CASE REPORT

Problems and Complications With Cold-Water Rescue

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A case description is presented of a 9-member rowing team whose scull swamped on a small lake in Victoria, Canada, because of a sudden winter storm, which immersed them in 4°C water for 50 minutes until a small rescue boat found them in darkness. Another 13 minutes of cold exposure in 6.7°C air occurred during boat transport to waiting ambulance paramedics. Two rowers died, one from severe hypothermia and the other from drowning as a consequence of cold incapacitation and hypothermia. The 2 coldest rowers, who were transported 8 km to a major hospital, arrived with rectal temperatures of 23.4°C and 25°C; the first was asystolic and the second was unconscious and in sinus bradycardia. Analysis of all the circumstances of this incident provided an opportunity to observe a continuum of responses in a heterogeneous group of rowers at risk of severe hypothermia. Several practical lessons concerning cold-water survival, rescue, and treatment can be learned. The effects of low body mass were associated with greater cooling rate. Diminished neuromuscular performance in the periphery appeared to be independent of body mass. Rough handling during moving of patients with marked hypothermia introduces the risk of producing ventricular fibrillation or cardiac arrest. Unconscious, nonshivering hypothermia victims who are rescued and insulated from cold could have a further afterdrop of 3°C to 4°C. During transport to a hospital, the use of heating devices concentrating on core regions may increase the chance of successful treatment in the hospital. Cardiopulmonary bypass may be indicated for severely hypothermic patients in asystole.

Key words: hypothermia, field treatment, mechanical stimulation, cardiac arrest, ventricular fibrillation, circum-rescue collapse, afterdrop

Introduction

A common problem facing rescuers of cold accident victims is the potential for the phenomenon of “death of the rescued.”¹ This can occur in the short-term without severe hypothermia and has also been referred to as “postrescue collapse”; “rewarming shock”; or, more recently, “circum-rescue collapse.”² This phenomenon is most likely a response to some reflex or noxious stimuli on the heart. A victim’s condition can also deteriorate over the long-term (ie, >30 minutes), where there is a continued decline in condition until death. In this case, a victim’s heart temperature may continue to cool until it reaches a threshold for spontaneous ventricular fibrillation or cardiac arrest.^{3,4}

Several practical lessons concerning this problem can be learned from a case of an elite, 9-member university rowing team whose scull swamped during an evening

winter storm (mid January 1988) on a small lake (about 3 km long and 1.5 km wide) in suburban Victoria, Canada. As a result, 2 male rowers died; one of hypothermia *per se* and one of drowning because of hypothermia (coroner’s conclusions).

Information for a case description of this unique incident was available from surviving rowers, search-and-rescue experts who attended on the lake, ambulance paramedics, hospital records, and the results of a coroner’s inquest. The authors of this report had no direct involvement in the events of the incident (except J.S.H. measured the water temperature of the lake at dawn the next morning). Although it occurred several years ago, we believe that this unique, multivictim case of accidental hypothermia adds valuable insights into cold-water safety, rescue, and treatment.

Case description

The rowing team (8 male scullers and 1 female coxswain) began training late in the afternoon at about 1600

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hours. The air temperature was 6.7°C. On the basis of their previous recent experience of the weather conditions, the rowers wore personal choices of several layers of diverse clothing (eg, t-shirts, underwear, socks, shirts, sweat pants, sweaters, toques, jackets). No flotation devices were worn or available. Early in the rowers' planned 1-hour training period, wind caused a "slight chop" on the water, which, by 1700 hours, had become a gale of 30 k·h⁻¹ that strengthened to a storm gusting to 80 k·h⁻¹. Waves over 0.5 m high pounded the boat, and the rowers struggled unsuccessfully to make headway toward the boathouse about 1 km away. Also, it was becoming dark. At about 1710 hours, a wave swamped the boat, putting all the rowing team in 4°C water. They could not raise themselves out of the water because the scull would sink. They decided to spread themselves out along the length of the scull and hold on to the hull, oars, and riggers as 2- to 3-foot waves crashed over their heads. One survivor later explained, "We believed that just by hanging on to the boat and kicking lightly, that we would stay warm without sinking the boat." They did not realize that activity increases cooling rate in cold water,⁵ as does involuntary movement caused by rough water conditions.⁶

By 1730 hours, it was fully dark and a 14-foot (4.3-m) inflatable rescue boat and 2 operators arrived at the lake. After launching, they began their search in the region where the missing rowers were expected, but the very poor visibility caused by the waves and darkness hampered their success. Meanwhile, at various times, different rowers lost their hold on the scull, and others had to help retrieve them. Eventually, the rescuers found the crew at about 1800 hours, after 50 minutes of immersion. The 2 rescuers pulled them out of the water with difficulty, for the victims were unable to be of assistance. One of the 9 crew members, rower 1 (male, age 19 years, weight 93 kg, height 1.9), slipped away from the scull just before the rescue boat arrived. Navy divers found him 9 days later. The verdict of the coroner's inquest was that he "drowned as a consequence of hypothermia."

At the time of removal from the water, the remaining 8 rowers all showed symptoms of hypothermia, and their eventual outcomes varied greatly. Although all 8 were conscious at the time of rescue, the rescuers noted that 3 victims were close to unconsciousness and had limited ability to move purposefully. During the 13-minute transport to shore near the boathouse, the rowers were exposed to cold wind and very rough "pitching" in the boat. The total time of cold-water and cold-air exposure was therefore about 65 minutes, which corresponds with the rowers' arrival at the boathouse at about 1815 hours.

In the heated boathouse (20°C), triage by ambulance

paramedics determined that 5 of the 8 remaining victims (rowers 2–6) were less seriously affected, based on levels of consciousness and strong shivering response. No measurements of core temperature were taken from these 5 rowers. They were allowed to use warm showers in the boathouse to overcome cold discomfort and assist their endogenous rewarming.

The other 3 victims (rowers 7–9) were considered to be in serious condition because they were unconscious and not shivering. Rower 7 (male, age 21 years, weight 75 kg, height 1.75 m) and rower 8 (male, age 18 years, weight 79.5 kg, height 1.83 m) were breathing slowly and had palpable pulses. They were immediately sent by heated ambulance to an urban tertiary care hospital for treatment. The transport distance was about 8 km. Rower 9 (male, age 19 years, weight 72 kg, height 1.8 m) appeared dead and was asystolic with pupils fixed and dilated. Ambulance paramedics made unsuccessful resuscitation attempts, including cardiopulmonary resuscitation and electrical defibrillation for about 10 minutes before transporting him to the same hospital and maintaining the resuscitation attempts. No core temperature measurements were made for rowers 7 to 9 during ambulance evaluation and transport to hospital; thus, the hospital medical team had no advance warning of the level of hypothermia.

Rowers 7 and 8 arrived at the emergency department of an urban tertiary care hospital at about 1835 hours. Rower 7 had a rectal temperature of 25°C. He was unconscious, was in sinus bradycardia (40–50 beats/min), had a systolic blood pressure of 100 mm Hg, and was shaking steadily and moving his limbs. He was immediately warmed with gastric lavage; continuous bladder irrigation; 43°C water-saturated inhalation; a warming blanket; and heat packs on his neck, axillae, and groins. After 80 minutes, his rectal temperature had risen to 30.4°C, with a heart rate of 85 to 90 beats/min and systolic blood pressure of 150 mm Hg. Twenty minutes later, he was alert and responding verbally. He improved steadily and recovered fully.

When rower 8 was examined at the hospital at 1835 hours, he was conscious, shivering vigorously, and suffering from retrograde amnesia. A problem arose with measuring his temperature because the low-reading thermometer was being used for rower 7. A standard rectal thermometer was used temporarily but did not register above its minimum level of 32.2°C. Nevertheless, he was treated with inhalation warming, warm blankets, and heat packs applied to core regions externally. He maintained consciousness, and after 90 minutes in the hospital had a rectal temperature of 36.2°C. Rewarming was discontinued and he recovered fully.

At 1845 hours, approximately 45 minutes after his

rescue from the 4°C lake water, rower 9 was examined in the hospital emergency department. He was still asystolic, had muscular rigidity, and had a rectal temperature of 23.4°C. Despite his poor prognosis because of his previous asystole for a period of at least 30 minutes since arriving at the boathouse, continuous cardiopulmonary resuscitation and defibrillation attempts were combined with inhalation warming, warm saline infusion via a jugular vein, and application of warm blankets and heat packs. After 2 hours of therapy, he remained asystolic despite warming to a rectal temperature of 28.3°C. At this time, peritoneal lavage was initiated and he was warmed to a rectal temperature of 31.6°C before resuscitation attempts were abandoned.

Discussion

Several insights and lessons are to be gained from this unique case of accidental cold-water immersion that may be valuable to search-and-rescue specialists, medical experts, as well as outdoor educators and participants.

It is well established that the cooling rate of the body core in cold water depends, in part, on body size, mass, and fatness.⁷ Rowers 7 and 9 were the smallest and “leanest” members of the rowing team (according to the rowing coach) and obviously cooled the greatest amount, ending up in the worst hypothermic condition. Rowers 2 to 6 were heavier and thus did not experience as much core cooling and did not require any specific treatment before being released.

Thus, when a number of victims are in cold water, priority should be given to protect the smallest and leanest individuals, such as helping them raise as much of their bodies out of the water as possible. If rescue had been delayed in this particular case, the absence of personal flotation devices could have resulted in more drownings than the one that did occur. Similarly, when a group of hypothermia victims are rescued, the smallest and leanest patients should be evaluated first because they are likely to have the greatest degree of hypothermia.

Although body mass greatly affects the rate of core cooling, it has less effect on manual performance.⁸ The fact that rower 1 (among the largest and heaviest of the rowers) was unable to hold on to the boat and drowned could be an example of the deleterious effect of cold on neuromuscular performance (cold incapacitation), which is more a function of peripheral temperature than core temperature.⁹

The death of rower 1 just before rescue is also consistent with “circum-rescue collapse.”² It has been suggested that knowledge of impending rescue may reduce a victim’s catecholamine and sympathetic tone. This

could result in decreased perfusion pressure and produce cardiac ischemia.¹⁰ This could cause fibrillation of a cold heart and may have led to the drowning of rower 1.

It is likely that rowers 9 and 7 provide evidence of short- and long-term postrescue deterioration, respectively. At the time of rescue, rower 9 was conscious and sufficiently functional to hold on to the swamped scull. However, only 15 minutes later upon arrival at the boathouse, he was in asystole and never recovered. This may be a case of “short-term postrescue collapse”² caused by the unavoidable rough handling during rescue. He had to be dragged over the side of the rescue boat twice (ie, at the immersion site and the boathouse dock), which at one of these stages likely precipitated ventricular fibrillation or cardiac arrest.^{3,4} Although rower 7 was also conscious when rescued and unconscious upon reaching shore, unlike rower 9 he did not die during the handling process but had a longer-term deterioration further into hypothermia that was treated successfully at the hospital when he arrived 35 minutes later with a core temperature of 25°C.

Although there were no direct temperature measurements before hospital admittance, post-cold-stress afterdrop of core temperature would continue after the victims were rescued from the water and transported to the warm boathouse. The following analysis attempts to explain the magnitude of afterdrop that may have occurred. After 1 hour of exercise thermogenesis of rowing, the core temperatures of rowers 9 and 7 may have been at or above 37°C just before swamping. If the cold stress includes immersion and rescue-boat transport in high, cold winds, mathematical and experimental models^{7,11–13} would predict final core temperatures of 33°C to 34°C for victims of sizes comparable with rowers 9 and 7 if they were not voluntarily active. But Keatinge⁵ demonstrated experimentally that voluntary activity (such as the kicking that the rowers did in the water) during cold immersion increases cooling rate by about 50%, which would lower the rowers’ core temperatures to about 31°C to 32°C. The flushing action of waves and turbulent water, especially if the rowers’ heads were often sprayed, would further increase heat loss,¹⁴ causing more possible cooling of up to 50%^{15,16} and a drop in the rowers’ core temperatures to about 28°C to 30°C. These values are consistent with functional characteristics of rowers 9 and 7 at the time of rescue; they were semiconscious, unable to effectively help themselves physically, and stiff. It is therefore likely that in the 20 to 30 minutes from arrival in the warm boathouse until arrival in the hospital, their rectal temperatures continued dropping about another 3°C to 4°C and reached the low levels of 25°C for rower 7 and 23.4°C for rower 9. Such decreases are consistent with other reports^{17–20} and emphasize the potential for marked

further cooling of the core despite a victim having been rescued and placed in a 20°C environment.

Another lesson emerging from this case is that at low core temperatures (ie, below about 28°C) there can be a fine line between potential survival and death. At or about these temperatures, rower 7 survived but rower 9 did not. This indicates the importance of both gentle handling of victims and minimizing further core cooling during and after rescue. The use of some heating devices during transport of a victim with severe hypothermia (ie, one who is unconscious and not shivering) may attenuate the further drop in core temperature^{21,22} and increase the chance of successful treatment in a hospital. Portable heating devices should be applied to the torso and neck and include electric heating pads,²³ a charcoal Heatpac (A/S Møre Tekstilfabrikk, Oslo, Norway),²⁴ and forced-air warming devices.²²

The hospital where the 3 most serious evacuated rowers were treated did not, for unknown reasons, institute cardiopulmonary bypass warming for the severely cold, asystolic victim (rower 9). Cardiopulmonary bypass would be especially important for arrested patients who are receiving cardiopulmonary resuscitation, because this modality would improve arterial oxygenation as well as efficiently rewarm the patient.²⁵

In conclusion, this case description provides an opportunity to observe a continuum of responses in a heterogeneous group of rowers immersed in very rough, cold water. The following points should be included in medical and paramedical education regarding cold water immersion and exposure. Effects of body mass and activity level can affect core cooling rate and ultimate chances of survival. This case also highlights the need for careful handling of the patients during rescue, early measurement of core temperature to discern the patients with the most severe hypothermia, and expeditious treatment by both ambulance and hospital personnel to prevent the apparent large magnitudes of afterdrop that can potentiate fatal levels of accidental hypothermia. Aggressive core warming (ie, peritoneal lavage) is indicated for patients with severe hypothermia. Cardiopulmonary bypass, if available, should be initiated for cold patients in asystole or ventricular fibrillation.

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