Hypothermic Death in the Arctic State

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ABSTRACT

Hypothermic deaths are seen across the United States, but are more commonly seen in Alaska compared to the other states due to its northern latitude and variable climate. Vulnerable populations, such as the homeless and people with substance abuse are at increased risk. Our approach is to examine the scene circumstances, patient health factors, and autopsy findings to arrive at an accurate categorization of cause and manner of death in these cases. Literature on hypothermia is reviewed and various features of hypothermia including scene findings and pathophysiological findings of the victims are discussed. Various Alaskan cases demonstrating common features seen in hypothermia death are discussed. Photographic demonstration of the typical findings in the cases are shown and described. Methods of diagnosis and prevention are given at the conclusion of the article. *Acad Forensic Pathol.* 2018 8(1): 64-82

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INTRODUCTION

Hypothermia is defined as a human body temperature below 95°F (35°C) (1). Onset occurs when heat loss from the body exceeds heat generated by normal metabolism and/or special means of raising the body temperature, such as shivering. Heat is lost by conduction (usually in water), convection (in the air), and by evaporation in the air from wet clothing or the surface of the body to the environment. Most cases of hypothermia are accidental in unsuspecting victims. A minority of cases are homicidal or even suicidal.

Alaska offers a variety of weather ranging from frigid cold with a record of -80°F (-62°C) in 1971 at Prospect Creek above the Arctic Circle to 100°F (37°C) at Fort Yukon, inland, in the summer of 1915 (2). People can suffer exposure in both extremes in the Alaskan outdoor environment. Being a northern state, chances of cold environmental exposure and hypothermia are more common than that of hyperthermia or heat stroke. Most hypothermia deaths in the United States occur in northern states where winter is moderate to severe, such as Alaska and Montana, though they occur elsewhere with some frequency. Hypothermic deaths can also occur in more moderate climate states, such as Georgia and North Carolina, that exhibit rapid temperature changes. Western states with high elevations, such as New Mexico, can have a profound temperature decline following sunset. Unprepared and unsuspecting travelers to the mountains in New Mexico may suffer dire consequences. Surprisingly, New Mexico has the third highest death rate by hypothermia in the United States (3). Homeless populations are often at an increased risk of exposure in many places and this is also true in Alaska. However, in Alaska there are remote villages where there are no roads and travel is often done by all-terrain vehicle (ATV), snow machine, or boat with an increased risk of exposure. Recreational activities of hikers, kayakers, hunters, and fisherman also are frequently seen. Also at risk are workers in some industries such as commercial fisherman, mining, and logging. The age adjusted rate of hypothermia deaths is ten times higher in Alaska at 3.0 per 100 000 than for the rest of the United States (4). Conditions can include artic-like

frigid cold with no wind or blizzard conditions with a very low wind chill factor. Temperatures in Alaska can rise above freezing, but conditions can be wet and moderately cold, especially in the temperate rainforests in the southeast Alaskan panhandle. This wet environment, including cold water immersion, commonly leads to hypothermia.

DISCUSSION

Ways to Generate Heat in Man

There are two ways to generate heat in man: chemical thermogenesis and shivering (1). Chemothermogenesis is the term used for an increase in the rate of cellular metabolism proportional to the amount of brown fat in the body. Brown fat is found in most mammals including humans. Infants have a large amount of brown fat compared to adults. Brown fat increases heat production in infants nearly 100%, compared to only 10 to 15% in adults. The overall thickness of an individual's subcutaneous fat is proportional to the heat retention. A thicker layer of subcutaneous fat in overweight individuals is more likely to prevent hypothermia during exposure than that seen in thin people, children, or the elderly (1). Shivering is the rapid involuntary skeletal muscle contraction or twitching as a physiologic method of heat production in humans and other mammals. Shivering can increase heat production as much as five times the normal metabolic rate. Hypothermia creates increased metabolism and oxygen demand; therefore, people with underlying medical issues, such as heart or lung disease, are more likely to be adversely affected and result in an increased morbidity and mortality (1).

Epidemiology

Hypothermia disproportionately affects vulnerable individuals including the elderly, homeless, and chronically ill people, especially those with chronic heart disease such as atherosclerosis (5). The elderly and young are especially vulnerable because the elderly have atrophic or diminished muscle mass and problems with mobility such as arthritis. Diminished muscular activity lowers metabolic heat production

by muscle tissue. Older adults may have a thin build therefore increasing heat loss through a thinner layer of subcutaneous fat. Degenerative vascular disease and age-related cerebral dysfunction can lead to poor central heat production and a disinclination to move or ambulate. Poor mental health leading to apathy concerning nutrition, heating of their immediate environment, and general well-being are factors leading to hypothermia in the elderly. People suffering from hypothyroidism are vulnerable to hypothermia due to the inability to thermoregulate in cases of advanced myxedema. It may be even difficult to differentiate accidental hypothermia from myxedema at more moderate temperatures or in an indoor environment (6). Septic individuals also may demonstrate a lowered body temperature. On admission to the hospital, people with sepsis may be hypothermic rather than febrile.

A study from two countries with contrasting climates, South Australia and Sweden, compared the circumstances and victim profiles in their corresponding reports on hypothermic deaths (7). The findings revealed that elderly women, 58% female compared to men, were more likely to die in indoor environments, such as their homes, in the warmer and more moderate climate of South Australia. Hypothermia victims were more likely to be men in outdoor environments in the colder winter climate of Sweden. The victims described in Australia usually had comorbid conditions, such as cardiovascular disease, and were found in homes with inadequate heating and or insulation. Clothing may also be inadequate. Some victims lived isolated from normal family contacts in squalid conditions. Bodies were often found decomposed several days after death due to their isolationist behavior minimizing contact with others that would normally check on them daily. Around 95% of the female victims in the South Australian study were not discovered prior to 24 hours after death. The Swedish individuals, usually males (66%), were found outdoors and many were intoxicated. The majority of the victims in Australia were found in the spring and autumn and the ones in Sweden were found in winter (7).

Infants are another subset of individuals at risk for hypothermia. They have a larger body surface to mass

ratio leading to increased heat loss. They are also dependent on others for general care and to place them in the proper environment. Children and infants suffering from neglect or abuse receive inadequate attention from the caregivers including poor nutrition or protection from the cold due to insufficient clothing, blankets, or heating conditions (8).

In Alaska, temperatures are moderate to severe in the winter, making traveling and living outdoors more likely to lead to the onset of hypothermia. Men are known to take more risks by staying outdoors longer than compared to women. Men have a higher rate of hypothermia than that of women, with a ratio of approximately two to one. Victims in the outdoors of Alaska include the homeless, hikers/adventurers, and hunters (4). Outdoor environments can expose workers such as fishermen, loggers, oil rig workers, miners, etc. to occupational hazards including prolonged cold exposure or immersion in cold water. Capsizing of a fishing vessel or falling from a boat or land into the frigid waters of the ocean, rivers, or lakes can lead to rapid drowning augmented by hypothermia, or cold-water drowning. Wet environments, common in Alaska, increase the likelihood of wet clothing and immersion therefore increasing the loss of heat from the body. Thermal conductivity of water is 20 to 25 times that of air, so a body will lose heat approximately three times faster in water than in air. Heat loss by evaporation is also increased through wet clothing in windy weather.

Alcohol abuse is a serious issue in Alaska that places Alaskans in the top 10% for the rate of alcoholism in the United States. The rate of binge drinking in Alaska is approximately 18.2 to 24.9% of all adults in a 30-day period in 2015 (9). Alcohol increases the risk of dying of exposure due to the vasodilatory effects on cutaneous vessels enhancing heat loss. Reports of survival of intoxicated hypothermic individuals may be related to the protection against ventricular fibrillation. Surgical patients undergoing hypothermic treatment to prevent hypoxic brain injury during long procedures are given alcohol to maintain a blood alcohol concentration of 400 mg/dL, thereby increasing circulation and reducing oxygen consumption in the brain (1).

Symptoms

Symptoms of hypothermia vary with the stage or severity. A person suffering from mild hypothermia (body temperature of 90.0°F to 95°F [32.2°C to 35.0°C]) will have a sensation of being cold and will shiver. Blood pressure, heart rate, and breathing rate increase. One may even hyperventilate, especially when exposed to cold water. In moderate hypothermia (82.5°F to 90.0°F [28.0°C to 32.2°C]), symptoms include depression of body functions with slurred speech, uncoordination with bradycardia, hypotension, and bradypnea (shallow breathing below 90°F [32°C]). Cold narcosis is the clouding of consciousness at 85°F (29°C) with inability of the hypothalamus to control body temperature. Blood pressure decreases with vasoconstriction to protect the body core temperature and prevent cardiac collapse. Atrial fibrillation is seen at 86°F (30°C). Cessation of hypothalamic thermoregulatory control and ventricular fibrillation is evident at the final stage or severe hypothermia (less than 82.5°F [28.0°C]). Reflexes are lost around 81°F (27°C) of body temperature (10). A severely hypothermic person will appear deceased.

Occasionally, sudden death can occur with immersion in cold water secondary to initial cold shock leading to rapid increase of heart rate, blood pressure, and catecholamines, which can precipitate ventricular fibrillation. Uncontrolled strong urge to gasp for air caused by immersion may lead to aspiration of a large amount of water. Breath holding is also impaired in cold water, increasing the risk of drowning (11).

Scene Findings

Scene investigation is imperative for the investigation of exposure-related deaths, which on autopsy can have subtle or nonspecific findings. Often, no specific anatomic findings are noted on autopsy. The autopsy is used to rule out natural disease or injury that could explain the cause of death in a relatively healthy person found dead in a cold environment. One must rule out other evidence of disease or injury to rule in hypothermia as a cause of death. As in cases of drowning, hypothermia is usually diagnosed on circumstantial

evidence of a dead body discovered in cold environmental temperatures, whether the temperature is frigid cold air or more moderate with exposure to water or immersion. The individual's medical history should be obtained by investigators to help determine their risk for the onset of hypothermia upon cold environmental exposure. Another question is whether the victim could have arrived at the scene on their own volition. Could they walk? Are there footprints leading to the body or could they drive or use other transportation to the scene? The body may be found outdoors or inside. Conditions inside a building such as inadequate heating, lack of fuel, and thermal insulation of the walls must be documented to determine if exposure is a factor. How was the body found or positioned in relation to objects or furniture in a house or the setting at the scene of death? The appearance of the body, its location, and the condition of the clothing or lack of clothing is important to note.

Paradoxical undressing is a term used for people often found outdoors partially dressed to fully nude in cold environments (**Image 1**). Items of clothing are cast off as the victim moves to his or her final resting place and these items are found individually along the path to the decedent. This is one of the last acts of the dying, disoriented, hypothermic victim. This odd behavior is explained by the sensation of heat or burning as the warm blood flows back to the frozen skin during the body's physiological failure of vasoconstriction. Up to 50 to 70% of victims discovered have been reported to undergo paradoxical undressing, though in practice a much lower frequency is encountered (12, 13).

Another unusual final behavior observed in hypothermic victims is terminal burrowing behavior or the "hide and die syndrome." It is theorized that in one's final confusion and disorientation the dying person may try to hide or protect himself from the cold temperature by burrowing into snow, brush, or other objects outdoors. In buildings, one may climb under clothes or under furniture. Books may be piled on top of the decedent. Small pantries or cupboards may be used for hiding. The body is often out of sight upon searching during the scene investigation. Some geriatricians believe that the odd behavior may be initi-

ated by cerebral vascular lesions that may precipitate hypothermia in the beginning (8, 12). The scene of death may be suspicious for an altercation or a break-in because of the disarray. One must use caution when interpreting the scene findings to rule out a break-in or homicide (14).

Autopsy Findings

Autopsy findings are often subtle or nonspecific. In many cases, unusual pink-brown or purple skin discoloration of the skin over large joints of the extremities is noted. (**Image 2**). The color is easily distinguished from normal livor mortis seen in dependent areas of

the body. The cheeks, chin, and nose may also be discolored. A victim may have a malar rash that should not be mistaken for the rash seen in cardiac patients, especially those with mitral valve stenosis. Acute gastric erosions, or Wischniewski's spots, are seen in approximately 88% of hypothermia deaths (12). The pathophysiology may be explained by "A *deterioration in the response to cold stress*" resulting from local ischemia and reperfusion after microcirculatory collapse in the gastric mucosa (12). Microscopic findings of these dark round lesions consist of mucosal erosions and or ulcerations filled with dark brown-black material at the surface of the gastric glands. The material is Perls' Prussian blue stain negative (14).

Image 1: Hide and die/paradoxical undressing. Man found under snow partially dressed.

As the body and organs may be frozen upon discovery (**Image 3**), gross tissues and microscopic sections are often well preserved by the cold, slowing the process of putrefaction and allowing for the possibility of biochemical testing. Such biochemical tests are nonspecific but may help in the diagnosis of hypothermia. Elevated urine catecholamines and elevated vitreous glucose in nondiabetic individuals are noted in some patients (15).

Acute pancreatitis or hemorrhagic pancreatitis with fat necrosis is occasionally found in decedents with hypothermia. Autolysis of the organ can mimic hemorrhagic pancreatitis and must not be overinterpreted as a specific finding (14).

Perivascular hemorrhages have been described in the brain, especially in the walls of the third ventricular space (15). These hemorrhages are nonspecific, particularly in the elderly who have a high incidence of cerebral vascular disease.

Cold agglutinins can lead to sludging of blood in the peripheral vessels and peripheral vasoconstriction causing ischemic changes or necrosis, the leading cause of frostbite. Cold agglutinins may obstruct small vessels causing microinfarcts in organs commonly seen in hypothermia.

Image 2: Discolored and abraded knees.

Prevention and Treatment

The best therapy for hypothermia is prevention by preparation for the cold before one is to enter the outdoors in Alaska, or any place where cold environmental conditions may be encountered. Education on the use of proper attire for travel in environments with extreme cold temperatures, such as adequate clothing including head coverings, is imperative. Avoiding heavy exertion, fatigue, and alcohol, and maintaining proper fluid and calorie intake will help prevent death by hypothermia. Scouting the location for nearby available shelter or knowledge/ability to make shelter should be known before going out adventuring (4).

Treatment in early or mild hypothermia involves passive rewarming by the use of blankets or warm drinks. Active rewarming requires professional medical personnel often using cardiopulmonary resuscitation (CPR) until the body is rewarmed. Intravenous fluids and urinary bladder lavage are used in the emergency setting. Upon discovery, a person may appear dead; however, a patient should not be declared dead until rewarmed and without vital signs throughout resuscitative efforts, as there are cases where individuals, especially small children found outside or in freezing water, have been revived. People rarely recover when the initial core temperature is less than 26°C or 78.8°F (14).

Image 3: Ice crystals in the lateral ventricles of this brain.

Four times as many people who suffered from hypothermia have undergone successful resuscitation as compared to hyperthermic patients (10). This is due to the slowing of cellular reactions in the cold rather than the irreversible denaturation of proteins in heat stroke.

CASE STUDIES

Case 1

A 39-year-old male mountain climber was found dead on route from his camp to the top of Denali (Mt. McKinley). The decedent was traveling alone and had

no known medical history. The altitude was 17 000 feet (5182 m) and the temperature was -5°F (-21°C). He was last seen alive earlier the same day. He was fully dressed and found collapsed in the snow within view of the campsite (**Image 4**). No avalanche or rock fall was noted. The autopsy revealed a frozen but healthy atraumatic male with no cardiovascular disease or other comorbid condition. Significant findings included a diffuse maroon discoloration of the face and Wischniewski lesions of the gastric mucosa (**Images 5 and 6**). His peripheral blood toxicological examination only revealed acetone of 13 mg/dL.

Image 4: Case 1: Body recovery near campsite.

Image 5: Case 1: The face had an unusual maroon color.

Case 2

A 23-year-old male was discovered in a snowbank next to a small out building. The decedent had a history of intoxication and was physically removed from a heated cabin after an argument ensued with friends in a remote area. He tried to get into the cabin owners' vehicle when he was physically assaulted and dragged out of the car. The decedent was locked out of the cabin and vehicle and was later found deceased next to the cabin (**Images 7 and 8**). Postmortem toxicology of the femoral blood was positive for ethanol (0.266 g/dL) and cannabinoids.

Case 3

An unidentified male was found on a trail in the snow with clothing strewn along the trail (**Image 9**). Only a T-shirt and an outer flannel shirt remained on the body (**Image 10**). His handgun was on his chest with five spent rounds and one live round on his chest. There was no trauma to the body. The overnight temperature was 10°F (-12°C). His peripheral blood toxicology was negative except for an acetone concentration of 6.5 mg/dL. He was later identified and age was given as 54 years old. The body on autopsy was frozen and there was pink-purple discoloration with abrasions of the knees and feet. The hands were pink. Moderate hypertensive and atherosclerotic cardiovascular dis-

Image 6: Case 1: Wischniewski spots of the gastric mucosa.

Image 7: Case 2: Body hidden behind snowbank, homicide by hypothermia.

Image 8: Case 2: Victim recovered buried or burrowed into snow.

Image 9: Case 3: Boots lined up in the snow on a trail.

Image 10: Case 3: Body in T-shirt and flannel shirt only with remaining clothing strewn around the trail.

ease with pulmonary emphysema was also noted on autopsy examination.

Case 4

A 64-year-old female was found barefoot outside in the woods 100 yards (91 m) from her home deceased in the snow (**Image 11**). The temperature was 26°F (-3°C). She was supine with her arms crossed on her chest and she was dressed in only a sweatshirt and spandex pants. There were prints of her bare feet in the snow around the body. On autopsy examination, abrasions and contusions were on the extremities and small hemorrhages were seen in the stomach. One odd

finding suggesting possible confusion before death was a paper clip in her stomach (**Image 12**). She also suffered from hypertensive and atherosclerotic cardiovascular disease, had an aortic valve replacement, had chronic obstructive pulmonary disease, and was dependent on home oxygen. Toxicological examination performed on peripheral blood was significant for alprazolam at 10 ng/mL and oxycodone at 100 ng/mL.

Case 5

A 29-year-old male was witnessed to plunge through a hole in the ice of a local river and was last seen holding on the edge with his forearms (**Image 13**). The dece-

Image 11: Case 4: Partially frozen extremities; abrasions are noted on top of the feet.

dent was at a scene of a structure fire in town the day before and stated that the fire was a sign that people needed to repent and the Ebola virus was near. Hours before his death, the decedent was found by a friend walking in wet clothing. The decedent stated that he wanted to go to heaven and he was wet because he had cleansed himself. The ambient temperature was 28°F (-2°C). His medical history included adjustment disorder, alcohol and drug dependence, and psychotic disorders with hallucinations. Only small abrasions and pink discoloration of the upper chest and head was noted on inspection. His postmortem toxicological examination of the peripheral blood was negative for drugs of abuse and ethanol.

Case 6

A 27-year-old male was found frozen in the snow with his snow machine (snowmobile) after he was reported late for a stop in a local village. He was lying on a tarp on snow covered ground, fully clothed for prolonged outdoor exposure (**Image 14**). The snow machine was nearby with no damage. The outdoor temperature was -45°F (-43°C) and the evening low temperature was -52°F (-47°C). Toxicological examination of peripheral blood was positive for cannabinoids (20 mg/dL). The autopsy findings included abrasions of the fingertips, freeze artifact of the body with advanced autolysis of skin and viscera, and rare petechiae of the gastric mucosa. Armanni-Ebstein change

Image 12: Case 4: Paper clip in the first part of the duodenum.

was noted in the renal cortex and the liver demonstrated microvesicular steatosis. There were 150 mL of green-brown, frozen particulate material in the stomach. No trauma of the head or brain was seen; however, a linear fracture of the left posterior fossa was identified after removal of the brain (**Image 15**).

CONCLUSION

Although any individual exposed to cold environmental temperatures is at risk of developing hypothermia, the elderly or those with medical ailments such as heart or lung disease are at greater risk of death due to the increased metabolic rate and oxygen demands placed on an individual in these environmental conditions.

Alaska is the state with the highest rate of hypothermia-related deaths in the United States. The institution of public policy with outreach programs and education may be helpful to reduce hypothermia-related death or injury.

Risk factors such as general health and behavioral characteristics prior to death should be considered when reviewing such cases. Thorough understanding of the environmental conditions, behavioral characteristics, medical history of the victims, and autopsy findings will lead to an accurate classification of cause and manner of death in hypothermia cases. This will avoid misclassification of hypothermic deaths as natural in medicolegal death investigations (10).

Image 13: Case 5: Footprints leading up to disturbed ice in the river.

Image 14: Case 6: Frozen snowmachiner's face.

Image 15: Case 6: Posterior fossa skull fracture.

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