Immersion, Drowning, Cold Water Shock & Hypothermia

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"The worst tragedy in the history of Northern California offshore racing"
'Lectronic Latitude, August 8, 2012

The Sydney 38 sailing vessel *Low Speed Chase* in the Full Crew Farallones Race – 8 crew
On April 14, 2012 14:36:40 PDT the vessel capsizes off the northwest point of SE Farallon Island
Sea State - 15' swells, 7' wind waves
Water Temp 51 ° F
90 seconds from Capsize to Vessel on Rocks
7 crew swept off the vessel into the water
5 crew Die in the Water - All with PFDs
3 crew Survive - 2 in PFDs struggle to shore through waves/shore break, 1 stays aboard vessel
USCG Rescue Helicopter On-Scene in 1 Hour
Medical Examiner Report of Cause of Death – Drowning

In the words of surviving crew, Bryan Chong, as reported in 'Lectronic Latitude, August 8, 2012

"I see another wave approaching in the distance. It's coming from the same direction as the other swells but it's massive. I've seen large waves before but this is unlike anything I've ever seen outside of big-wave surf videos. As the wave approaches it begins to face up, its front flattening as it crests. By the time our boat meets it, there's no escape route. Alan steers the boat into the wave and the bow of *Low Speed Chase* ascends the breaking wave, which seconds sooner would have been a giant swell and seconds later would have already broken. Instead, we're heading into a crashing wall of water with 9-10 knots of boat-speed and it breaks directly on us. I lock my right arm to the bottom lifeline and brace for the impact. The last thing I see is the boat tipping toward vertical with a band of water still above it. A single thought races through my head: 'This is going to be bad.'
I was underwater until the boat righted itself. Confused and disoriented I looked around while water cleared off the deck. Nick and I were the only ones still on the boat. The sails were shredded, the mast snapped and every flotation device had been ripped off…. Then a second wave hit us from behind. This one ripped me off the boat and into the break zone...I couldn't tell if I was in the water for a minute or an hour, but according to Nick it was about 15 minutes. People have asked me if I swam for shore. The best way to describe the water in the break zone is a washing machine filled with boulders. You don't really swim. The water took me where it wanted to take me..."

Lessons Learned:
All seven crew who were swept off the vessel into the 51°F water were subjected to cold water

shock. The two crew who survived in the water described their struggle to avoid drowning and that description is entirely consistent with cold water shock - defined as the body's initial response to sudden cold water immersion. These include reflex gasping, uncontrolled rapid breathing and inability to breath-hold. Stress on the heart can also be profound and life-threatening; heart rate and rhythm changes frequently occur, reducing blood supply to the brain, followed by confusion, disorientation, or sudden loss of consciousness.

To what extent cold water shock and progressive hypothermia impaired the other crew in the water will never be known, but it can be reasonably surmised from the survivors' interviews and the medical examiner reports that cold water shock ultimately played a major role in their deaths.

Key Concepts:

1) Describe an Immersion Incident.
2) Describe the human physiological events of sudden Cold Water Shock as outlined in the Giesbrecht "1-10-1" Model.
3) Describe the most important factors affecting the chance of surviving an Immersion Incident.
4) Describe the immediate On-Scene Management of an Immersion Incident
5) Describe the importance of following traditional CPR in Immersion Incidents which emphasizes rescue breathing followed by chest compressions.
6) Describe hypothermia(mild, moderate, and severe) including definition, symptoms, and treatment.

Definitions:

1) Immersion Incident: A sudden and accidental entering into a liquid environment and the liquid enters the airway

2) Cold Water: Less than 10˚-15.5˚C (50˚-60˚F)

3) Cold Water Shock: The first (and often fatal) consequence of a sudden cold water immersion event. Happens within seconds. Can last for minutes.

4) Cold Water Shock 1-10-1 Model (Giesbrecht): Immersion in **near freezing water**, but concepts apply to all Cold Water incidents -Cold Water Shock-Cold Water Incapacitation-Profound Hypothermia(Reference 2)

> **a) 1 minute of Cold Water Shock:** Gasp Reflex - Rapid Breathing – Heart Rate/Rhythm
>
> **b) 10 minutes until Cold Incapacitation:** Remaining time to assist in own rescue. Beginning to lose muscle control, swimming ability and dexterity. Maintaining the airway is a problem.
>
> **c) 1 hour of gradual Degradation of Mental State:** As the body

cools(hypothermia) confusion and disorientation begin, leading ultimately to loss of consciousness.

5**) Water Rescue:** Victim is rescued successfully, usually very early in the incident, is alive and with no evidence of liquid having entered the airway.

6) Drowning: Process of experiencing respiratory impairment from Immersion in liquid ultimately leading to decreased oxygenation of the brain.

a) Non-Fatal Drowning: Immersion in liquid

b) Fatal Drowning: Immersion in liquid that results in death

7) Hypothermia:

a) Mild: Rectal temperature below 37°C (98.6°F), higher than 34°C (93°F)

b) Moderate: Rectal temperature between 34°C (93°F) and 30°C (90°F)

c) Severe: Rectal temperature lower than 30°C (90°F)

8) Traditional CPR: Airway-Breathing-Circulation (ABC) – these are the American Heart Association guidelines emphasizing rescue breathing in immersion incident resuscitation.

The Immersion Incident

Drowning is the most immediate survival problem following accidental water entry. The whole drowning process from immersion to cardiac arrest usually occurs within a few seconds to a few minutes, but in unusual situations, such as immersion in ice water this process can last for an hour. If drowning is avoided in the first few minutes, then prevention of hypothermia is critical.

Human Immersion Sequence Leading to Fatal Drowning

- Upon initial entry into the water the victim tries keep his/her face above the surface and the mouth clear by spitting or swallowing.
- This is often followed by a conscious effort to breath-hold, usually lasting only a few seconds, seldom more than 1 minute.
- Breath-holding is quickly overcome by the reflex drive to breathe in and water enters the airways causing reflex gagging, choking, and coughing.
- In some cases the throat(larynx) goes into spasm but this spasm is soon terminated when the brain no longer receives sufficient oxygen.
- Aspiration of large amounts of water into the lungs begins, leading to terminal unconsciousness and compete cessation of breathing.
- The final stage is often a brief period of convulsions, heart dysrhythmias, cardiac arrest and a death-like appearance.

Cold Water Shock

The term Cold Water Shock is used to describe a series of physiological events occurring in sudden immersion in cold water. Figures 1 & 2. These human physiologic responses include an immediate gasp reflex, followed quickly by the onset of rapid and deeper breathing. The immediate danger of the gasp reflex is that if the face is underwater or there are waves splashing onto the face there will be an uncontrollable inhalation of water. Also the reflex to breathe rapidly will overcome any attempt to voluntarily control the timing of breathing or to slow down the breathing rate. Almost any attempt to breath-hold will fail. Blood circulation is also severely stressed. A sudden increase in blood pressure often occurs along with a marked speeding or slowing of the heart rate. At the same time, the heart rate changes can effect the ability to oxygenate the heart muscle and electrical conduction system, producing life-threatening arrhythmias including sudden cardiac arrest. It has been suspected that these heart arrhythmias have been responsible for the sudden cardiac arrest that has been observed even when the rescue has been rapid yet the victim is already lifeless.

The cold water researcher and physiologist Gordon Giesbrecht has developed the "1-10-1" model as an easily remembered aid in describing the sudden unexpected fall into extremely cold water. It's important to remember that this model best fits the time frames experienced in icy water but still has value in estimating the times of the stages for cold(not icy) conditions.

> **1 minute of Cold Water Shock:** As described above - the Gasp Reflex, Rapid Breathing, Increased Blood Pressure, Rapid Heart Rate, and Heart Rhythm Irregularities
>
> **10 minutes until Cold Incapacitation:** There is still time to assist in one's own rescue. Maintaining the airway remains a problem but there still may be enough muscle strength and coordination to attempt swimming a short distance and pull out of the water. As that window of opportunity closes there is a progressive loss of muscle control, swimming ability and dexterity.
>
> **1 hour to Noticeable Brain Dysfunction:** Gradually one becomes less oriented. Confusion and disorientation lead ultimately to a complete breakdown of rational thought and finally to loss of consciousness.

Fig 1 (reference 1)

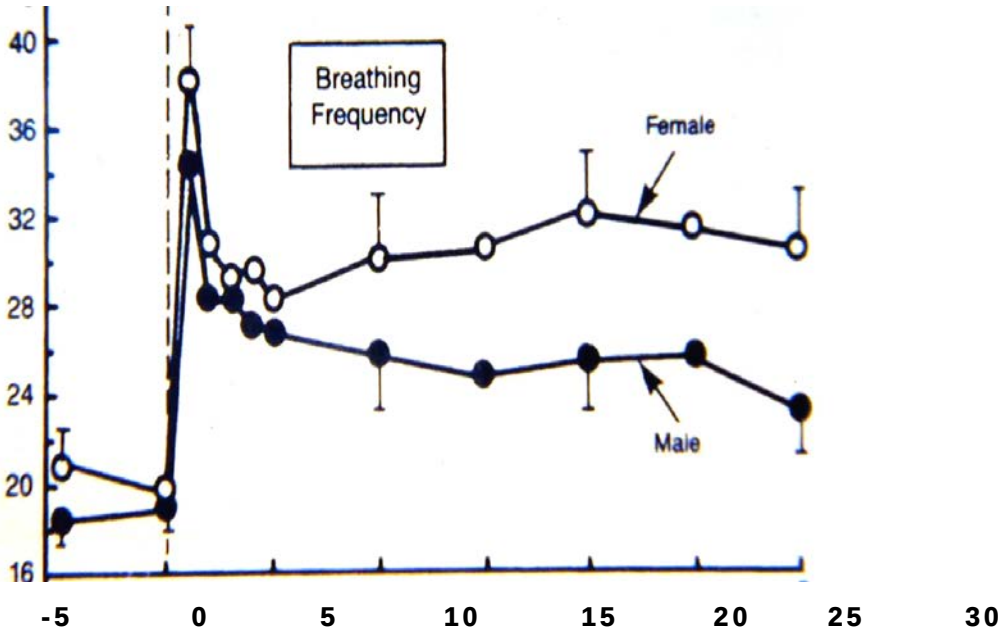
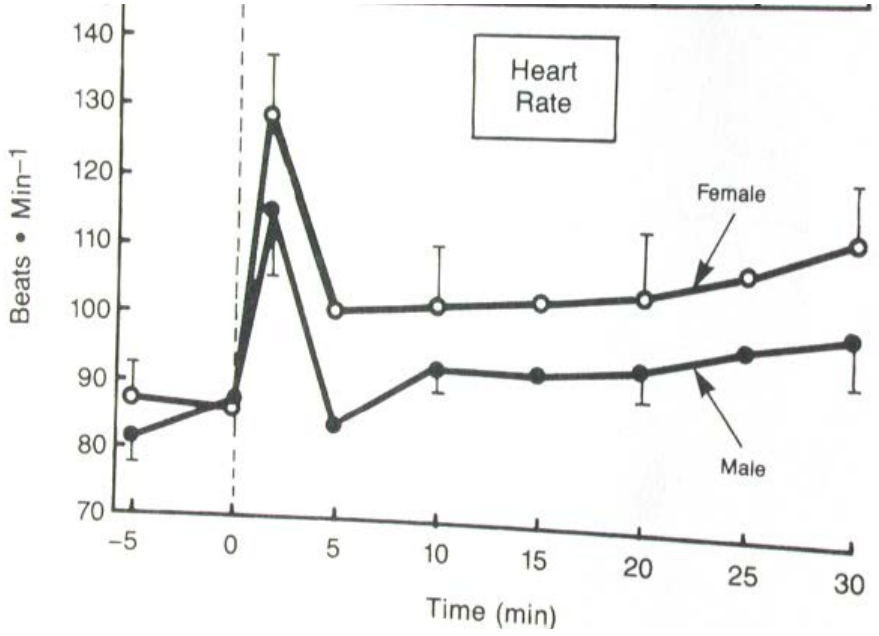


Fig 2 (reference 1)



Factors affecting chance of Survival

Ability to Swim: Important because swimmers have more confidence in the water environment and are less likely to inhale water or panic.

Sea State: No matter how strong a swimmer may be, the rougher the sea, the more difficult

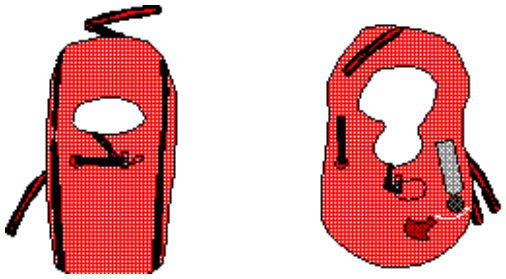
it is to keep the head above water and the airway clear of water.

Use of PFD: Wearing a PFD markedly increases the chances for survival, decreasing the need to struggle to keep the head above water, lessening physical activity in the water (which causes a more rapid loss of heat), and allowing the victim to assume the HELP or HUDDLE positions.

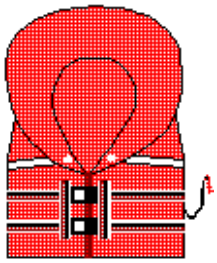
HELP Position (single victim)

HUDDLE (multiple victims)

Type of PFD: Although any type is better than none, high buoyancy life jackets that provide both freeboard (height of airway above the water) and a short heave period (the time necessary to bring an immersed victim to the surface) are superior to lower buoyancy "recreational" vests. Among the most effective are commercial SOLAS-approved Type I Offshore Life Jackets and 150N (33.7lb) buoyancy inflatable models.



Type II PFDs (near shore)



Type I PFD (offshore)

Availability of Life Raft: Exiting the water is critical to avoid drowning or hypothermia. Sometimes the quickest procedure is to enter a life raft rather than attempt to re-board the vessel.

Availability of Other Objects: Any floating object (cushions, throw rings, etc.) can be used as a support for the victim and helps reduce the effort of staying above water.

Water Temperature: Very cold water contributes considerably to drowning or hypothermia due to rapid loss of muscle strength and coordination, confusion and

disorientation, heart arrhythmias, and reflex hyperventilation (rapid breathing) leading to greater chances of water inhalation.

Physical Characteristics of Victim: Children are especially prone to hypothermia because of their high skin surface to body mass ratio. For the same reason, tall skinny people are far more susceptible to hypothermia than short, fat, or highly muscular types.

Protective Clothing: Clothing which is buttoned, buckled, and zipped causes a layer of water to be trapped inside, which helps insulate and thereby slows body heat loss. Survival suits can be lifesaving in extremely cold water.

Figure 1: Survival Suit

Behavior in the Water: It is critical to avoid panic and struggling, and to limit excess motion.

Use of Signaling Devices: PLBs, whistles, lights, and reflective tape on PFDs as well as the rapid deployment of signaling devices from the vessel (smoke or light flares) all help in locating a victim more quickly and thereby improving the odds of survival.

Goals of Rescue & Management of Cold Water Immersion Victims

- Prevention of Cardiopulmonary Arrest
- Stabilization of Core Temperature
- Call for Medical assistance as soon as possible
- Transport to Advanced Care if Indicated

General Principles of Rescue

These principles apply for all cases of immersion where hypothermia is suspected or obvious. Retrieve the victim with caution and in the horizontal position. Gentle handling and keeping the victim lying down helps prevent sudden drops in blood pressure and reduces the risk of a sudden heart arrhythmia in the moderate or severely hypothermic victim. It is important to minimize the victim's physical activity, preventing the afterdrop phenomenon. Afterdrop is when the core temperature continues to decrease even though the victim has been removed from the cold water. Even some mild hypothermic victims can have an afterdrop of several degrees core temperature, thus putting them at risk for the more serious consequences of moderate or severe hypothermia.

Examination and Life Support

CPR

1. Initiate traditional (ABC) CPR in persons who have been submerged for less than 60 minutes and who do not have obvious physical evidence of death.
2. Active efforts to expel water from the airway (by means of abdominal thrusts or placing the person head down) should be avoided because they delay the initiation of ventilation and greatly increase the risk of vomiting, with a significant increase in

mortality.

3. Cardiac arrest from drowning is due primarily to lack of oxygen. For this reason, it is important that CPR follow the traditional airway–breathing–circulation (ABC) sequence, rather than the circulation–airway–breathing (CAB) sequence, starting with five initial rescue breaths, followed by 30 chest compressions.
4. Continue with two rescue breaths and 30 compressions, until signs of life reappear, for at least 20-30 minutes until signs of life reappear or rescuers are exhausted, or advanced life support becomes available. (reference 4)

Evaluate for Trauma

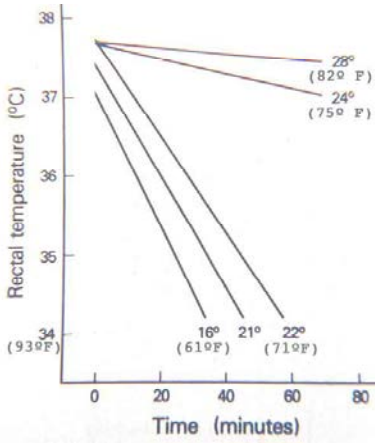
Victims who have entered the water may have had an injury which caused them to fall off the vessel. Being struck by the boom is a common example. Injuries may also have been sustained in the process of falling or after hitting the water. Striking rocks in shallow water or surf conditions are not uncommon. In any case, responders need to perform a careful trauma evaluation, looking especially for signs of head and neck injuries, spinal cord trauma, chest injuries, lacerations, or extremity fractures.

Evaluate for Hypothermia

Most often the responder will have to rely on the signs and symptoms alone. Remember one important point—vigorous shivering means the victim has only **mild** hypothermia, and thus a good outcome can be expected. Taking a rectal temperature is the standard for documenting hypothermia, but usually cannot be performed onboard. In addition, very few vessels carry "hypothermic" thermometers, which can accurately measure below 34°C (93°F). See Figure 3

Body Heat Loss in Cold Water (Figure 3)

Whenever a person enters cold water, heat loss begins— the colder the water, the faster the heat loss. Water conducts heat approximately 25 times faster than air. Hypothermia occurs when the heat loss is greater than the body's ability to generate heat. The following graph(Figure 3) demonstrates how quickly the body temperature drops in various water temperatures. These are rectal temperatures. The volunteers were only lightly clothed.



Thermal Insulation Shells (Figure 4)

Think of the body as a series of layers capable of insulating and protecting the vital internal organs (heart, lungs, liver, and kidneys). In cold water, these outer layers cool in the following order: skin, subcutaneous tissue, and lastly, muscles. Thus, when measuring body temperature, the skin temperature would be lower than the internal organ temperature (core temperature). The usual measurement of the core temperature is performed with a rectal thermometer. Maintaining the core temperature is the critical factor in survival.

1) Sign and Symptoms of Hypothermia

Mild Hypothermia(96˚ - 93˚F) Vigorous shivering, often painful, predominates. This is an important process by which the body rewarms itself. And it is a good sign. Responders who are not familiar with hypothermia often will assume the dramatic presentation of a rescued victim having pain and shivering must mean this is severe hypothermia. In general the victim is alert, perhaps slightly confused, perhaps uncharacteristically irritable, but there is no significant change in mental status. Dexterity, coordination, and strength are generally normal or only slightly impaired.

Moderate Hypothermia(93˚- 90˚F): At this point shivering may continue but more significant mental changes appear. Confusion, disorientation, lethargy, slurred speech, and a general apathetic appearance dominate the picture. Muscle coordination is deteriorating and strength is weakened. The victim is now entering into a serious physiologic state that can still be managed successfully in the field, but if not done properly can rapidly become life-threatening.

Severe Hypothermia(less than 90˚F): Consciousness is now decreasing as the victim slips into a coma. Shivering has stopped around 88˚F. As the victim further cools the heart rate and breathing rate decrease and the heart becomes susceptible to potentially fatal arrhythmias. Sudden cardiac arrest can occur with rough handling of the victim.

Treatment and Stabilization of the Hypothermic Victim

Once the victim has been rescued the first action is transport to a warm and secure environment aboard the vessel in order to prevent further heat loss. Keep the victim in a horizontal position as much as possible. Wet clothing should be carefully removed and the victim dried, avoiding any unnecessary jostling.

Mild Hypothermia: The victim is still able to be warmed using passive techniques. Specific treatment includes placing the victim in blankets or a sleeping bag to minimize convective or conductive heat loss. A vapor barrier such as a space blanket or plastic sheet may be added around the blankets or sleeping bag to stop evaporative heat loss. Warm drinks(no alcohol) can be given to the mild hypothermic victim who is fully awake and not showing signs of nausea or vomiting. Victims suffering only mild hypothermia usually need no additional rewarming assistance. “Buddy warming” or body-to-body contact consisting of another person entering the sleeping bag or blankets and pressing the side of the bare chest next to the victim’s bare chest can be considered. Although this technique is effective in warming the skin, it actually is not very useful in warming the victim. Yet it still has some benefit by warming the skin, thus decreasing the sensation of cold.

Moderate and Severe Hypothermia: This is a medical emergency requiring evacuation to a medical facility as soon as possible. Continue taking vital signs by repeating measurements of respiratory rate and heart rate every 15 minutes. Decreasing rates are a sign of slipping into a deeper state of hypothermia. Active rewarming techniques must be initiated if the victim is to survive. The simplest technique for active rewarming is the application of hot water bottles or warmed towels in plastic bags, or chemical heat packs.

These can be applied to the chest, neck, armpits, and groin. Caution must be used. Make sure a cloth barrier is between the heating device and the victim's body. Hypothermic skin is injured skin and can be further damaged by too much heat. No drinks should be given due to the high risk of gagging, choking , vomiting, and aspiration. Do not rub or stimulate the victim in any way since serious or fatal heart arrhythmias can result.

CPR in Cases of Hypothermia – special considerations

Take the vital signs for at least a minute: Many victims of moderate or severe hypothermia will have very weak and slow pulses—as slow as 4–6 beats per minute—and these victims could be mistakenly called pulseless if the pulse was taken for only a few seconds. The same is true when evaluating the respiratory effort and rate. At times the blood pressure is unobtainable, but it should not be assumed that circulation is not present. Some very cold hypothermic victims have markedly diminished pulses and respirations, yet there still is viable cardiac output. Performing CPR on these victims could produce a lethal heart arrhythmia such as ventricular fibrillation. Only when the responder cannot find any pulses(check the carotid artery in the neck) or respirations after the full minute of evaluation, CPR should be initiated and continued as described for the drowning victim.
Defibrillation: Some vessels now carry automatic external defibrillators (AEDs) and crews have learned how to use these life-saving devices. The recommendations for using defibrillators in the hypothermic victim are similar to other types of victims, with one major exception: do not give up CPR and defibrillation until the victim is warm and there are still no signs of life. This is because the cold heart is much less responsive to defibrillation shocks and may only respond later in the resuscitation process.

Activation of Support Teams and Transportation

Water rescue patients with no evidence of immersion effects who are mildly hypothermic can be allowed to stay onboard once they have been rewarmed and demonstrate normal mental status. Moderate to severe hypothermia must be considered a life-threatening incident. These victims should be transported to a higher level of care as soon as practical. The vessel needs to access medical direction early, by radio or telephone, in order to prepare for the evacuation. All transport should keep the victim in the horizontal position.