rebreathers.

19-2.4 **Oxygen Toxicity.** Oxygen toxicity affects the lungs (Pulmonary Oxygen Toxicity) or the central nervous system (CNS Oxygen Toxicity). Pulmonary oxygen toxicity may occur during long oxygen exposures such as recompression treatments, special 100-percent oxygen UBA operations, and saturation dives. Refer to paragraph 21-5.5.6.2 for information on pulmonary oxygen toxicity.

19-2.4.1 **Central Nervous System (CNS) Oxygen Toxicity.** During in-water diving operations, the most common and most serious form of oxygen toxicity involves the central nervous system (CNS). The symptom of CNS oxygen toxicity that has the most serious consequence is the oxygen convulsion. The convulsion itself is not harmful and there will be no long-term residual effects provided injury or drowning can be prevented.

19-2.4.2 **Symptoms of CNS Oxygen Toxicity.** CNS oxygen toxicity is usually not encountered unless the partial pressure of oxygen approaches or exceeds 1.6 ata. However, oxygen convulsion may be encountered at lower oxygen partial pressure. Symptoms of CNS oxygen toxicity may occur singly or together, in no particular order. There may be no warning of an impending convulsion. Signs and symptoms of CNS oxygen toxicity include:

- V:** Visual symptoms. Tunnel vision, a decrease in diver's peripheral vision, and other symptoms, such as blurred vision, may occur.
- E:** Ear symptoms. Tinnitus is any sound perceived by the ears but not resulting from an external stimulus. The sound may resemble bells ringing, roaring, or a machinery-like pulsing sound.
- N:** Nausea or spasmodic vomiting. These symptoms may be intermittent.
- T:** Twitching and tingling symptoms. Any of the small facial muscles, lips, or muscles of the extremities may be affected. This is the most frequent and obvious symptom.
- I:** Irritability. Any change in the diver's mental status, including confusion, agitation, and anxiety.
- D:** Dizziness. Symptoms include clumsiness, incoordination, and unusual fatigue.
- C:** Convulsions. The first sign of CNS oxygen toxicity may be a convulsion that occurs with little or no warning.

19-2.4.3 **Treating a Tethered Diver.** A tethered diver who thinks he has symptoms of oxygen toxicity shall inform the Diving Supervisor. The Diving Supervisor shall take action to lower the oxygen partial pressure by:

1. Decreasing diver depth 10 feet.
2. Discontinuing 100 percent oxygen and vent with a gas of lower oxygen content.

19-2.4.4 **Treating a Free-Swimming Diver.** Free-swimming divers on a 100-percent oxygen UBA shall alert their diving partner and surface if possible.

19-2.4.5 **Treatment for CNS Convulsions.** If a diver convulses, the UBA should be ventilated immediately with a gas of lower oxygen content, if possible. If depth control is possible and the gas supply is secure (helmet or full face mask), the diver's depth must be kept constant until the convulsion subsides. If an ascent must take place, it should be done as slowly as possible. A diver surfacing unconscious because of an oxygen convulsion or to avoid drowning must be treated as if suffering from arterial gas embolism. Convulsing divers in the recompression chamber should be protected from physical harm. When the convulsion subsides, the diver should be kept with head back and chin up to ensure an adequate airway until consciousness is regained. Forcing the mouth open to insert a bite block is

unnecessary. CNS oxygen toxicity occurring during recompression therapy is discussed fully in paragraph 21-5.5.6.1.

- 19-2.4.6 **Treating CNS Oxygen Toxicity in Specific Operational Environments.** Refer to Volume 3 for information about treatment of CNS oxygen toxicity in specific operational environments for surface-supplied helium-oxygen diving, and to Volume 4 for MK 16 diving operations and 100-percent oxygen rebreather dives.
- 19-2.5 **Nitrogen Narcosis.** *Narcosis* is a state of stupor or unconsciousness caused by breathing inert gases at pressure while diving. The most common form, nitrogen narcosis, is caused by breathing compressed air at depth.
- 19-2.5.1 **Symptoms of Nitrogen Narcosis.** Symptoms of nitrogen narcosis may occur singly or together, in no particular order. Signs and symptoms include:
- Loss of judgment or skill
 - A false feeling of well-being
 - Lack of concern for job or safety
 - Apparent stupidity
 - Inappropriate laughter
 - Tingling and vague numbness of lips, gums, and leg
- 19-2.5.2 **Treatment of Nitrogen Narcosis.** The only effective way to counteract the narcotic effect of nitrogen is to lower the nitrogen partial pressure. Specifically:
1. The diver should ascend or be brought to a shallower depth.
 2. If mental acuity is not restored, the dive shall be aborted.
- 19-2.5.3 **Nitrogen Narcosis in MK 16.** When diving MK 16 UBA (maintaining a constant ppO_2 of 0.75) with N_2O_2 as the diluent, nitrogen narcosis becomes a significant factor at deep depths.
- 19-2.6 **Hyperventilation.** *Hyperventilation* is rapid breathing in excess of metabolic requirements, usually as the result of a conscious voluntary effort or by apprehension. Hyperventilation excessively lowers the carbon dioxide levels in the blood and increases the blood oxygen level slightly. This, in turn, may lead to a biochemical imbalance that gives rise to dizziness and twitching or tingling of the extremities, which may be mistaken for CNS oxygen toxicity. Usually, this twitching is also accompanied by some degree of spasm of the small muscles of the hands and feet which allows a sure diagnosis to be made. Treatment is to slow down the breathing rate by direction and reassurance, which allows the condition to correct itself. Refer to Chapter 3 for more information on the signs, symptoms, and treatment of hyperventilation.
- 19-2.7 **Shortness of Breath (Dyspnea).** The increased density of the breathing gas at depth, combined with physical exertion, may lead to shortness of breath that may become severe and cause panic in some divers.

Dyspnea is usually associated with carbon dioxide buildup in the body, but may occur without it. When dyspnea occurs, the diver must rest until the shortness of breath subsides. This may take several minutes. If dyspnea does not subside with rest, or if it returns with even slight exertion, it may be due to carbon dioxide buildup. In open-circuit UBAs, ventilation rates should be checked to make sure they are adequate; the helmet should be ventilated if necessary. Adequate ventilation rates are at least 4 acfm for moderate work and 6 acfm for very hard work. Ventilation should not drop below 1 acfm, even at rest.

In demand systems, excessive dead space from a damaged oral-nasal may be the cause. In closed or semiclosed UBAs, the CO₂ absorbent canister may be spent. If these causes are likely, the dive must be aborted to correct them.

19-3 PULMONARY OVERINFLATION SYNDROMES

Pulmonary overinflation syndromes are disorders that are caused by gas expanding within the lung. The disorders encountered in diving are arterial gas embolism, mediastinal and subcutaneous emphysema, and pneumothorax. Normally, only arterial gas embolism (AGE) requires recompression therapy ([Chapter 20](#), paragraph 20-2).

19-3.1 Mediastinal and Subcutaneous Emphysema. *Mediastinal emphysema* is caused by gas expanding in the tissues behind the breast bone. Symptoms include mild to moderate pain under the breast bone, often described as a dull ache or feeling of tightness. Deep inspiration, coughing, or swallowing makes the pain worse, and the pain may radiate to the shoulder, neck or back.

19-3.1.1 Causes of Subcutaneous Emphysema. *Subcutaneous emphysema* results from movement of the gas from the mediastinum to the region under the skin of the neck and lower face. Mild cases are often unnoticed by the diver. In more severe cases, the diver may experience a feeling of fullness around the neck and may have difficulty in swallowing. The diver's voice may change in pitch. An observer may note a swelling or apparent inflation of the diver's neck. Movement of the skin near the windpipe or about the collar bone may produce a cracking or crunching sound (crepitation).

19-3.1.2 Treatment of Mediastinal and Subcutaneous Emphysema. Suspicion of mediastinal or subcutaneous emphysema warrants prompt referral to medical personnel to rule out pneumothorax. Treatment of mediastinal or subcutaneous emphysema with mild symptoms consists of breathing 100 percent oxygen at the surface. If symptoms are severe, shallow recompression may be beneficial. Recompression should only be carried out upon the recommendation of a Diving Medical Officer who has ruled out the occurrence of pneumothorax. Recompression is performed with the diver breathing 100 percent oxygen and using the shallowest depth of relief (usually 5 or 10 feet). An hour of breathing oxygen should be sufficient for resolution, but longer stays may be necessary. Decompression will be dictated by the tender's decompression obligation. The appropriate air table should be used, but the ascent rate should not exceed 1 foot per minute. In this specific case, the

delay in ascent should be included in bottom time when choosing the proper decompression table.

19-3.2 Pneumothorax. A *pneumothorax* is air outside the lung that is trapped in the chest cavity. This condition can result from a severe blow to the chest or a rupture of lung tissue due to overpressurization.

19-3.2.1 Symptoms of Pneumothorax. Pneumothorax is usually accompanied by a sharp unilateral (one side) pain in the chest, shoulder, or upper back that is aggravated by deep breathing. To minimize the pain, the victim will often breathe in a shallow, rapid manner. The victim may appear pale and exhibit a tendency to bend the chest toward the involved side. A collapsed lung may be detected by listening to both sides of the chest with the ear or a stethoscope. A completely collapsed lung will not produce audible sounds of breathing. In cases of partial pneumothorax, however, breath sounds may be present and the condition must be suspected on the basis of history and symptoms. In some instances, the damaged lung tissue acts as a one-way valve, allowing gas to enter the chest cavity but not to leave. Under these circumstances, the size of the pneumothorax increases with each breath. This condition is called tension pneumothorax. In simple pneumothorax, the respiratory distress usually does not get worse after the initial gas leakage out of the lung. In tension pneumothorax, however, the respiratory distress worsens with each breath and can progress rapidly to shock and death if the trapped gas is not vented by inserting a catheter, chest tube, or other device designed to remove gas from the chest cavity.

19-3.2.2 Treating Pneumothorax. Mild pneumothorax can be treated by breathing 100 percent oxygen. Cases of pneumothorax that demonstrate cardiorespiratory compromise may require the insertion of a chest tube, large-bore intravenous (IV) catheter, or other device designed to remove intrathoracic gas (gas around the lung). These devices should only be inserted by personnel trained in their use and the use of other accessory devices (one-way valves, underwater suction, etc.) necessary to safely decompress the thoracic cavity. Divers recompressed for treatment of arterial gas embolism or decompression sickness, who also have a pneumothorax, will experience relief upon recompression. A chest tube or other device and a one-way relief valve may need to be inserted at depth to prevent expansion of the trapped gas during subsequent ascent. If a diver's condition deteriorates rapidly during ascent, especially if the symptoms are respiratory, tension pneumothorax should always be suspected. If a tension pneumothorax is found, recompression to depth of relief is warranted to relieve symptoms until the thoracic cavity can be properly vented. Pneumothorax, if present in combination with arterial gas embolism or decompression sickness, should not prevent immediate recompression therapy. However, a pneumothorax may need to be vented as described before ascent from treatment depth.

19-3.3 Prevention of Pulmonary Overinflation Syndrome. The potential hazard of the pulmonary overinflation syndromes may be prevented or substantially reduced by careful attention to the following:

- Medical selection of diving personnel, with particular attention to eliminating those who show evidence of lung disease or who have a past history of respiratory disorders. Divers who have had a spontaneous pneumothorax have a high incidence of recurrence and should not dive. Divers who have had pneumothorax from other reasons (e.g., surgery, trauma, etc.) should have their fitness for continued diving reviewed by an experienced Diving Medical Officer, in consultation with appropriate respiratory specialists.
- Evaluation of the diver's physical condition immediately before a dive. Any impairment of respiration, such as a cold, bronchitis, etc., may be considered as a temporary restriction from diving.
- Proper, intensive training in diving physics and physiology for every diver, as well as instruction in the correct use of various diving equipment.

19-4 BAROTRAUMA

Barotrauma, or damage to body tissues from the mechanical effects of pressure, results when pressure differentials between body cavities and the hydrostatic pressure surrounding the body, or between the body and the diving equipment, are not equalized properly. Barotrauma most frequently occurs during descent, but may also occur during ascent.

19-4.1 Squeeze. Squeeze during descent occurs when gas in a cavity is compressed. The types of squeeze most frequently encountered in diving are:

- *Middle ear squeeze* is the most common form of barotrauma, caused by a blocked or dysfunctional eustachian tube or from improper equalization. This will cause immediate pain—which becomes progressively worse as the eardrum stretches—and possibly vertigo, hearing loss, and tinnitus. If descent is continued without equalizing the pressure, the eardrum may eventually rupture. If this occurs the pain will immediately disappear, but nausea and vertigo may result from cold water entering the middle ear.
- *External ear squeeze* is caused by a hood or other piece of equipment covering the external ear passage. This may result in the same symptoms as a middle-ear squeeze.
- *Sinus squeeze* is caused by blocked passages that vent the sinuses to the upper respiratory air passages.
- *Lung (thoracic) squeeze* is caused by compression of air in the lungs to a volume less than residual volume. This could happen in a breathhold.
- *Whole body squeeze* can occur when the air supply in a dry suit fails to balance water pressure. This could be precipitated by a sudden or unexpected increase in depth, by malfunctioning or maladjusted supply and exhaust valves, or by the absence or failure of the safety non-return valve.

- *Face mask squeeze* can occur when the diver fails to equalize air in the mask by nasal exhalation. In a full face mask, malfunctioning air supply or valving can cause face mask squeeze.
- *Suit squeeze* is caused by a pocket of air in a dry suit that becomes trapped under a fold or fitting and pinches the skin in the fold area.
- *Tooth squeeze* is caused by a pocket of air in a filling.

19-4.1.1 **Treating Squeeze During Descent.** To treat squeeze during descent:

1. Stop descent.
2. If efforts to equalize pressure fail, ascend a few feet.
3. Avoid clearing on ascent.
4. Avoid a forceful Valsalva
5. If further efforts to equalize pressure fail, abort the dive.
6. If the diver reports dizziness, ventilate the diver, abort the dive, and evaluate the need to send down the standby diver to assist.
7. Report the squeeze to the medical personnel trained in diving medicine for appropriate treatment.

19-4.1.2 **Treating Reverse Squeeze During Ascent.** Reverse squeeze occurs when gas trapped in a cavity cannot escape as it expands during ascent. To treat reverse squeeze of the middle ear or sinus during ascent:

1. Stop ascent and, if clearing does not occur spontaneously, descend 2 to 4 feet.
2. Ascend slowly and in stages to allow additional time for equalization.
3. Avoid forceful Valsalva.
4. Evaluate the need to send down the standby diver to assist if difficulty persists. Vertigo may develop.
5. Upon surfacing, report the problem to the medical personnel trained in diving medicine for appropriate treatment.

19-4.1.3 **Preventing Squeeze.** Sinus and ear squeeze are best prevented by not diving with nasal and sinus congestion. If decongestants must be used, check with medical personnel trained in diving medicine to obtain medication that will not cause drowsiness and possibly add to symptoms caused by the narcotic effect of nitrogen.

19-4.1.4 Refer to Chapter 3 for more information on the signs and symptoms of the various types of squeeze.

19-4.2 Gastrointestinal Distention as a Result of Gas Expansion. Divers may occasionally experience abdominal pain during ascent because of gas expansion in the stomach or intestines. This condition is caused by gas being generated in the intestines during a dive, or by swallowing air (aerophagia). These pockets of gas will usually work their way out of the system through the mouth or anus. If not, distention will occur.

19-4.2.1 **Treating Intestinal Gas Expansion.** If the pain begins to pass the stage of mild discomfort, ascent should be halted and the diver should descend slightly to relieve the pain. The diver should then attempt to gently burp or release the gas anally. Overzealous attempts to belch should be avoided as they may result in swallowing more air. Abdominal pain following fast ascents shall be evaluated by a Diving Medical Officer.

19-4.2.2 **Preventing Intestinal Gas Expansion.** To avoid intestinal gas expansion:

1. Do not dive with an upset stomach or bowel.
2. Avoid eating foods that are likely to produce intestinal gas.
3. Avoid a steep, head-down angle during descent to minimize the amount of air swallowed.

19-4.3 Ear Barotrauma. Simple ear squeeze is discussed in paragraph 19-4.1. More serious forms of ear barotrauma are rupture of the eardrum or round or oval window.

19-4.3.1 **Eardrum Rupture.** Ear squeeze may result in eardrum rupture. When rupture occurs, this pain will diminish rapidly. If eardrum rupture is suspected, the dive shall be aborted. Vertigo and/or nausea may occur if water enters the middle ear. Suspected cases of eardrum rupture shall be referred to medical personnel. Antibiotics and pain medication taken orally may be required. Never administer medications directly into the canal of a ruptured eardrum unless done in direct consultation with an ear, nose, and throat medical specialist.

19-4.3.2 **Inner Ear Barotrauma.** The round window and oval window are membranes that separate fluid in the inner ear from the middle ear. Inner ear barotrauma involves the rupture of one of these membranes and may be associated with the diver who had difficulty clearing his ears (vigorous Valsalva). However, a rupture may arise for no apparent reason. Often symptoms of inner ear barotrauma will become evident on the bottom or after the diver reaches the surface. Symptoms may include vertigo, hearing loss, or tinnitus. Any hearing loss occurring within 72 hours of a hyperbaric exposure should be evaluated for inner ear barotrauma.

Symptoms of inner ear barotrauma can be confused with symptoms of inner ear decompression sickness or arterial gas embolism for which recompression therapy

is the only appropriate treatment. Symptoms of inner ear barotrauma will not be relieved or may worsen with recompression. If there's a possibility that the symptoms of vertigo, deafness or tinnitus may be due to decompression sickness, or if other neurological symptoms are present, institute recompression therapy. During decompression from treatment depth, the diver with suspected inner ear barotrauma should not be exposed to excessive positive or negative pressure when breathing oxygen on a built-in breathing system (BIBS) mask. The diver should be kept in an upright sitting position. After surfacing from treatment, bed rest, head elevation, and hospitalization are indicated until an audiological workup can be completed by medical specialists.

19-4.4 Middle Ear Oxygen Absorption Syndrome. *Middle ear oxygen absorption syndrome* refers to the negative pressure that may develop in the middle ear following a long oxygen dive. Gas with a very high percentage of oxygen enters the middle ear cavity during an oxygen dive. Following the dive, the oxygen is slowly absorbed by the tissues of the middle ear. If the eustachian tube does not open spontaneously, a negative pressure relative to ambient may result in the middle ear cavity. Symptoms are often noted the morning after a long oxygen dive. Middle ear oxygen absorption syndrome is difficult to avoid but usually does not pose a significant problem because symptoms are generally minor and easily eliminated. There may also be fluid (serous otitis media) present in the middle ear as a result of the differential pressure.

19-4.4.1 Symptoms of Middle Ear Oxygen Absorption Syndrome. The diver may notice mild discomfort and hearing loss in one or both ears. There may also be a sense of pressure and a moist, cracking sensation as a result of fluid in the middle ear.

19-4.4.2 Treating Middle Ear Oxygen Absorption Syndrome. Equalizing the pressure in the middle ear using a normal Valsalva maneuver or the diver's procedure of choice, such as swallowing or yawning, will usually relieve the symptoms. Discomfort and hearing loss resolve quickly, but the middle ear fluid is absorbed more slowly. If symptoms persist, a Diving Medical Technician or Diving Medical Officer shall be consulted.

19-5 DISORDERS OF HIGHER FUNCTION AND CONSCIOUSNESS

Divers may experience sensations while at depth which they would describe as dizziness, or in some situations may lose consciousness. The causes of these conditions are not always obvious and surfacing the diver may not be possible because of decompression obligations. Therefore, it is important to know what could cause these disorders in order to decide the possibility of injury to the diver.

19-5.1 Vertigo. The sensation of the diver spinning or the environment spinning is called *vertigo*. Vertigo is common and usually transient in divers. There are two types of vertigo: transient and persistent.

19-5.1.1 Transient Vertigo. Transient vertigo typically lasts less than 1 minute. There are two common forms of transient vertigo: caloric and alternobaric. Caloric vertigo may be due to unequal cold water stimulation of the ear. This is seen when passing

through thermoclines, slow clearing of the external ear canals, or eardrum rupture. Alternobaric vertigo may be caused by pressure differences between the middle ears on ascent or descent, and typically resolves when the ears are cleared. Travel should be halted until the vertigo resolves. Once the vertigo resolves, then the dive may be continued.

19-5.1.2 **Persistent Vertigo.** Persistent vertigo lasts greater than 1 minute. Symptoms may be caused by inner ear barotrauma, decompression sickness or arterial gas embolism. If persistent vertigo is suspected, abort the dive and consult Diving Medical Personnel. All cases of persistent vertigo shall be evaluated by a Diving Medical Officer.

19-5.2 **Unconscious Diver on the Bottom.** An unconscious diver on the bottom is a serious emergency. Only general guidance can be given here. Management decisions shall be made on site, taking into account all known factors. The advice of a Diving Medical Officer shall be obtained at the earliest possible moment.

If the diver becomes unconscious on the bottom:

1. Make sure that the breathing medium is adequate and that the diver is breathing.
2. Check the status of any other divers.
3. If there is any reason to suspect gas contamination, shift to the standby supply.
4. Have the dive partner or standby diver ventilate the afflicted diver to remove accumulated carbon dioxide in the helmet and ensure the correct oxygen concentration.
5. When ventilation is complete, have the dive partner or standby diver ascertain whether the diver is breathing. In the MK 21, the presence of breath sounds may be audible over the intercom.
6. If the diver appears not to be breathing, the dive partner/standby diver shall attempt to reposition the diver's head to open the airway. Airway obstruction will be the most common reason why an unconscious diver fails to breathe.
7. Check afflicted diver for signs of consciousness.
 - If the diver regains consciousness, allow a short period for stabilization and then abort the dive.
 - If the diver remains unresponsive but is breathing, have the dive partner or standby diver move the afflicted diver to the stage. This action need not be rushed.
 - If the diver appears not to be breathing, make further attempts to open the airway while moving the diver rapidly to the stage.

8. During recovery of the affected diver:
 - If conscious, allow a period for stabilization, then begin decompression.
 - If unconscious, bring the diver to the first decompression stop or the surface at a rate of 30 fsw/min. Decompress the diver using surface decompression procedures if required.
9. If the diver remains unconscious at the first decompression stop and breathing cannot be detected in spite of repeated attempts to position the head and open the airway, an extreme emergency exists. One must weigh the risk of catastrophic, even fatal, decompression sickness if the diver is brought to the surface, versus the risk of asphyxiation if the diver remains in the water. If the affected diver is not breathing, leave the unaffected diver at his first decompression stop to complete decompression and surface the affected diver at 30 fsw/minute, deploying the standby diver as required. Start CPR or Advanced Cardiac Life Support (ACLS) on the surface if needed. Recompress immediately and treat accordingly.

19-6 NEAR DROWNING

- 19-6.1 **Causes and Prevention.** A swimmer or diver can fall victim to drowning because of overexertion, panic, inability to cope with rough water, exhaustion, or the effects of cold water or heat loss.
- 19-6.1.1 **Drowning in Hard-Hat Diving.** Drowning in a hard-hat diving rig is rare. It can happen if the helmet is not properly secured and comes off, or if the diver is trapped in a head-down position with a water leak in the helmet. Normally, as long as the diver is in an upright position and has a supply of air, water can be kept out of the helmet regardless of the condition of the suit.
- 19-6.1.2 **Drowning in Lightweight or Scuba Diving.** Divers wearing lightweight or scuba gear can drown if they lose or ditch their mask or mouthpiece, run out of air, or inhale even small quantities of water. This could be the direct result of failure of the air supply, or panic in a hazardous situation. The scuba diver, because of direct exposure to the environment, can be affected by the same conditions that may cause a swimmer to drown.
- 19-6.1.3 **Prevention of Drowning.** Drowning is best prevented by thoroughly training divers in safe diving practices and carefully selecting diving personnel. A trained diver should not easily fall victim to drowning. However, overconfidence can give a feeling of false security that might lead a diver to take dangerous risks.
- 19-6.2 **Treatment.** To treat near drowning:
1. Assess airway, breathing, and circulation.
 - Rescue breathing should be started as soon as possible, even before the victim is removed from the water.

2. Give 100 percent oxygen by mask.
3. Call for assistance from qualified medical personnel and transport as soon as possible.

19-7 THERMAL STRESS

Thermal stress occurs when the difference between the water and body temperature is large enough that the body will gain heat (hyperthermia) or lose heat (hypothermia). In both conditions mild exposures will lead mainly to discomfort, but one must always be aware of the signs and symptoms of more severe stress. In these cases, either proper protective equipment should be worn, or exposure limited.

19-7.1 Hyperthermia. Hyperthermia is related to a rise in body core temperature. Divers are susceptible to heat stress when their thermal garment sufficiently insulates their body from the water and they are unable to dissipate their body heat. Members of the dive team who are not in the water are more likely to suffer heat injury. The treatment of all cases of hyperthermia shall include cooling of the victim to reduce core temperature.

19-7.1.1 Mild to Moderate Hyperthermia. In mild to moderate cases of hyperthermia (heat exhaustion), the victim will complain of frontal headache, nausea, weakness, excessive fatigue, and/or dizziness. If these symptoms occur, the dive supervisor will be notified. Cooling should be started immediately by spraying with water and fanning. Oral fluid replacement should begin as soon as the victim can drink and continue until he has urinated pale to clear urine several times. If the symptoms do not improve within 5 minutes, the victim shall be evaluated by Diving Medical Personnel.

19-7.1.2 Severe Hyperthermia. In severe cases of hyperthermia (severe heat exhaustion or heat stroke), the victim will experience disorientation, tremors, loss of consciousness and/or seizures. This is a medical emergency. If these symptoms occur, the dive supervisor shall be notified. Cooling measures shall be started and the victim shall be transported immediately to a medical treatment facility.

19-7.1.3 Cooling Measures. Cold water or ice should never be used on the whole body because this will cause vasoconstriction which decreases blood flow to the skin, which may slow the process of lowering core temperature. Ice packs to the neck, armpit or groin may be used. The most efficient means of cooling is achieved by removing all clothes, spraying the victim with a fine mist of lukewarm-to-cool water, and then fanning.

19-7.2 Hypothermia. Immersion hypothermia is a potential hazard whenever diving operations take place in cool to cold waters. A diver's response to immersion in cold water depends on the degree of thermal protection worn and water temperature. The signs and symptoms of falling core temperature are given in Table 3-1 (Chapter 3). Responses to falling core temperature are individual.

19-7.2.1 **Mild Hypothermia.** To treat hypothermia, rewarm the victim. In mild cases, the victim will experience uncontrolled shivering, slurred speech, imbalance, and/or poor judgment. If these symptoms occur, the dive supervisor shall be notified immediately. Passive and active rewarming measures should be initiated and continue until the victim is sweating. If the victim requires more than a few minutes of rewarming, he shall be evaluated by Diving Medical Personnel.

19-7.2.2 **Severe Hypothermia.** Severe cases of hypothermia are characterized by loss of shivering, decreased consciousness, irregular heartbeat, and/or very shallow pulse or respirations. This is a medical emergency. Avoid any exercise, keep the victim lying down, initiate only passive rewarming, and immediately transport to the nearest medical treatment facility.

CAUTION Do not institute active rewarming with severe cases of hypothermia.

WARNING CPR should not be initiated on a severely hypothermic diver unless it can be determined that the heart has stopped or is in ventricular fibrillation. CPR should not be initiated in a patient that is breathing.

19-7.2.3 **Rewarming Techniques.**

1. Passive:

- Remove all wet clothing.
- Wrap victim in a blanket (preferably wool).
- Place in an area protected from wind.
- If possible, place in a warm area (i.e. galley).

2. Active:

- Warm shower or bath.
- Place in a very warm space (i.e. engine room).

19-7.3 **Physiological Effects of Exposure to Cold Water.** In addition to hypothermia, other responses to exposure to cold water create potential hazards for the diver. The effect of these responses may be cumulative and magnified by underlying hypothermia.

- **Diving Reflex/Bradycardia.** The Mammalian or diving reflex, which is caused by either sudden exposure of the face to cold water or immersion of the whole body in cold water, can result in bradycardia (slowing of the heart rate), peripheral vasoconstriction, and increased blood supply to the brain and heart.
- **Laryngeal Stimulation.** Inhaling a small amount of water can induce spasm of the laryngeal muscles and possibly cause airway obstruction.

- **Carotid Sinus Reflex.** External pressure on the carotid artery from a tight fitting neck dam, wet suit, or dry suit can activate receptors in the arterial wall, causing a decrease in heart rate with possible loss of consciousness. Using an extra-tight-fitting dry or wet suit or tight neck dams to decrease water leaks increase the chances of activation of the carotid reflex and the potential for problems.
- **Breath Holding and Bradycardia.** Breath-hold diving causes a decrease in heart rate to approximately 60–70 percent of pre-dive levels and an increase in the incidence of cardiac arrhythmia (irregular heartbeat). Exposure to cold water also exacerbates the degree of bradycardia. It is unknown whether the bradycardia and arrhythmias associated with removing or losing a face mask contribute to diving casualties. It is reasonable that when operationally required, such as during buddy breathing or an underwater dive rig switch-over, the “breathholding” diver should be closely monitored by the unaffected dive buddy.

Emergency medical training should emphasize emergency procedures as outlined for treating an unconscious diver on the bottom (see paragraph 19-5.2), treating a diver who has nearly drowned (see paragraph 19-6), treating a hypothermic diver (see paragraph 19-7.2), and the material covered in this section

19-8 OPERATIONAL HAZARDS

Most physical emergency situations, such as umbilical fouling, entrapment, and equipment failure, have been mentioned in previous chapters. Those with direct medical implications will be recounted briefly in this section, with elaboration when necessary for a clear understanding of the problem and the solution.

- 19-8.1 **Uncontrolled Ascent.** A diver caught in an uncontrolled ascent must exhale continuously to avoid arterial gas embolism. When ascending, the diver should vent enough air to prevent the variable volume dry suit from rupturing at the surface while maintaining positive buoyancy. Treatment of an uncontrolled ascent is found in paragraph 21-3.6.4 for air diving.
- 19-8.2 **Otitis Externa.** *Otitis externa* (swimmer’s ear) is an infection of the ear canal caused by repeated immersion. The water in which the dive is being performed does not have to be contaminated with bacteria for otitis externa to occur. The first symptom of otitis externa is an itching and/or wet feeling in the affected ear. This feeling will progress to local pain as the external ear canal becomes swollen and inflamed. Local lymph nodes (glands) may enlarge, making jaw movement painful. Fever may occur in severe cases. Once otitis externa develops, the diver should discontinue diving and be examined and treated by Diving Medical Personnel. Unless preventive measures are taken, this condition is very likely to occur during diving operations, causing unnecessary discomfort and restriction from diving.
- 19-8.2.1 **External Ear Prophylaxis.** External ear prophylaxis, a technique to prevent swimmer’s ear, should be done each morning, after each wet dive, and each

evening during diving operations. External ear prophylaxis is accomplished using a 2 percent acetic acid in aluminum acetate (e.g., Otic Domboro) solution. The head is tilted to one side and the external ear canal gently filled with the solution, which must remain in the canal for 5 minutes. The head is then tilted to the other side, the solution allowed to run out and the procedure repeated for the other ear. The 5-minute duration shall be timed with a watch. If the solution does not remain in the ear a full 5 minutes, the effectiveness of the procedure is greatly reduced.

- 19-8.2.2 **Occluded External Ear Canal.** During prolonged diving operations, the external ear canal may become occluded with wax (cerumen). When this happens, external ear prophylaxis is ineffective and the occurrence of otitis externa will become more likely. The external ear canal can be examined periodically with an otoscope to detect the presence of ear wax. If the eardrum cannot be seen during examination, the ear canal should be flushed gently with water, dilute hydrogen peroxide, or sodium bicarbonate solutions to remove the excess cerumen. Never use swabs or other instruments to remove cerumen; this is to be done only by trained medical personnel. Otitis externa is a particular problem in saturation diving if divers do not adhere to prophylactic measures (see paragraph 15-18.2).
- 19-8.3 **Underwater Trauma.** Underwater trauma is different from trauma that occurs at the surface because it may be complicated by the loss of the diver's gas supply and by the diver's decompression obligation. If possible, injured divers should be surfaced immediately and treated appropriately. If an injured diver is trapped, the first priority is to ensure sufficient breathing gas is available, then to stabilize the injury. At that point, a decision must be made as to whether surfacing is possible. If the decompression obligation is great, the injury will have to be stabilized until sufficient decompression can be accomplished. If an injured diver must be surfaced with missed decompression, the diver must be treated as soon as possible, realizing that the possible injury from decompression sickness may be as severe or more severe than that from the other injuries.
- 19-8.4 **Injuries Caused by Marine Life.** These types of injuries will depend on the geographical location and local marine plants and animals. In planning diving operations, potential marine hazards should be identified and local experts consulted on treatment experience and antisera availability for treating envenomization. Treatment advice should be formalized into procedures and filed in [Appendix 5C](#) for ready reference during operations. Suitable references on the subject are listed in [Appendix 5C](#).
- 19-8.5 **Communicable Diseases and Sanitization.** Using unsanitized diving equipment presents a health hazard that can be avoided easily through proper cleaning procedures. Cleaning and disinfecting procedures vary depending on the equipment and how it is used. Cleaning instructions for diving equipment are provided in the appropriate equipment operations and maintenance manual and PMS maintenance requirement cards.

19-9 MEDICATIONS AND DIVING

There are no hard and fast rules for deciding when a medication would preclude a diver from diving. In general, topical medications, antibiotics, birth control medication, and decongestants that do not cause drowsiness would not restrict diving. Diving Medical Personnel should be consulted to determine if any other drugs would preclude diving.