Chapter 3 – The Dangers of Sudden Immersion in Cold Water

by

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INTRODUCTION

As you will read repeatedly throughout the papers in this lecture series, death at sea until now has been regarded by many as fate and an occupational hazard. For a full account of sea survival, then the textbook "Essentials of Sea Survival" by Golden and Tipton is recommended for all survival instructors [13].

Hypothermia was described by Herodotus [20] during the Persian/Greek War as far back as 450 BC – but life was cheap and no one paid much attention to the cause of drowning. Brief interest was shown in the 18th Century when James Lind (1792) described post-rescue collapse, Hutchinson (1794) wrote a book "To preserve the health and comfort of sea voyagers", and Currie (1797) noted hypothermia and post-rescue collapse.

As described in the lecture on immersion suits, the Royal Navy policy of impressments was not discontinued until 1815. So there was no incentive to provide flotation systems, protective clothing and investigate the cause of drowning. After all, their Lordships would argue, if a ship sank in battle there was plenty of flotsam and jetsum to provide support. In 1805, at the Battle of Trafalgar, sailors clung to masts and spars for 15 hours before rescue.

The advent of iron ships in the mid 1850s only exacerbated the drowning statistics. In 1892, the USA was the first nation to regulate the carriage of lifejackets on passenger vessels. They were reluctantly followed by Britain, France, Germany, and Denmark. The Titanic accident in 1912 caused the formation of the International Maritime Organization (IMO) who produced the Safety of Life at Sea (SOLAS) regulations. Now there was international regulation requiring the carriage of life jackets. Lord Mersey in his investigation of the Titanic accident did not ask why the passengers on the Titanic were floating dead in perfectly good life jackets on the surface of the water. The path of least resistance was to assign the diagnosis drowning – and this to a certain degree is still what is happening in 2007.

During the First World War 12,000 Royal Navy sailors, 10,000 merchant seamen and 5,000 German sailors drowned. Yet no one paid much attention to this dreadful statistic, and certainly no serious physiological examination into the cause of death was initiated.

The loss of life was equally dreadful in the Second World War. The Talbot report published in 1946 showed that 20 – 30,000 Royal Navy officers and men had died. One third killed in action and two thirds killed during the survival phase. This two thirds drowned principally due to the cold. They could have been saved if they had the right survival equipment and training. This report precipitated a very extensive research programme under the auspices of the Royal Navy Personnel Research Committee. Numerous publications and reports were produced. The most significant textbooks being:

- Burton, A.C. — Man in a Cold Environment 1955 [7]
- McCance, R.A., et al. — The Hazards to Men Lost at Sea 1956 [23]
- Nicholls, G.W.R. — Survival at Sea 1960 [25]
- Newburgh, L.H. — Physiology of Heat Regulation and the Science of Clothing 1968 [28]
- Keatinge, W.R. — Survival in Cold Water 1969 [21]
- Smith, F.E. — Survival at Sea – MRC report 1976 [30]

All this was excellent, but there was one problem; everyone concluded that the cause of death and drowning was due to hypothermia. The 4 physiological stages of sudden immersion in cold water were known, but the first two stages – cold shock and swimming failure were considered to be only of academic interest.

It wasn't until 1981 that Golden and Hervey [11] produced their classic paper on the 4 stages of immersion. For the first time it became clear why people were drowning and this lecture will concentrate more on the first two stages which probably contribute more to the cause of death than the later two stages. The four stages are as follows:

Stage 1: Initial immersion responses or cold shock. Due to rapid skin cooling. This kills within 3 – 5 minutes of immersion.

On initial immersion, there is a large inspiratory gasp followed by a four-fold increase in pulmonary ventilation, i.e. hyperventilation. This on its own can cause small muscle spasms, tetany and drowning. Along with this, there is a large increase in heart rate and blood pressure. These latter cardiac responses may cause death, particularly in older, less healthy people. These effects last for the first two to three minutes, just at the critical stage of ship abandonment [32, 34] when one is struggling to adjust to the wind and waves and avoid inhalation of water.

Death from cold shock is not uncommon. Here is an example of an incident typical of those that continue to be regularly reported in the Canadian press each year. It demonstrates the practical evidence that cold shock kills.

Teen drowns after lunch-hour plunge (Globe & Mail, April 16, 1998)

Toronto – A 14-year-old high-school student drowned yesterday after jumping into the frigid water of Lake Ontario. Hours after the incident, police still do not know why Peter Arthur went into the water, which was only about 4°C. There were two other teenagers with him at the time. When Peter failed to surface, his friends sought help from nearby construction workers, who called the police. When they arrived they jumped into the lake, which is about 3½ meters deep at that location, and searched for the missing teen for 10 minutes, until the icy water forced them to shore Sgt. McCann said. As the two officers sat on nearby rocks, huddled in blankets, members of the Toronto police marine unit arrived and took over the search. Dragging the area with a net, they located the teen, who by that time had been in the water for about 30 minutes. Firefighters performed cardiopulmonary resuscitation until paramedics arrived to continue treatment. But Peter was pronounced dead at Toronto East General Hospital at 12:55 pm.

Disaster strikes a fishing vessel (October 1992)

The fishing vessel *Nopsa,* a 16.8-metre (55-foot) black cod longline trap vessel, was near the end of a 3-week trip. It was located on the Bowie Seamount, approximately 90 nautical miles west of the Queen Charlotte Islands on British Columbia's north coast. There was a crew of five on board, and after much bad weather the seas were finally calm. At approximately 2155 hours, the crew had 30 of the string of 60 traps on board. The current trap was somewhat heavier than the previous traps, and two of the deckhands were having trouble stacking it on top of the other traps on deck.

On the second attempt, the trap fell to the deck, causing the two deckhands to scramble to safety. One man moved to the center of the vessel, and the other moved to the starboard rail. The crew member who had moved to the rail of the vessel misjudged his location and slipped forward of the guardrail securing the trap storage area and fell headfirst into the water. He was not wearing personal flotation protection. Although the initial response from the crew was laughter, they quickly realized that the deckhand was in distress and began rescue attempts. The crew member was recovered on board within 9 minutes of entering the water; however, he was unconscious by this time and attempts to revive him were unsuccessful. During rescue attempts, a variety of lines and floating objects were thrown well within reach of the man overboard, but he made no attempt to grab onto any of them and aid in his own rescue. He was able only to continue to cry out for help. The water temperature was between 10° and 11°C. [27]

Stage 2: Short-term immersion or swimming failure. Due to rapid muscle and nerve cooling. This kills within about 5 – 30 minutes of immersion.

Again, the newspapers report these tragic preventable accidents regularly.

Son helpless as mom died (Daily News, Halifax, June 5, 2002)

A Chester man who can't swim watched Tuesday as his mother was overcome by frigid, choppy water off Quaker Island, Lunenburg Co. Kathleen Haase, 44, and her son Michael, 25, were spending the day exploring the small grassy island about two kilometers south of Chester. When their small speedboat started to drift away from the island as the tide rose, Kathleen Haase tried swimming after it. She could swim, but the water Tuesday was only about 10°C. Wayne and Geraldine Truck were going past the island in their 11-meter sailboat when they heard the son's distant screams for help. "We didn't see anyone splashing in the water," Wayne Truck said. "She undoubtedly had succumbed." They caught the drifting speedboat and were bringing it back to the island when they discovered Kathleen Haase floating face down in the "bitterly cold" water, about 50 meters from the shore. Rescue crews worked to revive her on the boat ride and in the ambulance to South Shore Regional Hospital in Bridgewater. But she never recovered and was pronounced dead in hospital.

Fishing Technician drowns in Skeena River, B.C. (March 2002)

In another incident, which occurred on 27 March 2002, two fishery technicians were conducting eulachon research in the Skeena River on British Columbia's north coast. Although the portion of the Skeena River on which the technicians were working is not considered "tidal", it is influenced by the tides at the mouth of the river. The water rises and falls on-cycle as water levels change further down the river. The technicians had walked out to an island in the river at low water to conduct part of their survey. When they attempted to return, they found that the river was now too deep to cross back to the mainland. In their initial attempt to re-cross the river, both men filled their chest waders. The technicians returned to the island cold and wet to wait the 5 hours before the river would be low enough to cross. They had no survival gear and were not equipped to start a fire. After some discussion and against the advice of his partner, one of the technicians decided to swim across the channel. The narrowest part of the channel at that time was approximately 90 metres (300 feet) across. Their truck was parked on the far side of the channel next to the highway running alongside the river.

Being in good physical condition and a good swimmer, the technician felt confident he could cross the river to the vehicle and go for help. He removed his chest waders, draped them across his shoulder and began to swim. His partner watched him make excellent progress and decided to also attempt the swim. He later reported that the water was so cold that it hurt too much to continue the crossing, so he returned to the island to monitor the progress of his partner. The swimmer reached within 3 metres (10 feet) of the far shore, at which time he simply sank and subsequently drowned in about 1 metre (3 feet) of water. The river water temperature ranged between 0° and 1°C. The pathologist reported the incident as a "simple drowning". The author questioned a possible relationship between the drowning and the water temperature. The coroner, however, confirmed the pathologist's diagnosis that there was no evidence of hypothermia, and in fact the event was a "simple drowning caused by local cooling". [27]

Swimming failure is much more common than one would expect. It is not diagnosed because the investigator does not delve into the precise history of what happens during immersion. Death certification is simply "drowning". People do not understand that it is very dangerous to swim in cold, dense water. Swimming ability in warm water bears no relationship to swimming ability in cold water. The angle of attack increases, drag increases, stroke rate increases and stroke length decreases [33]. This all adds up to an exhausted human who becomes more vertical in the water and finally disappears beneath the waves. A cry for help expels 4 litres of air from the chest cavity and waving the arms removes the last vestige of buoyancy. This results in the survivor disappearing beneath the waves.

Unfortunately people do not realize that the temperature of water in lakes and rivers does not warm up until very late summer and even then rarely gets much higher than 15°C which is a very dangerous temperature to swim in for any length of time if not wearing any flotation equipment. Again sadly, drowning under such conditions is not an uncommon event.

Divers locate bodies of missing N.S. teenagers
(Toronto Globe & Mail, June 22, 2007)

The bodies of two teenage boys who went missing near a Halifax-area lake were pulled from the water yesterday. They were last seen Monday, when they were thought to have been using a section of dock as a raft at First Lake. They did not come home that evening. RCMP divers located both of them at one part of First Lake at about 8:15 pm, Corporal Joe Taplin, a spokesman for the local RCMP detachment, said late yesterday. The boys' bodies were found in about 10 metres of water near the west end of the lake. First lake is several kilometers long and about 700 metres at its widest point. Its depth varies between 3 and 10 metres for most of its 83 hectares but drops in the middle to 25 metres.

Stage 3: Hypothermia.

- Hypothermia by definition is a body core temperature of 35°C or lower. Death occurs from drowning sometime after 30 minutes in the water.

As the deep body temperature falls, humans lapse into unconsciousness. Death may occur in two ways – drowning through incapacitation, and cardiac arrest. Death from drowning will occur in 50% of lightly dressed individual, approximately one hour after immersion in water at 5°C, or two hours in water at 10°C, or in six hours or less at 15°C [10].

If the deep body temperature continues to fall, death occurs on average from cardiac arrest somewhere below a body core temperature of 24°C, however the lowest recorded survived deep body temperature in an accident victim is 13.7°C [8].

COMET (May 1973)

The COMET had 27 persons on board and sank in Block Island Sound, Rhode Island, about seven miles offshore, in 48°F [9°C] water. The COMET had no EPIRB and the only lifesaving apparatus was a 20-person buoyant apparatus. About 15 of the survivors held onto the buoyant apparatus at some point, including two of three who set out in a swamped dinghy to get to the buoyant apparatus. Six others were able to use an 8' X 10' piece of flotsam for partial support. Almost everyone on board had a lifejacket on when they abandoned ship. The two or three people who were not able to get a lifejacket were able to use either the buoyant apparatus or the flotsam. The first death occurred in the dinghy about ½ hour after the sinking. Deaths continued until rescuers happened on the scene 4 hours later. A total of 16 persons died in this time.

Survival predictions were made from experimental data and case histories from shipwrecks. The first classic curve was published by Molnar in 1946 [24]. Since then, there have been attempts to update these survival curves. The latest being by Tikuissis in 1997 [30]. These are all very commendable efforts, but probably are never going to be validated. Caution must be used in interpreting the results for Search and Rescue Organizations. For full details on the subject, please refer to Chapter 7 of "Essentials of Sea Survival" [13].

Stage 4: Post-rescue collapse or circum rescue collapse. Death occurs during or shortly after rescue. The basic cause of death is due to a collapse of blood pressure when the victim is pulled from the water.

Up to twenty percent of immersion deaths occur during extraction from the water, or within hours after rescue [10]. This was first noticed in 1875, by Reinke, a police surgeon in Hamburg. He recorded cases of sailors who had fallen into the canals and harbour and died within 24 hours of being rescued [9]. During the Second World War, the Germans and Allies noted that some of those were rescued alive, died shortly afterwards. Matthes [22] noted how ditched German aircrew who had been conscious in the water and aided in their own rescue, became unconscious and died shortly afterwards. McCance, et al. (1956) [23] found that seventeen percent of those shipwrecked survivors rescued from the water at 10°C or less died within hours of rescue. None of the people rescued from water above 20°C died.

If one understands the basic principles of the physiology of sudden immersion in cold water, then it becomes obvious that to prevent each stage at which drowning can occur, it is essential to develop a survival or immersion suit. It must be designed for the specific occupation that are at risk, i.e. ship abandonment, helicopter ditching, river pilots, etc., and most important it must be integrated with all the other equipment and tested under as extreme conditions as safely possible.

PEOPLE CONTINUE TO DROWN ESPECIALLY IN COLD WATER

This fact was exquisitely pointed out at the Drowning Conference held in Amsterdam in 2003 under the guidance of Dr. Bierens. A full conference proceedings and follow-on work was published in 2006 [3]. Additional data has been added with the very recent Canadian Red Cross publication "Drownings and Other Water-Related Injuries in Canada, 1991 – 2000. Module 2: Ice & Cold Water" by Barrs in 2006 [2]. Both documents are highly recommended for a more in depth review of the problem and general statistics.

Why do so many people still drown and should lifejacket/PFD be mandatory is discussed at length in the report by Smart Risk [14].

EVALUATING THE UNDERLYING CAUSE OF DROWNING

If the underlying cause of the drowning is not known, then how is it possible to prescribe good preventative measures? In cooperation with several agencies in the U.K., Oakley and Pethybridge [29] collected more specific data on drownings in the U.K. between 1991 and 1996. In 2005, Brooks, et al. [5], analysed both B.C. Fishermen's drownings and in 2006, drownings reported to the Maritime Coastal Agency [6]. In both cases as described in a separate paper on drowning and the underlying causes, there was considerable detail concerning the physical/mechanical problems of the accident, and virtually nothing on the human factors side and the underlying cause of the drowning [4]. An accident investigation checklist is included in the other paper.

SUMMARY

Sudden unexpected immersion in cold water is potentially very dangerous. The water temperature of 15°C or below provokes the physiological reaction or cold shock and swimming failure. This likely contributes to over half of the deaths through drowning. Survival instructors and survival schools have done a good job on training for the protection of hypothermia, but must change the emphasis to the first two stages of immersion. Everyone who earns their living flying over or working on the water must be aware of this fact. Accident

investigators must attempt to delve into the underlying cause of the drowning, and physicians, physiologists and operators of marine vessels and maritime helicopters must work together with the regulators and industry to improve our protective clothing and content of marine survival courses.

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