CHAPTER 10

IMMERSION HYPOTHERMIA, NEAR-DROWNING AND WATER SURVIVAL

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INTRODUCTION

Immersion in cold water is a hazard for anyone who participates in recreational, commercial or military activities in the oceans, lakes, and streams of all but the tropical regions of the world. For practical purposes, significant risk of immersion hypothermia usually begins in water colder than 77° F. This means that the risk of immersion hypothermia in North America is nearly universal during most of the year. Cold water immersion is associated with two significant medical emergencies: near drowning and hypothermia. The following pages discuss these topics, with emphasis on the body's response to immersion and on the treatment of hypothermia and near-drowning. The chapter concludes with a brief primer on surviving in cold water.

PHYSIOLOGICAL RESPONSES TO COLD-WATER IMMERSION

Sudden immersion in cold water results in an immediate decline in skin temperature which, in turn, stimulates a cold-shock reflex. This reflex causes an instantaneous gasping for air and sudden increases in heart rate, respiratory rate, blood flow and blood pressure. The cold-shock reflex (see below for a more complete discussion) only lasts for a few minutes, but it can be deadly if the victim's head is underwater (leading to immediate aspiration and drowning) or if the victim has no flotation assistance and cannot keep his/her head above the water. As body temperature declines, metabolism increases and shivering begins. Also, the muscles of the extremities cool rapidly, leading to a loss of manual dexterity and grip strength. As the body continues to cool, shivering eventually ceases, heart rate and blood pressure decrease, and the victim begins to suffer mental impairment, difficulty in thinking clearly, impaired perception, and finally loss of consciousness. An unconscious victim in the water will drown, oftentimes even if he/she is wearing a personal flotation device. If an immersed unconscious hypothermia victim does not drown, continued body cooling will eventually lead to cardiac arrest.

The following is a simple guide to the levels of hypothermia and their associated signs and symptoms: Note: for accuracy, body temperatures should be measured in the esophagus, if possible, or at the eardrum (but not by infrared sensor), or rectally. Oral temperatures and axillary (armpit) temperatures are not accurate in hypothermia.

Normal: Core body temperature @98.6 ± 1.0° F.

Mild hypothermia: Core body temperature 90-95° F. Shivering; impaired manual dexterity, grip strength and muscle coordination; impaired mental processes.

Moderate hypothermia: Core body temperature 82-90° F. Shivering ceases; loss of consciousness (at body temperatures under 86° F.); increased risk of cardiac irritability and dysrhythmias (irregular or abnormal heart rhythms).

Severe hypothermia: Core body temperature <82° F. Extremity stiffness; vital signs difficult to measure or absent; severe risk of ventricular fibrillation or cardiac arrest from rough handling during rescue or treatment; cardiac arrest or ventricular fibrillation usually occurs spontaneously at body temperatures below 77° F.

The body's responses to cold-water immersion can be divided into three stages: 1) initial immersion and the cold-shock response; 2) short-term immersion and loss of performance; and 3) long-term immersion and the onset of hypothermia. Each phase is accompanied by specific survival hazards for the immersion victim from a variety of physiological mechanisms. Deaths have occurred in all three phases of the immersion response.

Stage 1: Initial Immersion: the Cold Shock Response: The cold shock response occurs within the first 1-4 minutes of cold water immersion and is dependent on the extent and rate of skin cooling. The responses are generally those affecting the respiratory system and those affecting the heart and the body's metabolism. Rapid skin cooling initiates an immediate gasp response, the inability to breath-hold, and hyperventilation. The gasp response may cause drowning if the head is submersed during the initial entry into cold water. The significant lessening of breath holding time makes it more difficult to escape underwater from a capsized vessel, and it further increases the risk drowning in high seas. Finally, hyperventilation may cause a low level of blood carbon dioxide, which can lead to decreased brain blood flow and oxygen supply. This may lead to disorientation, loss of consciousness and drowning.

Skin cooling also initiates peripheral vasoconstriction (the constriction of small blood vessels in the skin and superficial tissues) as well as increased cardiac output, heart rate and blood pressure. The increased workload on the heart may lead to myocardial ischemia (low blood oxygen levels in the heart muscle) and arrhythmias (abnormal heart rhythm), including ventricular fibrillation. Thus, sudden death can occur either immediately or within a matter of minutes after immersion in susceptible individuals (i.e., victims with pre-existing heart disease or high blood pressure.

Stage 2: Short-Term Immersion: Impaired Performance: For those surviving the cold shock response, significant cooling of muscles and other soft tissue, especially in the extremities, continues with most of the effect occurring over the first 30 minutes of immersion. This cooling has a direct negative effect on neuromuscular activity (nerve and muscle control). This effect is especially significant in the hands, where blood circulation is negligible, leading to finger stiffness, poor coordination of gross and fine motor activity, and loss of power. It has been shown that this effect is primarily due to peripheral and not central cooling. The loss of motor control makes it difficult, if not impossible, to execute survival procedures such as grasping a rescue line or hoist, operating a radio, using signaling devices, etc. Thus the ultimate cause of death is drowning, either through a failure to initiate or maintain survival performance (i.e., keeping afloat, swimming, grasping onto a liferaft, etc.) or excessive inhalation of water under turbulent sea conditions.

These phenomena have obvious survival implications. It is, of course, advisable to avoid cold water exposure completely. If cold-water immersion does occur however, it is best to quickly determine and execute a plan of action: 1) try to enter the water without submersing the head; 2) escape (i.e., pull oneself out of the water, inflate and board a liferaft); 3) minimize exposure (i.e., get as much of one's body as possible out of the water and onto a floating object); 4) ensure flotation if one must remain in the water (i.e., don or inflate a personal flotation device); and 5) call for assistance (i.e. activate signaling devices). It may be difficult to execute these actions while the cold shock is active. However, once the respiratory effects have subsided, immediate action should be taken. If self-rescue is not possible, actions to minimize heat loss should be initiated by remaining as still as possible, curling up in a fetal position. This posture is often called the "Heat Escape Lessening Posture", or HELP, but it requires the use of personal flotation device (PFD) – see Figure (1)), or huddling with other survivors. Drawstrings should be tightened in clothing to decrease the flow of cold water within clothing layers.

Figure 1

Stage 3: Long-term immersion: hypothermia: Many cold-water deaths likely result from drowning during the first two stages of cold-water immersion. In general, true hypothermia usually only becomes a significant contributor to death if immersion lasts more than 30 minutes. The individual who survives the immediate and short-term stages of cold-water immersion faces the possible onset of hypothermia as continuous heat loss from the body eventually decreases core body temperature.

The rate of body core cooling during cold-water immersion depends on the following variables: water temperature and sea state; clothing; body morphology; amount of the body immersed in water; behavior (e.g. excessive movement) and posture (e.g. fetal position, huddling, etc.) of the body in the water; amount of shivering; and other non-thermal factors.

RESCUE AND MANAGEMENT OF HYPOTHERMIA

The primary goals in pre-hospital management of victims of accidental immersion hypothermia are prevention of cardiopulmonary arrest, prevention of continued cooling, moderate core rewarming if practicable, and transportation to a site of definitive medical care. Aggressive rewarming in moderate or severe hypothermia is usually ill-advised, since the means to either diagnose or manage the many potential complications are often unavailable outside the hospital. However, when transportation to a site of definitive care is impossible, as is often the case aboard a vessel, rewarming the patient using the principles and techniques of management described in the following paragraphs, is appropriate.

Retrieval of a victim from cold water immersion must be performed with caution. Sudden reduction of the “hydrostatic squeeze” applied to tissues below the water’s surface may worsen low blood pressure. Since a hypothermic patient’s normal cardiovascular defenses are impaired, the cold heart may be incapable of increasing cardiac output in response to a sudden drop in blood pressure. A victim’s vertical posture may also worsen low blood pressure. Low blood volume, secondary to combined cold- and immersion-induced urination, and increased blood viscosity only aggravate these effects. The net result of sudden removal of a hypothermic patient from the water is similar to the sudden deflation of antishock trousers on a patient in hypovolemic (low blood volume) shock: abrupt hypotension (low blood pressure). This has been demonstrated experimentally in mildly hypothermic human volunteers, and it has been suspected as a cause of post-rescue death in many immersion hypothermia victims. Accordingly, rescuers should attempt to maintain hypothermic patients in a horizontal position during retrieval from the water and aboard the rescue vehicle. If rescuers cannot recover the patient horizontally, they should place the victim in a supine posture as quickly as possible after removal from cold water.

The patient’s core temperature may continue to decline (depending on the quality of insulation provided, the patient’s own heat production, active or passive manipulation of extremities, and the site of core temperature measurement) even after he/she has been rescued. This phenomenon is called afterdrop. To diminish this effect, the patient’s physical activity must be minimized. Conscious patients should not be required to assist in their own rescue (for example, by climbing up a scramble net or ship’s ladder) or to ambulate once out of the water (as by walking to a waiting ambulance or helicopter). Physical activity increases afterdrop, presumably by increasing the blood flow to cold muscle tissue with relatively warm blood. As this blood is cooled, venous return contributes to a decline in heart temperature, increasing the risk of ventricular fibrillation. Experiments on moderately hypothermic volunteers (esophageal temperature 91° F) demonstrated a threefold greater afterdrop during treadmill walking than while lying still. Such an exercise-induced enhancement of afterdrop could precipitate post-rescue collapse and death. Throughout the rescue procedures and during subsequent management, hypothermic patients must be handled gently. Excessive mechanical stimulation of the cold heart is another suspected cause of deaths after rescue.

Once the patient has been brought aboard the recovery vessel, vital signs, including core body temperature (using the techniques previously mentioned), must be carefully measured. Measure pulse and respirations for a full minute to ensure accuracy. For mild hypothermia, (e.g., the patient is alert and vigorously shivering), remove the wet clothing, provide a barrier to evaporation, and insulate the patient from further heat loss (including the head and neck). For patients who are fully conscious and who can eat or drink, supplying sugar containing food or drinks is appropriate, in order to provide energy for the patient's shivering. Warm fluids may also be provided. A hot shower or bath may be used for rewarming. Otherwise, insulate the patient in a sleeping bag so as to retain the heat of shivering. Heating pads or other warm objects may also be used, but their value is reduced because these external sources of heat usually decrease the patient's shivering, which is a more efficient means of rewarming.

For moderate or severe hypothermia (e.g., the patient is not shivering, has a reduced level of consciousness or is unconscious), maintain the patient in a horizontal posture. Do not permit them to sit, stand or exercise, and do not put them in a hot shower or hot bath. If available, administer heated, humidified oxygen. Insulate them as above, but do not provide any food or fluids by mouth. Moderate or severely hypothermia victims have both a reduced gag reflex and a diminished cough reflex, thus increasing their risk for aspiration (inhaling) fluid or food particles. External sources of heat should be used to rewarm the patient (e.g., forced heated air, heating pads, hot water bottles, warmed blankets, radiant heat, body-to-body rewarming, etc.). However, be aware that cold skin is easily burned (severe burns have resulted from hot water bottles placed directly on hypothermic skin), so insulate the skin from direct contact to warm objects. If available, administer warm intravenous fluids (heated to 104-108° F). If the patient requires intubation, ventilate and pre-oxygenate for 3 minutes before intubating. Avoid hyperventilation. If the victim is in cardiopulmonary arrest (for severely hypothermic patients, check the pulse for 60 seconds before diagnosing pulselessness) CPR and modified techniques of Advance Cardiac Life Support (ACLS) must be instituted. Do NOT administer any of the cardiac drugs used in the usual ACLS protocols, as the cold patient does not metabolize these drugs normally. If defibrillation is required, use only one shock if the core temperature is less than 86° F; further defibrillations are permitted at higher body temperatures, if necessary.

Near-Drowning

Drowning is the most common cause of death for victims who accidentally fall into the sea or who enter the water as a result of a vessel sinking or capsizing. Submersion is the term used to describe a victim whose body and head are both underwater; immersion is the term used to describe a victim whose body is underwater, but whose head remains out of the water. The term near-drowning is used for victims who are undergoing treatment or who have survived water submersion or immersion and where they aspirated water into their airways. The term drowning is usually reserved for someone who has already died following water aspiration into their airways. Near-drowning during submersion occurs when the victim can no longer hold his breath and inhales water. It is important to understand that near-drowning can also occur for immersed victims who become hypothermic, or who otherwise cannot keep their nose and mouth free of the water, even while wearing flotation equipment (e.g., from loss of consciousness or inability to cope with heavy seas).

Aspiration of water into the airways initiates several reflex defense mechanisms: coughing to clear the airways, or when the head is totally submerged, laryngospasm (closing of the vocal cords) to prevent water from entering the airways and lungs. A victim in laryngospasm can no longer breathe, and will eventually lose consciousness from hypoxia (lack of oxygen). When the vocal cords relax, water can then enter the airways and lungs, either passively (if the victim has stopped breathing) or actively if the victim is still breathing.

In all cases, the primary physiologic problem in near-drowning is hypoxia. The human body can normally withstand hypoxia for 4-6 minutes. This is true both for cardiac arrest on land and for near-drowning in warm water (>80° F). However, near-drowning in cold-water can result in a much longer survival time (up to 60 minutes of underwater time or hypoxia). This dramatic increase in potential time for successful resuscitation is likely due to rapid cooling of the brain, particularly if the victim continues to breathe cold-water after losing consciousness, and to the effects of the mammalian diving reflex (a physiologic mechanism used by whales, seals, porpoises, etc. wherein the heart rate slows dramatically and blood flow is distributed mainly to vital organs). For these reasons, victims of cold-water near-drowning should be vigorously resuscitated and not declared dead prematurely, simply because they were submerged for longer than 4-6 minutes.

The treatment of all near-drowning cases involves the careful removal of the victim from the water (taking care to protect the neck in the event of spinal injury), assessment for breathing and pulse (check for a full minute, if the victim has been in cold water), clearing the airway of any water, vomit or other objects), CPR, administration of oxygen, and defibrillation if necessary when appropriately trained medical personnel and equipment are available. The most crucial part of near-drowning resuscitation is supplying oxygen to the victim and reversing the effects of hypoxia.

In clearing the airway prior to CPR, do not perform the Heimlich maneuver! The Heimlich maneuver has no role in drowning resuscitation, unless a solid foreign body obstructs the airway (this does not mean water or vomit) and ventilation is otherwise impossible. For ACLS, the same modifications of normal protocols apply for cold-water near-drowning victims as for hypothermia victims (see above: for victims colder than 86° F., no administration of cardiac drugs and only one defibrillation attempt). Hypothermic near-drowning victims should be rewarmed while CPR is ongoing, and no victim should be declared dead until they are rewarmed and fail to respond to CPR or other resuscitative efforts. Transportation from a vessel to a site of more definitive medical care is recommended, particularly if the ship is not equipped for ACLS.

Water Survival

Survival in the water depends on the avoidance of both drowning and hypothermia and on the many factors related to these risks. These include: 1) ability to swim; 2) ability to keep the head out of water (even without flotation aids); 3) ability to avoid panic; 4) sea state; 5) availability and type of personal flotation device (PFD); 6) availability of a life raft; 7) availability of other floating objects to increase buoyancy (such as a capsized boat); 8) water temperature; 9) physical characteristics of the survivor (i.e., body size and weight); 10) type of protective clothing worn against immersion hypothermia and initial immersion cold shock; 11) behavior of the survivor in the water; 12) availability of signaling devices (whistles, flares, strobe lights, radios, and mirrors) and the ability to use these devices; and 13) proximity of rescue personnel.

Drowning is the most immediate survival problem following water entry. To maintain airway freeboard and to avoid drowning, a survivor must possess the physical skills and psychological aptitude to combat the effects of wave action. Although a PFD assists in maintenance of airway freeboard (the distance above the water of the survivor's nose and mouth), waves can still submerge a survivor's head, especially in rough seas (see Figure (1)). But even in moderately calm seas, survivors at night (who cannot see oncoming wavers) or those with a diminished level of consciousness may inhale water, even while wearing a PFD. To reduce the risk of drowning in rough seas, a survivor can increase effective airway freeboard by partially exiting the water (for example, clinging to an overturned vessel or other debris floating in the water – see Figure (2)) or by climbing totally out of the water into a life raft or onto a capsized vessel. In both these environments, however, the survivor may still be exposed to waves.

Figure 2

In cold-water survival, it is important to remember that swimming or other movement in the water increases the body's heat loss. Cold water transmits heat 25 times faster than air at the same temperature. Therefore, as rapidly as the body produces heat through swimming or muscle activity, cold water removes it, increasing the body's cooling rate. Therefore, for a survivor wearing a PFD, holding still with legs curled up and arms on the chest (i.e. a semi-fetal position – the HELP position) increases survival time, as does huddling with other survivors (see Figure (3). Even more importantly, a survivor should get as much of his body out of the water as possible. Elevating the body out of the water onto an overturned boat or other floating objects can significantly increase survival time. If a survivor has an option to get out of the water, even if the air conditions are cold, wet and windy, he should do so as soon as possible; he should not worry about wind-chill. Being immersed in cold water is far worse than being exposed to cold air and wind in almost any combination of air and water temperatures. In addition, a survivor should protect the head and neck from exposure to cold water. Immersion of the head in cold water accelerates the body's heat loss, impairs mental functioning, and hastens loss of consciousness (and therefore drowning).

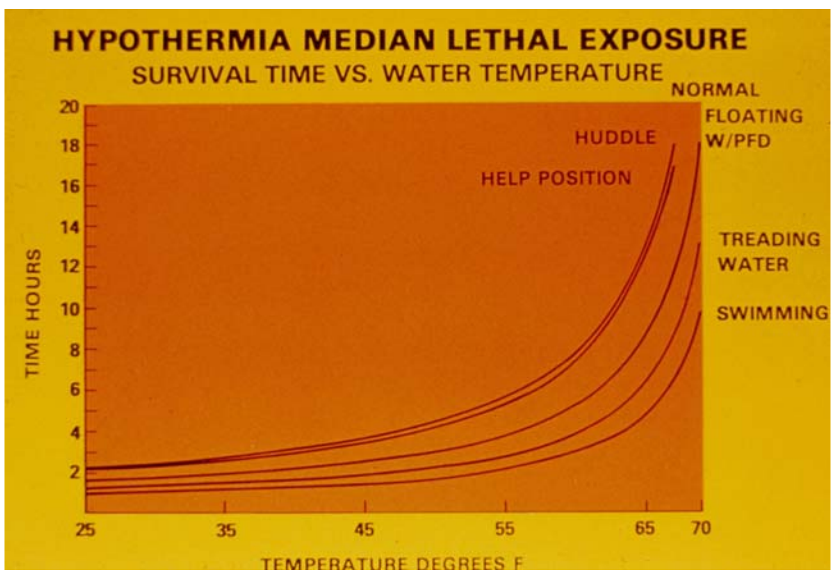

Figure 3

The prediction of survival time in cold water is complex, given the many variables discussed above. However, Figure (4) provides a rough estimate of survival times at various water temperatures (given in both degrees C. and degrees F.). The graph shows predicted calm-water survival times of lightly clothed, non-exercising humans in cold water. The graph shows a line for the average expectancy and a broad zone that indicates the large amount of individual variability associated with different body size, build, and degree of fatness, clothing worn, survival posture and behavior in the water, state of health, and the amount of the body immersed in the water. The zone would include approximately 95% of the variation expected for adult and teenage humans under the conditions specified. In the zone where death from hypothermia is highly improbable, cold water can still cause death from drowning from "cold shock" (as discussed above) in the first few minutes of immersion, especially for those not wearing personal flotation devices. It is important to note that Fig. (4) refers to only calm-water survival times. It is important to understand that rough water decreases survival times.

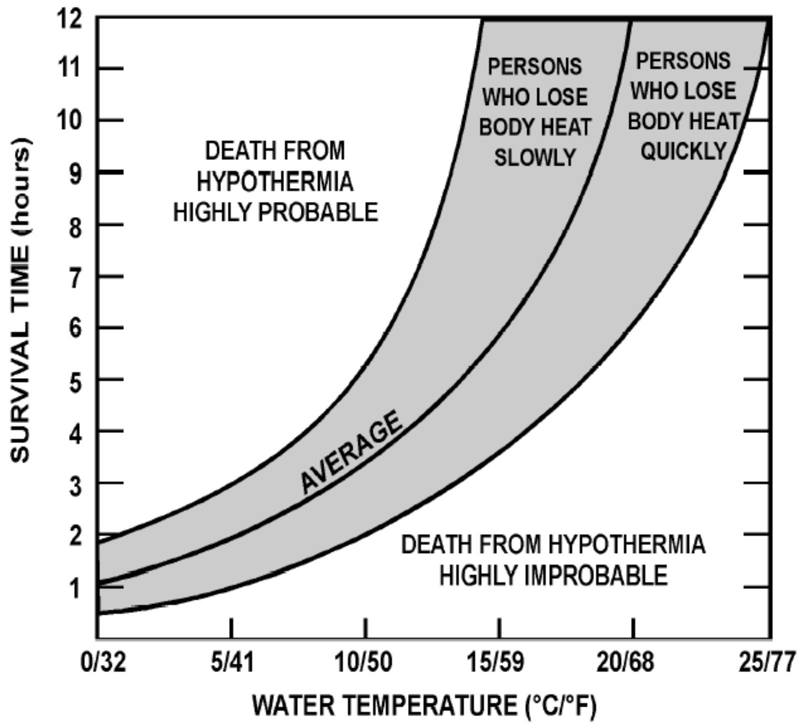

Figure 4
Predicted Survival Times in Calm Water
(see text for constraints on using this graph)

For victims who fall through ice into the water, survival time is significantly longer than the few minutes that most people assume to be true. Unless a victim drowns during the cold-shock response (in the first few minutes) from inability to keep his airways free of the water, hypothermia will not result in death in ice water for most people for an hour or longer. Once the discomfort of the reflex gasping and rapid breathing subsides, there is plenty of time to attempt to get out of the water onto the ice and/or activate signaling devices. It is quite difficult to pull oneself out of the water onto ice after having broken through the surface. However, it can be done if the survivor elevates his legs (to a near horizontal position) and kicks in the water while at the same time pulling himself out by his arms. It is important for the survivor to do this as soon as possible after water entry, before the cooling of arm and leg muscles reduce muscle strength. If the victim cannot get totally out of the water, he should try to get his arms and as much of his trunk as possible out of the water and onto the ice. If the survivor's wet clothing then freezes to the ice, it will prevent him from sliding back into the water, even if he loses consciousness. Having part of his body out of the ice water significantly increases survival time and allows a greater chance for eventual rescue.

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