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diving medicine

the facts

HYPOTHERMIA MEANS 'LESS TEMPERATURE' AND IS A SIGNIFICANT PROBLEM FOR DIVERS IN COLD (AND SOMETIMES EVEN WARM) WATER. FROM THE PERSPECTIVE OF TEMPERATURE REGULATION, THE BODY CAN BE DIVIDED INTO TWO AREAS. THE CENTRAL CORE INCLUDES THE BRAIN, SPINAL CORD, CHEST, ABDOMEN AND PELVIC CONTENTS. THIS CONTAINS ALL OF THE 'IMPORTANT PARTS' AND THE BODY MAKES EVERY EFFORT TO MAINTAIN THE TEMPERATURE OF THIS REGION CONSTANT AT 37ºC. THE PERIPHERAL SHELL COMPRISES THE ARMS, LEGS, SUBCUTANEOUS TISSUES AND SKIN. THE TEMPERATURE OF THESE TISSUES IS ALLOWED TO FLUCTUATE QUITE WIDELY IN AN ATTEMPT TO KEEP THE CORE TEMPERATURE CONSTANT.

Hypothermia is defined as a core temperature of 35ºC or less. It can occur in 10 to 20 minutes if an unprotected person is immersed in cold water or may develop slowly over hours or days in warm water/cool air. Water conducts heat 26 times faster than air and convective heat loss in water can be 1,000 times more than in air. Therefore, divers are at real risk of hypothermia. Conductive heat loss is by direct contact. In divers this is heat transfer between the skin and the water or between the surface of the drysuit and the water. The rate of heat loss is proportional to the temperature difference between the two substances. Convective heat loss is due to the movement of air or water. If the water is still, the water next to the skin will heat up and the rate of heat loss will slow. If the water is moving, the heated water next to the skin is continuously being replaced with fresh, cold water and the rate of heat loss is much faster.

Clinically, hypothermia is classified as mild, moderate, severe and profound. Mild hypothermia is a core temperature of 35ºC and it is usually associated with maximal shivering, loss of fine motor skills, apathy and fatigue. Moderate hypothermia is a core temperature of 35-32ºC and one sees shivering, muscular weakness, confusion and amnesia. Severe hypothermia, core temperature of 32-25ºC, is associated with no shivering, increased muscle tone, loss of consciousness, absence of detectable vital signs and heart arrhythmias. A core temperature of less than 25ºC is usually associated with heart arrhythmias and death, although people have been brought back who have had core temperatures as low as 16ºC.

The body has several mechanisms to conserve heat. The first is the relationship between body size and shape. Large people have a higher mass to surface area ratio. This means that large people have more tissue to generate heat and less skin to lose heat through. Therefore, large people stay warmer longer when exposed to cold. Subcutaneous fat is also a good insulator and fat people tolerate cold better than skinny people.

When a person is exposed to cold, the body reduces blood flow to the periphery which allows the skin and superficial tissues to cool. This reduces the temperature difference between the skin and the environment and thereby reduces conductive heat loss. The body also opens arterial–venous fistulas so that some of the warm blood does not go to the arms and legs but returns directly to the core. In addition, arteries to the arms and legs run beside the large veins carrying blood back from the arms and legs. This arrangement works as a heat exchanger. The arterial blood gives some of its heat to the returning venous blood, thus conserving heat. The physiological adaptations to cold become more effective with repeated exposure, but this adaptation is lost in 2-4 weeks.

Me getting ready for a dive through 40cm of ice into the Ottawa River Caves in Ontario, Canada, a fair number of years ago!

The body also has ways to increase heat production. Babies and many animals have 'brown fat'. This special type of fat generates a large amount of heat. Unfortunately, adult humans do not have brown fat. A resting muscle has very little blood flow and is just as good an insulator as fat. When a muscle works it can generate a lot of heat. Unfortunately, the increased blood flow means that the muscle is no longer a good insulator. The practical result of this is that shivering and exercise will warm the core if the person is in air or well insulated from the water. An unprotected person in cold water will actually cool faster if they shiver or exercise because the increase in heat loss is greater than the increase in heat production. Hypothermia, even mild, can have significant effects on the diver. The effects of fatigue, impaired thinking, loss of manual dexterity and muscle strength is obvious. Hypothermia also increases the effect of narcosis and the risk of DCS (reduced off gassing). I recently suffered my first case of DCS when my drysuit flooded and I was very cold (but not shivering) during more than two hours decompression in a cave in Florida. The water temperature was 22ºC and I was wearing lots of underwear! If the diver's hands get too cold, the loss of strength can be quite dangerous. After one particularly miserable dive my hands were so weak that I could not open the two inch Fastex buckles on my dive harness!

The major sources of heat loss in the diver are conductive and convective losses from the skin to the water (direct or through the wet/drysuit). The major areas of concern are the head, the sides of the body, and the groin, as the blood vessels in these areas do not constrict much with cold exposure. Therefore, in these areas, maximal insulation is required. If you sweat inside your drysuit and the insulation gets wet it will not be nearly as effective.

Under a drysuit it is important to always wear a thin layer of special synthetic underwear (available at any hiking shop) next to the skin that will wick the sweat/water away from the skin and keep the skin dry. Additional layers of underwear can be worn on top of this depending on the water temperature and the insulating properties of the drysuit. Heat loss through the lungs is very important if you are diving deep (increased gas density). In fact, if you are wearing a drysuit with good underwear, the major sources of heat loss become the head, breathing, and the hands. Finally, if you are fairly well insulated from the water, shivering and exercise will be very effective in helping you stay warm (large increase in heat production, minimal increase in heat loss).

The initial response of an unprotected person to sudden immersion in cold water is very dramatic. There is a gasping response that will result in aspiration if the person's mouth is underwater. This is followed by 1-2 minutes of very rapid breathing that results in excessive loss of CO2 from the body. This hypocapnia can cause muscle cramps, reduced blood flow to the brain, and reduce the level of consciousness. In addition, the sudden shock can cause some people to have a cardiac arrest (heart attack). Therefore, divers and anyone else out on cold water should be protected from the water in case of sudden immersion and should be wearing some form of lifejacket.

The initial first aide for a person who is hypothermic should be to remove them from the water, replace wet clothing with dry, and insulate them as much as possible to prevent further heat loss. You must handle them very gently as the cold heart is susceptible to arrhythmias. You should obtain the history from the patient and other bystanders, note if they are shivering or not, and their level of consciousness. If the patient is conscious, you should give them warm, sweet fluids to drink but no diuretics >

Me getting ready for a 60 metre deep cave dive in 1ºC water, lots of current, over 1,000 meters above sea level in the Canadian Rocky Mountains in Alberta.

DAVID SAWATZKY, S.C., C.D., B.Med.Sc., M.D., M.Sc., is a diving medical specialist on contract at Defence Research and Development Toronto from 1998 to 2005. Previously he was the Canadian Forces Staff Officer in Hyperbaric Medicine at DCIEM (1986-1993) and later the Senior Medical Officer at Garrison Support Unit Toronto (1993-1998). He's written a monthly column on diving medicine in Canada's *Diver* Magazine since 1993, has been on the Board of Advisors for the International Association of Nitrox and Technical Divers (IANTD) since 2000, and is an active cave, trimix and closed circuit rebreather diver/instructor/instructor trainer. David's first love is cave diving exploration and he's been exploring and surveying underwater passages in Canada since 1985. David was responsible for the exploration and mapping of almost 11 kilometres of underwater passages in the Ottawa River Cave System. In 1995, he executed the first successful rescue of a missing trained cave diver. David received the Canadian Star of Courage for this rescue which took place in the chilly Canadian waters of Tobermory, Ontario. He still dives as much as possible, but admits his three year old son Lukas, two year old daughter Emeline and wife (Dr Debbie Pestell) are currently higher priorities than diving!

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(coffee, tea, alcohol). They should be evacuated to medical care as quickly as possible.

Beware of 'paradoxical undressing'. As the core temperature drops and the person becomes confused, the blood vessels to the skin will lose the ability to constrict and they will dilate. This sudden rush of warm blood to the skin may be interpreted by the victim as 'too hot' and they may take their clothes off in an attempt to cool down. A naked hypothermic woman is not always naked as a result of sexual abuse.

There is no easy, reliable way to measure core temperature in the field. Oral and ear temperatures are highly unreliable in the hypothermic patient. Rectal temperatures are usually not practical and you may be reduced to a quick check of armpit temperature with your hand. Vital signs may also be extremely hard to detect and you should spend extra time checking to see if the person is breathing and if they have a pulse. CPR must not be started unless it can be continued without interruption until the person can be delivered to a hospital as CPR may cause the heart to fibrillate. A person should not be assumed to be dead until they have been rewarmed!

When a hypothermic person is found in the water, they may suddenly die when they are rescued. The person is very hypovolemic and if they are lifted vertically out of the water, there may be no blood returning to the heart and they quickly die. Therefore, if at all possible, the hypothermic victim should be removed from the water in a horizontal position.

All hypothermic patients will experience a continued fall in core temperature of 1-2°C after rewarming has commenced. This 'afterdrop' is a physical effect and due to the temperature gradients in the tissue, NOT primarily due to cold blood returning from the arms and legs to the core.

If the person is shivering, they will rewarm effectively if you simply insulate them well so that they stop losing heat. Applying heat to the head, chest and groin, bundling them with a rescuer, giving them warm air/oxygen to breath, warm drinks and showers all feel great but have very little effect on the rate of rewarming. The only simple and effective method of active rewarming is a bath with water of 35-42°C. The arms and legs should be put in the water. At a hospital, several other methods of active rewarming are available.

Preventing hypothermia is the optimal solution. Insulate the head, wear appropriate thermal protection and if you get cold, abort the dive. Eat regular, high carbohydrate meals/snacks and drink warm, non-diuretic fluids. Ensure that you are well rested before diving and maintain a high level of physical fitness to increase your ability to generate heat. When you enter the water in a drysuit if you can feel that the water is cold through the suit, you are not wearing enough underwear for a long dive. Appropriate thermal protection will not only protect you from hypothermia, it will greatly increase your enjoyment of diving!