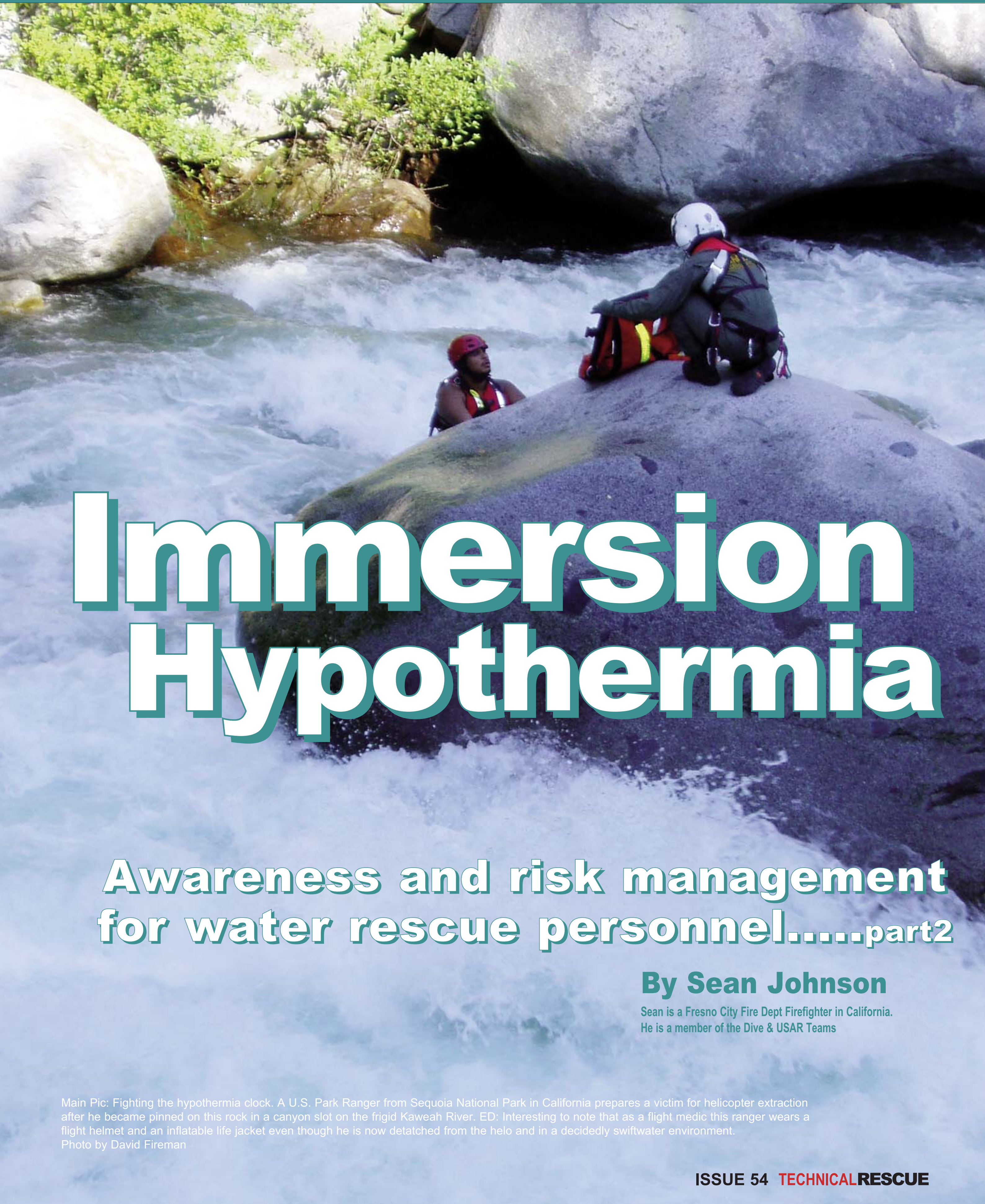

Immersion Hypothermia

Awareness and risk management for water rescue personnel.....part2

By Sean Johnson

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Main Pic: Fighting the hypothermia clock. A U.S. Park Ranger from Sequoia National Park in California prepares a victim for helicopter extraction after he became pinned on this rock in a canyon slot on the frigid Kaweah River. ED: Interesting to note that as a flight medic this ranger wears a flight helmet and an inflatable life jacket even though he is now detatched from the helo and in a decidedly swiftwater environment.
Photo by David Fireman

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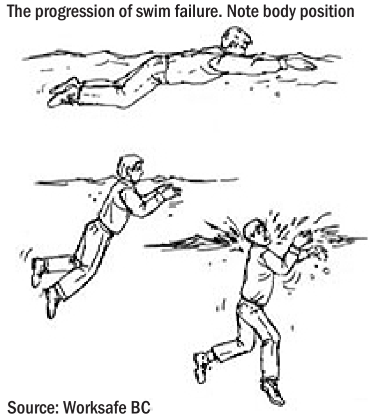
AQUATIC

Technical rescuers have brain and brawn--you have to be both intelligent, and aggressive. Calculating risk is part of thejob, as is the willingness to accept a degree of risk to make a save. While both of these abilities are what draws a certain personality to this job, sometimes our aggressiveness can get us into trouble.

Experience has proven that rescuers will push their limits in order to accomplish the objective. For the firefighters out there who have taken any Rapid Intervention Crew (RIC) you study cases of firefighter fatalities where the firefighter got into trouble but called for help too late because they tried to fix the problem themselves. As an incident commander or team leader, you need to be aware of this. There is a possibility that your team will push themselves beyond their physical limits which could lead to rescue of the rescuers.

Operations in cold water present a challenge in that there is a point where the effects of hypothermia overcome the rescuers physical abilities. The key is to be aware of these effects and set limits for your team. In Part I we looked at Stage I - basic mechanisms of cold water immersion, hypothermia and the functions of cold water shock and its effects on the body. In Part II we are looking at the effects on the body of continuous immersion which will allow you and your team to make informed decisions and calculated risks. We will then finish by looking at how proper personal protective equipment along with acclimation can minimize these risks

The progression of swim failure. Note body position



Source: Worksafe BC

Stage II Short Term Response

The onset of Stage II is very rapid and generally occurs within 2-3 minutes after initial immersion. Stage II, just like Stage I carries a major risk of drowning. Stage I and II are where most drownings occur in cold water with Cold Water Shock and Immediate Disappearance Syndrome occurring in Stage I and Swim Failure occurring in Stage II. Stage II involves cooling of nerves and muscles near the surface of the skin but core temperature is still normal. The onset of stage II depends on several factors including whether or not the victim is wearing thermal protection, individual body mass and makeup, water temperature, ambient temperature and whether the water is still or moving. The victim is not hypothermic at this point but they are still a high drowning riskparticularly if wearing inappropriate clothing (like fire-kit) that will be saturated and heavy. There are protective physiological responses at work in this stage which also have adverse effects on function and ability.

A major contributing factor to cold water drownings seen in Stage II is Swim Failure. Swim failure in cold water immersion has nothing to do with swimming ability. In fact several drownings involved people who were good swimmers![2].

Swim failure is a collection of body reflexes and inabilities as a direct result of immersion in cold water. The initial hyperventilation reflex in cold water shock carries into this phase. When we are taught how to swim we are taught to time our breaths with a ratio to swim strokes. Because our lungs are inflated during the strokes we are buoyant and therefore our swimming is effective. Because of reflex hyperventilation, our breath to stroke ratio is off and the buoyancy advantage is eliminated. This causes the swimmer to struggle to stay above water. Because the victim is struggling he is also increasing his demand for oxygen which further increases the respiratory rate.

This struggle causes the distressed swimmer to assume a highly ineffective swimming profile. In addition, superficial cooling of the limb muscles and nerve tissue decrease the range of swimming motion which adds to the struggle. Hyperventilation, ineffective swimming and anxiety have untoward effects which continue to compound and eventually lead to a total failure of swimming ability. If you want to experience this first hand, the next time you are swimming laps in a shallow pool try to increase your respiratory rate while maintaining your swim speed. You will find it is very difficult, if not impossible. Swim failure has claimed the lives of many people because of the misconception that swimming ability can overcome the effects of cold water. Prevention through public education can save lives. If you live near a body of cold water, create public service announcements which educate people about swim failure. The following chart is an excellent public education tool adapted from Paul S. Auerbach's book Wilderness Medicine, 5th ed.

Time Available if You Fall into Ice Cold Water: 1-10-1 Principle*	
1 Minute	You have 1 minute to get your breathing under control, so don't panic.
10 Minutes	You have 10 minutes of meaningful movement to get out of the water or attain a stable situation.
1 Hour	You have up to 1 hour before you become unconscious from hypothermia, if you don't panic and struggle unnecessarily. Note: If you are wearing a personal flotation device, you may have an additional hour before your heart stops due to hypothermia
* Times are subject to individual variability and factors such as water temperature and amount of the body immersed.	

Remember, exposure protection DELAYS the effects of immersion hypothermia, it does not eliminate them. Even though you have strong swimmers on the team they must wear PFDs if they are in or near the water.

Besides the danger of swim failure there are other operational safety concerns associated with Stage II. Even with core temperature near normal, peripheral shunting and vessel constriction create a protective "Shell" around the body to slow heat loss. This protective function causes complications which mainly affect motor function. The loss of a rescuer's strength and range of motion can really start to complicate matters and may eventually necessitate rescue of the rescuer. Good thermal protective gloves should be considered mandatory personal protective equipment. impaired muscular function and the resulting temporary physical disability is a safety issue that must not be overlooked. Swimmers may not be able to perform simple self rescue techniques such as

COLD WATER SURVIVAL TIME CHART source: US Navy

Water Temperature		Loss of Dexterity	Exhaustion or	Expected Survival
Degrees C	Degrees F	with no protective clothing	Unconsciousness	Duration
0.3	32.5	Under 2 min	Under 15 min	Under 15 to 45 min
0.3 to 4.5	32.5 - 40	Under 3 min	15 to 30 min	30 to 90 min
4.5 to 10	40 - 50	Under 5 min	30 to 60 min	1 to 3 hrs
10 to 15.5	50 - 60	10 to 15 min	1 to 2 hrs	1 to 6 hrs
15.5 to 21	60 - 70	30 to 40 min	2 to 7 hrs	2 to 40 hrs
21 to 26.5	70 - 80	1 to 2 hrs	2 to 12 hrs	3 hrs. to indefinite
Over 26.5	Over 80	2 to 12 hrs	Indefinite	Indefinite

pulling themselves back into the boat, holding a throw bag, holding onto a victim, climbing or anything else you can think of that involves using your hands! Moving water can conduct heat away from the unprotected body up to 250x faster than air. If you have a victim attempting to hold onto something in the current, it is a race against time before Stage II hypothermia sets in and your victim is swept away. Once again if you have a victim in exposure protection the onset may be delayed. What happens to victims can happen to your personnel as well. Just because your rescuers are in dry suits does not make them immune to the effects of hypothermia. As with any other job requiring work in environmental stressors, work/rest cycles should be established. Preplan your cold water incidents to include the temperature of the water each shift so you know exactly what an unprotected person can survive. You can then adapt this information as a guideline to determine swimmer exposure time limits

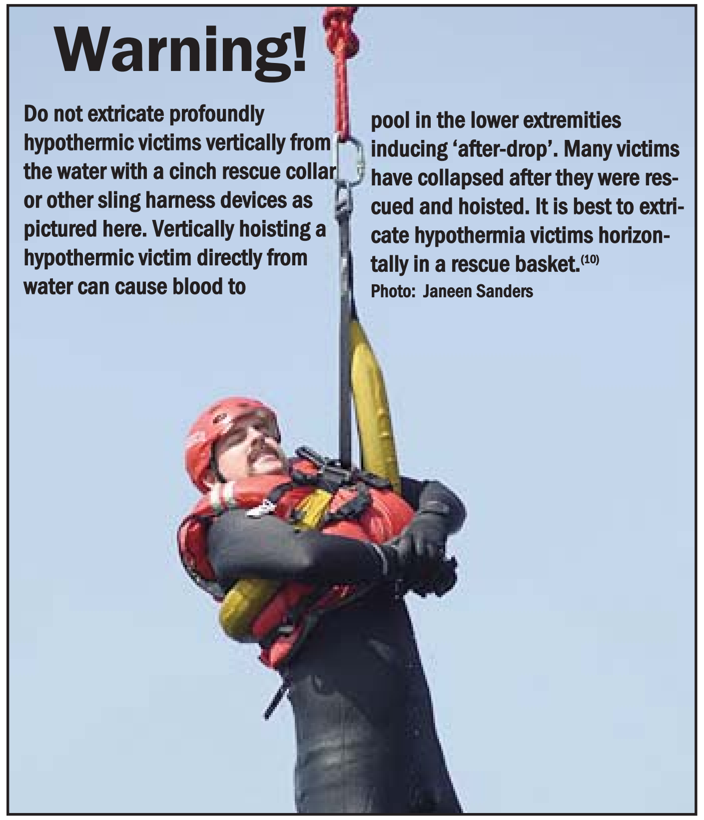
Stage III Long Term Response

Stage III Immersion Hypothermia is where the signs and symptoms of core cooling appear. The Shell-Core model of physiological responses delays the onset of core hypothermia until we reach this stage. Consequently, deaths that occur in this stage and later are generally attributed to hypothermia [11]. The amount of time an individual can remain in this stage before death is determined by multiple variables including temperature of the water, body mass, amount of exposure protection.
Generally speaking most people who are immersed without exposure protection will progress to hypothermia within approximately 30 minutes [3]. If you are successful and rescue your victim before fatal hypothermia sets in it is a complicated rescue because they can still collapse and die later which we will discuss next. As the victim's core temperature begins to decrease, body systems start to shut down eventually leading to coma and death as seen in this chart.

Warning!

Do not extricate profoundly hypothermic victims vertically from the water with a cinch rescue collar or other sling harness devices as pictured here. Vertically hoisting a hypothermic victim directly from water can cause blood to pool in the lower extremities inducing 'after-drop'. Many victims have collapsed after they were rescued and hoisted. It is best to extricate hypothermia victims horizontally in a rescue basket.[10]

Photo: Janeen Sanders



Stage IV Post-Immersion

Post -Immersion is the last but critical phase of immersion hypothermia. This is where the Physicians motto of "First do no harm" really comes into play. You could have just pulled off a spectacular rescue but if you are not mindful of

Stages of Core Temp Hypothermia

CORE TEMP		SIGNS & SYMPTOMS
°F	°C	
98.6	37	Normal core temperature
		MILD
96.8	36	Increased metabolic rate due to exercise and shivering
95	35	Maximum shivering thermo genesis
93.2	34	Amnesia, slurred speech, cardiac dysrrhythmias and judgment problems
91.4	33	Loss of coordination (ataxia) and apathy. Vasomotor paralysis. Vasoconstriction stops, insulation layer compromised.
		MODERATE
89.6	32	Stupor; oxygen consumption 75% of normal
87.8	31	Shivering stops
86	30	Possible cardiac arrhythmia; pulse and cardiac output 66% of normal
84.2	29	Decreasing consciousness, pulse, and respirations; dilated pupils
82.4	28	Increased sensitivity to ventricular fibrillation; pulse and oxygen consumption 50% of normal
80.6	27	Loss of voluntary motion and reflexes
		SEVERE *difficult to detect pulse at this stage, try sternal refill or perfusion of the gums*
78.8	26	Major acid–base problems; no response to pain
77	25	Cerebral blood flow 30% of normal; possible pulmonary edema
73.4	23	Loss of corneal reflexes
71.6	22	Maximum risk of ventricular fibrillation; oxygen consumption 25% of normal
68	20	Pulse 20% of normal
64.4	18	Asystole

post-immersion care you can kill your patient. There have been many documented fatalities where the victim collapsed and died in the ambulance or airship enroute to the hospital after a successful rescue.This phenomenon has been called circum-rescue collapse in the medical community. In fact up to 20% of those recovered alive die due to circum-rescue complications, either before and during rescue or within hours after [4]. **The main tactic to minimize post-immersion complications is extremely gentle handling of the patient.** The profoundly hypothermic patient has a lot of underlying pathophyisiological processes going on and is particulalry prone to arrythmic distress if handled roughly. If the patient needs to be removed from the water it is best to do so by keeping the patient in a horizontal position. We will understand why this is important shortly. Now let's look at some immersion hypothermia pathology.
Anytime you have a situation where blood pools in the body for an extended period a condition called metabolic acidosis occurs. Metabolic acidosis is a condition in which circulation has been interrupted or stopped completely and blood pools in one area. This leads to an increase in plasma acidity and occurs over prolonged time. If blood flow is restored and the acidic plasma enters circulation the end result could be fatal.
Many times an additional complication occurs where a sudden shift in circulation causes acute hypovolemia. This phenomenon was seen frequently with the use of Pneumatic anti-shock trousers or MAST pants. Patients were in shock and seemingly stabilized with MAST pants but when the pants were deflated the patient would immediately destabilize and go into cardiac arrest.
This phenomenon has caught many rescuers off guard who think they have had

a successful rescue only to have the patient collapse and die post extrication. In the Urban Search and Rescue world it is referred to as crush or compartment syndrome because their entrapped/crushed patients would collapse due to metabolic acidosis after the heavy object was removed. This same process is occurring in late stage immersion hypothermia as well except it is referred to as "rewarming acidosis" [5]. Interruption of circulation in the extremities results in pooling of cold blood which begins the cycle that ends in acidic blood. This is another reason why you must be extremely careful handling a severely hypothermic patient.
Another post-immersion complication is after-drop. After-drop is the sudden infusion of cold blood to the heart and can be fatal. The heart does not tolerate cold blood and will result in electrical conduction problems. There have been many documented deaths were improper rewarming resulted in after drop [6].
The good news is that the body's responses to hypothermia are on a predictable scale. The bad news is that unfortunately many of these deaths were preventable. Anyone who has worked in emergency services for a while knows that even if you do everything right sometimes you lose a patient. But we can do a lot more by way of educating our own personnel in the prevention of future deaths from improper rewarming.
The key to proper rewarming is to rewarm the core before the shell. The degree on invasive procedures depends on the degree of hypothermia. Some mild cases of hypothermia may be treated in the field without hospitalization provided you have the proper equipment and logistical support. For the profoundly hypothermic patient all procedures strive for a controlled rewarming starting at the core and ending at the shell. Specific protocols for rewarming are extensive and beyond the scope of this article. I would highly recommend a consult with your local emergency physician and find out what his/her recommendations are for field treatment.

Inhalation Rewarming

One technology that is non-invasive, can be implemented in the field and has had promising results is inhalation rewarming.[7] The link between air exchange and body heat regulation is a concept that is often overlooked during rescue operations and can account for 10% to 30% of the body's heat loss.[8]
Divers are especially susceptible to this in addition to accelerated immersion hypothermia because of total cold water submersion along with the effects of breathing 'chilled' compressed air from a tank.
The military has been using rebreathers for many years for several reasons. One of the many advantages of a rebreather is breathing warm air because your are in fact rebreathing air that has been expelled from your lungs at normal body temperature. Many divers who have used rebreathers report greater thermal comfort and they are growing in popularity in the sport diver community as well.
To date, inhalation rewarming seems the most effective non-invasive treatment for hypothermia. It is safe, effective and easy to manage. If you can put a mask on, you can implement inhalation rewarming therapy. It is understood

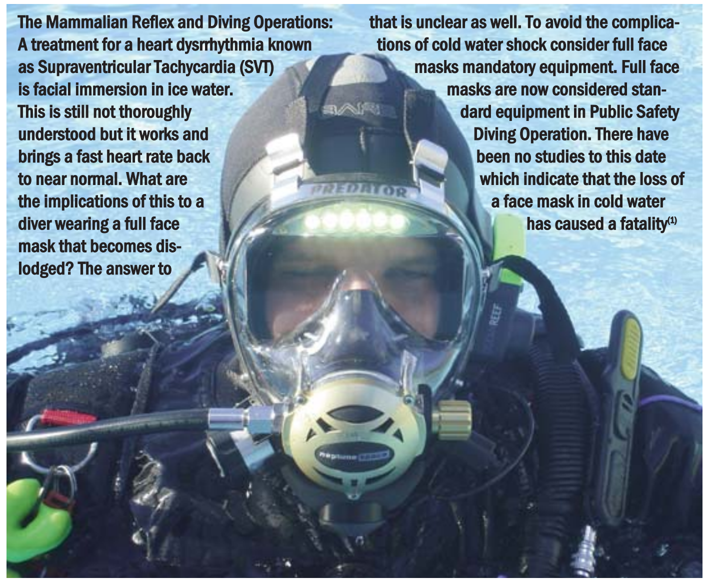
Many rescue swimmer tactics such as the shallow water crossing pictured here require grip strength and muscular function. What would happen to these swimmers if they lose their grip? Photo by author

that breathing warm air directs heat to the core through the upper and lower airways. Several important body systems are located very near these areas including the hypothalamus and the brain stem which regulates life supporting body functions. If the brainstem becomes chilled then body life support functions are altered. Conversely if the brainstem is rewarmed and stabilized then life support functions may be stabilized. The use of inhalation rewarming can be a great risk management tool that can be implemented in a rehabilitation/medical monitoring station for your rescue team. In the absence of inhalation reqarming consider warming packs under the arms and groinand always consider trasport on one of the reflectively insulated mummy-bags.

Operational Risk Management

Cold water rescue operations are logistically demanding. It is imperative that you have enough resources to support medical monitoring and rehabilitation of your swimmers and divers. There are several things that can be done during the incident and also implemented in your training which will make your people more resilient to injury.

- **Acclimation.** You can take away some of the intensity of cold water shock though slow gradual immersion. Granted this may not be possible if you have a time critical rescue but you should try to implement it as much as you can. There have been several studies which indicate that gradual acclimation to cold water can greatly decrease the amount of stress encountered by cold water shock[9]. Even if your swimmers are in drysuits, if the face and neck are exposed then the risk of cold water shock is there. Cold water shock is a function of nerve receptors in the skin and face and therefore any exposed skin should be acclimated. You should also take the temperature of the water before sending your teams in it so you know exactly what you're dealing with
- **Have a rehabilitation station set up**. Have an area for your swimmers and divers to rewarm themselves. This means a portable shelter, a heat source, food, extra clothing, warm blankets, and medical support with the training and equipment to recognize and treat hypothermia. There should also be a medical evacuation pre-plan in place
- **Set maximum exposure limits**. Enforce work/rest cycles. Remember your team will work themselves to exhaustion if you are not monitoring them. Immersion in cold water is an extreme task and therefore should have a short work cycle
- **Maintain swimming fitness**. Swimming fitness does not change how immersion hypothermia affects you but it does make a difference as to how far you can travel before succumbing to it. Additionally, rescue swimmers in exposure protection can generate and retain heat from motion and exercise.
- **Be aware of equipment limitations**. The accepted standard for Personal Flotation Devices (PFD) in swiftwater rescue is Type II or Type V. Be aware that these PFDs will not keep an unconscious swimmer's head out of the water.



The Mammalian Reflex and Diving Operations: A treatment for a heart dysrrhythmia known as Supraventricular Tachycardia (SVT) is facial immersion in ice water. This is still not thoroughly understood but it works and brings a fast heart rate back to near normal. What are the implications of this to a diver wearing a full face mask that becomes dislodged? The answer to that is unclear as well. To avoid the complications of cold water shock consider full face masks mandatory equipment. Full face masks are now considered standard equipment in Public Safety Diving Operation. There have been no studies to this date which indicate that the loss of a face mask in cold water has caused a fatality[1]

Even a strong swimmer can succumb to cold water shock or aspirate water and become unconscious. Type II and Type V are still excellent PFDs but be aware of this limitation and make sure your swimmers are aware of it.

- **Wear exposure protection suitable for the mission**. The technology for wetsuits and drysuits has come a long way over the past several years. It is obvious that the exposure protection you select needs to be suitable for the water temperature you are operating in but it might not be so obvious that the critical areas are the torso, head and neck. A latex hood seal with a fleece lining is an excellent choice for this mission. What it all comes down to is keeping cold water off exposed skin to mitigate the effects of cold water shock. There are several suits and fleeces on the market now with clever features that address these needs. If this not possible with your current level of PPE then make sure your swimmers acclimate. A swimmer or diver in the proper exposure protection can retain the heat they generate trough exercise and stave off hypothermia for a long time.

CONCLUSION

We will be called out to rescues in cold water again. Although we provide exposure protection for our personnel there are still inherent risks. Cold stress during water rescue operations can have a negative impact on rescuer health and safety. Cold water immersion both sudden and long term can degrade the performance of your personnel and if unrecognized can cause significant injuries. If you are on an extended incident than the effects can be gradual and go unnoticed until it is too late as we saw with the U.S. Army Ranger School incident described in Part I. Immersion hypothermia is a misunderstood concept by the general public as well and we, as rescuers, need to do a better job in educating the public and raising awareness. Prevention is going to be our best ally in this fight. After all who out there actually enjoys getting in the freezing water? Personally if I had my way I would be on a rescue team in the Caribbean but that's another life.

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