CONSIDERATIONS IN THE CARE OF INDIVIDUALS WITH SEVERE HYPOTHERMIA

LESSONS FROM THE 1986 MOUNT HOOD TRAGEDY

On May 12, 1986, four adults and fourteen high school sophomores began from 6,000 feet the technically easy ascent of the south side of Mt. Hood (11,235 ft). In deciding to go, two mistakes were made. Their clothing and equipment were adequate for a climb in good weather but not for storm conditions. (At the start they were wearing everything they had with them.) Secondly, they thought a storm had just passed and expected good weather to follow. Actually they started out during a window in the storm, a common event in that area.

One adult and four students turned back after a few hours. The others turned back a few hundred feet from the summit in rapidly deteriorating weather. At 9,000 feet, because they could not continue, they dug a small snow cave. The next morning, the two fittest individuals descended to obtain help, but in "white out" conditions lost their way, traversed much of the mountain during their descent, and could not direct rescuers back to the snow cave.

On May 14 the bodies of three teenagers were found on an exposed ridge at 8,600 feet. In the afternoon of May 15, the first day of good weather, the snow cave was found by probing rescuers under four feet of new snow. Two of the teenagers had signs of life; all were transported to hospitals in Portland and re-warming and resuscitation was attempted with cardiopulmonary bypass. Only the two with signs of life survived; one had both legs amputated.

ADMISSION TEMPERATURES

VICTIM	ºC	ºF
1	3.0°	37.4°
2	6.0°	42.8º
3	6.4°	43.5º
4	7.0°	44.6°
5	7.1°	44.8°
6	7.8°	46.0°
7	12.0°	53.6°
8	19.5°	67.1°
9*	22.0°	71.6°
10*	23.6°	74.5°

* = Survivor

(Data on one victim not included at the family's request.)

In October, 1986, Portland physicians caring for the Mount Hood victims held a conference on bypass rewarming to which many of the individuals most knowledgeable about accidental hypothermia in the United States and Canada were invited. The discussion of accidental hypothermia at this conference is summarized below.

THE COMMITMENT OF RESCUERS AND PHYSICIANS

The commitment of everyone involved was inspiring. Rescuers unquestionably risked their lives in the extreme weather conditions. Winds that knocked them off their feet were known to exceed sixty miles per hour because winds of that speed produced by helicopter rotors do not knock people down. Three men were needed to close the door of a Snow Cat against the wind. Goggles iced up and fractured in the driving snow. One rescuer lost a glove and suffered frostbitten fingers; a second, whose jacket did not overlap his pants well, had "frostnip" of his "spare tire."

The rescuers refused to give up the search even though no probability of finding survivors appeared to exist, which resulted in the successful resuscitation of two students. After word reached Portland that the snow cave had been found, rescue helicopters were in the air within five minutes, which would have been impossible if the pilots had not been with their machines and had the engines warm. Yet over sixty hours had elapsed since the rescue had started!

All of the expenses for a preliminary organizational conference and the conference on bypass rewarming — travel, housing, and meals for thirteen out-of-state participants, meeting room rental, and court recorder and transcription expenses — were paid by the Portland cardiovascular surgeons.

HYPOTHERMIA CLASSIFICATION

Conference members agreed that hypothermia should be divided into mild and severe forms; no need exists for a moderate category. The basis for distinguishing the two categories is the victim's ability to rewarm himself, which usually is lost at body temperatures of 30° to 33°C (86° to 91°F), although great individual variation exists.

In the absence of other injuries or illnesses, an individual's level of consciousness is a reliable indicator of the severity of hypothermia. Impaired consciousness, such as the inability to stand or walk unassisted, is indicative of a temperature in the low 30's C (mid 80's to low 90's F). Total unconsciousness indicates an even lower body temperature and the need for aggressive rewarming.

TEMPERATURE AND RESUSCITATION

Body temperature is not a practical basis for prehospital resuscitation decisions because obtaining an accurate temperature is so difficult. Profoundly hypothermic individuals usually have their jaws tightly clinched, and prehospital personnel almost uniformly refuse to at tempt rectal measurements, particularly in a threatening environment. Moving the victim to disrobe him and take a rectal temperature could precipitate ventricular fibrillation.

The coldest reported accidental hypothermia victim to be successfully resuscitated had a core temperature of 15.2°C (59.4°F). Cardiovascular surgery patients are routinely cooled to temperatures as low as 9ºC (48ºF) and rewarmed with no subsequent hypothermia related problems, which indicates that 15.2ºC (59.4ºF) is not an absolute lower limit for survival. It may be close to the lowest temperature from which uncontrolled accidental hypothermia victims can be revived with current knowledge and techniques. A very high mortality can be expected for previously healthy accidental hypothermia victims with body temperatures between 15º and 20ºC (59º and 68ºF). Accidental hypothermia victims over forty years of age or with significant preexisting disease, of which chronic alcoholism and abuse of other substances are quite common, and individuals who are hypothermic as the result of drowning, have a much higher mortality.

CARDIOPULMONARY RESUSCITATION (CPR)

A victim of profound hypothermia without effective blood circulation can survive only a limited time without sustaining significant neurologic damage — one hour or somewhat longer, based on cardiovascular surgical experience. CPR has a definite role in the prehospital care of severe hypothermia victims, particularly when evacuation is prolonged. Individuals with a detectable heart beat, no matter how slow, should not receive CPR or assisted ventilation because ventricular fibrillation would probably result. At least a full minute, preferably three minutes or longer, should be spent trying to detect a carotid pulse before assuming a hypothermia victim has no effective cardiac activity. A portable EKG monitor may be necessary to detect cardiac activity in victims of severe terrestrial hypothermia, and whenever available such units should be carried by rescue groups. (In a wilderness environment, portable monitors can not be relied upon for distinguishing between asystole, ventricular fibrillation, or baseline artifacts, but can reliably indicate the presence of QRS complexes.) Hypothermia victims with a functioning heart commonly have a reduced blood pressure, and blood pressure measurement may be further hindered by the absence of Korotkoff sounds.

CPR should be initiated in the field only by a team of experienced individuals in a safe, protected environment. If a hostile environment poses a major threat to the team, CPR should be postponed or abandoned entirely.

CPR should be given at one-half the usual rate to hypothermia victims to avoid respiratory alkalosis and to allow a longer cardiac-filling interval.

CPR should be instituted immediately following a witnessed cardiac arrest, particularly when transportation to a hospital is expected to require more than a few minutes. CPR probably should be administered to individuals with unwitnessed cardiac arrest who appear resuscitatable, but each situation can be expected to be so unique that more definitive recommendations are not possible.

The initiation of CPR usually should be postponed if the victims can be transported to a hospital in minutes.

CPR should not be initiated for hypothermia victims considered unsuitable for resuscitation due to extremely low body temperature, associated severe illness or injuries, a noncompressible chest, prolonged cardiac inactivity, or drowning with more than one hour of witnessed submersion.

PRECAUTIONS DURING TRANSPORT

Severe hypothermia victims must be handled gently; even minor bumps or jolts can precipitate ventricular fibrillation. (Subsequently, medical and rescue personnel from Canada, Alaska, and other parts of the United States who have had extensive experience with severe hypothermia victims in the wilderness, have urged that such individuals not be moved at all until they have been rewarmed. A possible exception would be the situations in which the victims can be moved directly into a helicopter and transported smoothly to a hospital. The unavoidable jolts encountered in any other form of rescue transportation inevitably produce ventricular fibrillation and almost none of these individuals survive.

The role of drugs in preventing fibrillation is unclear; perhaps no role exists. Bretyllium is the only antiarrhythmic drug with demonstrated effectiveness at low body temperatures. Others have not been evaluated, largely because the limited need for this information does not justify the expense. Evaluation of the activity at low body temperatures of other widely used drugs, particularly antimicrobial agents and catecholamines, is badly needed.

Parenteral administration of drugs may be impossible due to collapse of peripheral veins and limited circulation in muscle and subcutaneous tissue. Metabolism of drugs is greatly reduced in hypothermia, and the accumulation of unmetabolized drugs can lead to toxicity during rewarming. Partial correction of almost universal dehydration with intravenous fluids prior to moving the victim is desirable, but may be impossible due to the difficulty in accessing a vein.

If the victim is breathing, oxygen administration at a generous flow rate prior to transport may reduce the risk of fibrillation. Dry oxygen is suitable if the victim can be transported to a hospital in minutes. Humidified oxygen heated to 40º to 45ºC (104º to 113ºF) could transfer a minimal amount of heat to the patient and help to limit any further temperature drop.

OUTCOME OF THE 1986 TRAGEDY

One of the two survivors had only minimal residual disability. The other had both legs amputated at the knees. That winter he was skiing on prostheses. The last news of him was that he was a graduated student in music at Oxford University.

As a result of this misfortune, a small, lightweight electronic signaling device that was developed to trace the migration patterns of whales and is detectable by satellites has been adapted for use on Mount Hood. The location of the wearer can be determined within 100 feet. Climbers, for a nominal fee, can rent these instruments. The manufacturer would not release the device for such use on Mount Hood until the Oregon Legislature had enacted a measure that protected him from any liability actions, and will not allow it to be used in other climbing areas.

Also as a result of this accident - at least in part - the Portland Chapter of the International Television Association in cooperation with Portland Mountain Rescue produced an instructional video, *Land of One Season: The Basics of Mountain Safety*. It was available from Trade Northwest, Inc., 8259 SW Cirrus Drive, Beaverton, OR 97005 (1-800-828-9816)

A transcript of the conference is (was?) available from the U.S.A. Research Institute of Environmental Medicine, Natick, MA, or from the U.S. Government Printing Office. (Wilkerson JA, Hamlet MP, Ed: *MEDICAL AFTER ACTION CONFERENCE, MOUNT HOOD, 1986, BYPASS REWARMING*. Report Number T10-88, U.S. Army Research Institute of Environmental Medicine, Natick, Massachusetts, February 1988.)

DESPERATE NATURE OF SEVERE HYPOTHERMIA IN A REMOTE WILDERNESS

In a remote wilderness, an individual with severe hypothermia is in a truly desperate situation, usually a hopeless situation if helicopter evacuation is not available.

1. A severely hypothermic individual can not rewarm himself. He is dependent upon external heat sources for rewarming.

2. In an environment cold enough to produce severe hypothermia, particularly above tree line where wood for a fire is not available, significant external rewarming is usually impossible.

a. Tents provide protection from wind but no significant insulation. Snow caves provide some insulation, but can not be warmed above freezing. (The snow melts.) A severely hypothermic individual with a body temperature of 80°F would nor rewarm in a hospital room with a temperature of 70°F.)

b. Insulated clothing and sleeping bags only limit heat exchange. They do not add warmth.

c. Adequate heat sources are not available. Heated stones, hot water bottles, body-to-body contact provide almost insignificant amounts of heat. Heated, humidified aerosols provide only a small amount of heat.

3. The individual can not be evacuated successfully overland if more than an hour is required to reach a hospital. Persons in hand carried stretchers or in snowcats are subjected to many bumps and jolts, some of which usually are fairly severe. Even mild jolts precipitate ventricular fibrillation (an ineffective heart rhythm), which produces irreversible brain damage after about one hour, and is usually lethal. (It rarely can be electrically converted if the heart temperature is below 32°C.)

WHAT CAN BE DONE?

1. Do not let it happen. Almost all severe hypothermia is the result of dumb mistakes.

2. Have helicopter transportation available.

3. Develop adequate heat sources. An electrically heated sleeping bag powered by a gasoline-powered, portable electric generator?

CALCULATION OF POTENTIAL HEAT TRANSFER BY HEATED AEROSOLS

The potential heat transfer by an aerosol of heated air humidified to saturation was calculated for hypothermic body temperatures of 20° C (68° F), 22.5° C (72.5° F), 25° C (77° F), 27.5° F (81.5° F), 30° C (86° F), and 32.5° C (90.5° F).

The temperature of the aerosol prior to inhalation was considered to be 45°C (113°F), the temperature to which such aerosols are usually heated. Calculations were based on environmental temperatures of -15°C (5°F), a temperature commonly encountered on ski slopes, and 20°C (68°F), the lower end of the range of temperatures expected in hospital emergency rooms.

Because heated, humidified oxygen has also been used for rewarming hypothermia victims, calculations of the heat transfer by oxygen were also made. The results were so similar to the results for air they have not been included.

Hypothermic individuals in a hospital are sometimes hyperventilated to increase the heat transfer. The increase in heat transfer resulting from manual ventilation at a tidal volume of five liters per minute has been calculated and is presented.

ASSUMPTIONS

Several assumptions were necessary for these calculations:

1. Minute tidal volumes are lower than normal (4 - 6 l/min) with severe hypothermia, but measurements of those volumes in accidental hypothermia victims apparently have not been made. The following were assumed to be representative:

Temperature	Tidal Volume
20°C	2.0 l/min
22.5°C	2.5 l/min
25°C	3.0 l/min
27.5°C	3.5 l/min
30°C	4.0 l/min
32.5°C	4.5 l/min

In view of repeated observations that respiratory activity may be impossible to detect in severely hypothermic individuals, the tidal volumes for lower body temperatures may be somewhat high; mildly hypothermic individuals tend to hyperventilate and the minute volume at 32.5°C may be somewhat low. The results of the calculations indicate that any inaccuracies are insignificant.

For these calculations, individuals being manually ventilated were assumed to have a minute tidal volume of five liters per minute (5 l/min).

2. Standard atmospheric pressure of 760 Torr (mmHg) was assumed. The effects of pressure changes associated with higher altitudes have been calculated and are presented.

3. The specific heat of gasses and gas mixtures

changes with temperature. These changes are small (fourth decimal place) and were assumed not to significantly alter the calculated results.

4. For these calculations, the inspired gas was assumed to be cooled (or heated) to body temperature and humidified to saturation. Such complete temperature exchange and humidification does not occur, but the differences would not alter significantly the calculated results and the conclusions that can be drawn from them.

5. To simplify the calculations, dry air was assumed to be 20 percent oxygen and 80 percent nitrogen. (During the calculations these values were proportionally reduced to account for the vapor pressure of water.) Air at -15°C was assumed to be dry; fully saturated, the water vapor content could only be 0.16 percent. (At -15°C vapor pressure of water is 1.24 Torr.)

6. For the calculations of heat exchange in an emergency room, an environmental humidity of fifty percent was assumed as well as a temperature of 20°C. In view of the small amount of water vapor in cold, winter air, even when fully saturated, and the frequency with which doors to the outside are opened in busy emergency rooms, this assumption appears valid.

BASIS FOR CALCULATIONS

1. The amount of heat given up when heated air is cooled or warmed to body temperature was determined from the weight of each gas in the mixture, the respiratory tidal volume, and the specific heat of each gas.

2. The quantity of heat released by condensation of water (or required to vaporize water) in the respiratory tract was calculated by determining the vapor pressure of water in saturated air at the various temperatures, calculating the change in weight of the water vapor in the air resulting from those pressure changes, and multiplying that weight by the heat of vaporization of water at a temperature midway between the beginning and final temperature of the aerosol.

RESULTS

(The range for all values is from a body core temperature of 20°C to a body core temperature of 32.5°C except where stated.)

1. The total heat available from the heated aerosol ranges from 4.3 Kcal/hr C to 6.0 Kcal/hr (maximum occurs at a body temperature of 30°C). Only 1.0 to 1.2 Kcal/hr can be transferred by cooling the inhaled, heated air. The remaining 3.3 to 4.8 Kcal/hr result from condensation of water vapor within the respiratory tract.

2. Maximum heat loss to the environment by warming and humidifying to saturation dry air at a temperature of -15°C ranges from 3.1 cal Kcal/hr to 11.3 Kcal/hr. Of this loss, the heat required to humidify the air to saturation ranges from 1.2 Kcal/hr to 5.5 cal/hr. The heat required to warm the inhaled cold air ranges from 1.9 Kcal/hr to 5.7 Kcal/hr.

3. The total heat exchange (heat gained plus heat loss prevented) ranges from 7.4 Kcal/hr to 17.1 Kcal/hr. Heat exchange for individuals with body temperatures of 25°C and 27.5°C, the individuals with the most severe hypothermia who appear to have a major potential for recovery, is 11.2 and 13.2 Kcal/hr.***s***

4. In an indoor environment with a temperature of 20°C and 50 percent relative humidity, the heat available from the heated aerosol remains the same, but the heat loss prevented is only 0.6 to 3.9 Kcal/hr. Maximum heat exchange in this situation ranges from 4.9 Kcal/hr to 9.7 Kcal/hr.

5. Assisted ventilation can not further reduce

heat loss to the environment, but can increase heat gain from the aerosol. At -15°C environmental temperature, the total heat exchange ranges from 13.9 Kcal/hr to 17.8 Kcal/hr.

6. Assisted ventilation in a 20°C environment with 50 percent humidity produces smaller increases in heat exchange as body temperature rises. The range is 11.4 Kcal/hr to 10.4 Kcal/hr.

7. The gain in heat exchange from ventilation is almost identical in -15°C and 20°C environments, and ranges from 6.5 Kcal/hr to 7.0 Kcal/hr.

ADDITIONAL CONSIDERATIONS

1. Actual heat exchange must be significantly lower for several reasons:

A. No system works at 100 percent efficiency; few can achieve 75 percent efficiency. A reasonable assumption is 50 percent.

B. Most of the heat transfer from inhaled gasses takes place in the upper airway, not in the lung. Air that has been cooled to body core temperature in the lungs is rewarmed as it leaves the body and extracts heat from the upper air passages.

C. Heat transfer is progressively reduced by the lower atmospheric pressures of higher altitudes. At an altitude of 8,000 feet the density of air under standard conditions is 74 percent of that at sea level; at 18,000 feet the density is 50 percent of that at sea level.

1. Reduced atmospheric pressure decreases the density, and therefore the specific heat and heat transfer capability of gasses.

2. Reduced atmospheric pressure decreases the vapor pressure of water and the amount of water vapor available to condense withinthe lungs.

D. Since most of the heat transfer takes place in the upper air passages, the heat is conducted to tissues in the head and neck, and perhaps the respiratory centers in the brain stem, and not the lungs.

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7 November 1998