LESSONS FROM HISTORY

Resuscitation of an Unconscious Victim of Accidental Hypothermia in 1805

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In 1805, W.D., a 16-y-old boy, became hypothermic after he was left alone on a grounded boat in Leith Harbour, near Edinburgh, Scotland. He was brought to his own house and resuscitated with warm blankets, smelling salts, and massage by Dr. George Kellie. W.D. made an uneventful recovery. We discuss the pathophysiology and treatment of accidental hypothermia, contrasting treatment in 1805 with treatment today. W.D. was hypothermic when found by passersby. Although he appeared dead, he was rewarmed with help from Dr. Kellie and his assistants over 200 y ago using simple methods. One concept that has not changed is the critical importance of attempting resuscitation, even if it seems to be futile. Don't give up!

Keywords: emergencies, resuscitation, rewarming, unconsciousness, prehospital

Introduction

On May 20, 1805, Dr. George Kellie, president of the Royal Medical Society and a Fellow of the Royal College of Surgeons (Edinburgh), reported a case of “Torpor from Cold,” describing the successful resuscitation from accidental hypothermia of W.D., a 16-y-old boy (see online Supplemental Material).¹ Although the methods of resuscitation from deep accidental hypothermia were less developed in 1805 than today, W.D. made a full recovery. We summarize the case and Dr. Kellie's analysis and compare differences in resuscitation and knowledge of hypothermia between 1805 and today.

Case Summary

On February 26, 1805, W.D., a 16-y-old boy, had been sailing in the vicinity of Leith Harbour, near Edinburgh, with companions, when their boat ran aground just short of the pier at about 1630 (Table 1). The companions managed to get themselves ashore, leaving W.D. alone on the boat, after promising to return shortly. Three hours later, at about 1930, 2 seamen passing by noticed W.D. lying in the stern of the boat. At first, they thought he was asleep, but then they realized that he was cold and apparently lifeless. They transported him to a nearby house and placed him near the fire. Dr. Kellie was called and arrived at about 2000 with his assistants. He described the scene:

When we arrived, [W.D.] was stretched out, before the fire, on his back, with very little appearance of life; the whole

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Table 1. Timeline of patient W.D. on February 26, 1805

~1300	Boat left harbor.
1630	Boat grounded on return.
~1930	W.D. was found unconscious.
2000	Dr. Kellie arrived and examined W.D.: “[R]espiration was obscure and insensible; but the pulse was quite distinct, even at the wrist.”
2030	Treatment was started. (At 2330, rewarming had been applied for 3 h.)
2130	Jaw tone was increased.
2145	Breathing was clearly visible; pulse was regular and full (heart rate 100 beats·min ⁻¹).
2330	Body temperature seemed normal.
0000	W.D. felt warm, was breathing normally, and had a full bounding pulse.
0300	W.D. awoke, spoke normally, complained of thirst, drank a basin of tea, and fell asleep.
0900	Dr. Kellie returned, just after W.D. had finished his usual breakfast; W.D. complained of thirst and abrasions from the application of smelling salts (HR 90 beats·min ⁻¹).

Reported times are in bold. Estimated times are in regular text.

body, with the exception of the face, which was well coloured, was of a deadly pale appearance, and very cold. The powers of sensation, and of muscular motion, were completely suspended. The head and limbs, perfectly flexible, fell lifeless to the ground, from whatever position they were raised to; the mouth was half open, and the jaw, obedient only to the hand, could be moved upwards and downwards, but returned to the half-closed position; the respiration was obscure and insensible; but the pulse was quite distinct even at the wrist, though irregular and slow. The organs of sense were equally inexcitable; a candle held close to the exposed eyes made no impression, the eye-balls remained fixed and motionless; the pupils, though dilated, contracted irregularly, while yet exposed to the light, in the way I have sometimes observed them to do in the recently dead.

Starting at about 2030, Dr. Kellie and his assistants attempted to stimulate breathing, support the circulation, and rewarm W.D. with vigorous rubbing of the body and extremities and the application of external heat using warm flannels (blankets). Dr. Kellie’s assistants, “little satisfied with the slow effects,” requested that venesection (bloodletting) be performed to see if W.D. would bleed. About 120 mL (4 ounces) of blood was drained from an arm vein. Following this, ammonium water (smelling salts) was used to stimulate breathing. The first application of smelling salts to the nose caused contraction of the facial muscles but did not stimulate breathing. However, when the assistants poured a small quantity of smelling salts on the chest and upper abdomen and rubbed it in vigorously, W.D.’s breathing increased dramatically. The assistants repeated these procedures at short intervals with the same effects. They continued applying warm blankets and rubbing the body and extremities. Soon, W.D.’s breathing was accompanied by movements of the neck and shoulders. The assistants were then able to stimulate breathing and movement further by applying more smelling salts to the nose. The

pulse became more regular and more rapid. At about 2130, an hour after the start of treatment, W.D.’s jaw was more closed and resisted attempts to open the mouth. The rescuers thought that he might be able to swallow, so they tried, initially unsuccessfully, to give him fluid. After several attempts with stimulation of the lips and tongue, he managed to swallow a few teaspoons of warm brandy and water. The process was repeated several times.

About 2 h after Dr Kellie had been called, W.D.’s life “seemed secure.” Breathing was clearly visible and the pulse was regular and full, at 100 beats·min⁻¹. The face and chest were warm, although the extremities were still cold. The assistants applied warm bricks to W.D.’s feet, covered him with blankets, and continued to massage his limbs. At about 2330, after 3 h of resuscitation, the body temperature seemed normal.

At midnight, when Dr Kellie left, W.D. felt warm and was breathing normally, with a full, bounding pulse. W.D. did not regain consciousness until 0300, when he awoke as if from sleep, spoke to his father, complained of thirst, drank a bowl of tea, and went back to sleep again for a few hours. Dr Kellie returned at 0900, just after W.D. had finished breakfast, which he had eaten enthusiastically. He complained of thirst and about the abrasions from the application of the smelling salts. His pulse was normal at a rate of 90 beats·min⁻¹. He remembered feeling cold, tired, and sleepy but had no further recollection of events.

Discussion

PHYSIOLOGY

Dr. Kellie discussed “caloric” (heat).¹ In the early 19th century, caloric was thought to be a fluid that flows from warmer to cooler bodies. This concept anticipated the laws of thermodynamics, formalized later in the century.

Dr. Kellie concluded that “[O]f the general exciting or stimulant power of heat, there can be no doubt.” He dismissed the illusion that cold is “a positive and active energy,” correctly stating that cold is just a decrease in temperature: “[F]or any degree of temperature... cold is still heat.”

Dr. Kellie observed that the effects of temperature depend on the organism. Some living beings “perish or become torpid from a diminution of temperature, which is yet sufficient for the life and activity of a great many others.”

Dr. Kellie stated that changes in temperature could have stimulant or sedative effects: “[A]s the temperature descends, it stimulates less and less.” This is an oversimplification. In humans, cooling of the skin stimulates shivering, increasing heat production as much as sixfold compared to resting, nonshivering metabolism.²⁻⁴ If core temperature continues to drop, shivering continues at high intensity until the core temperature decreases to about 32°C. Shivering then begins to diminish, ceasing at a core temperature of about 30°C.⁵ Metabolism, minute ventilation, heart rate, blood pressure, and cardiac output increase as core temperature falls to about 32°C, then progressively decrease at lower core temperatures.⁶ In contrast to shivering and metabolism, central nervous system function only decreases with cooling. Sedative effects become noticeable below a core temperature of about 33°C, progressing to coma at lower temperatures.⁷

PATHOPHYSIOLOGY

During prolonged exposure to cold, if heat loss exceeds heat gain, core temperature decreases. “Torpor” can mean unresponsiveness, as in the title of the case report. Torpor can also describe the lethargy of animals in hibernation or the inability of poikilothermic animals, such as amphibians or reptiles, to move when they are cold. In animals that hibernate, torpor is controlled and the body is allowed to cool, in contrast to accidental hypothermia as the result of excessive cold exposure. Although people who are unconscious because of hypothermia may die, Dr. Kellie observed that survival is sometimes possible: “[T]he capability of resuscitation is sooner lost in humans [than in animals]; the torpor terminates rapidly in death, though there are not wanting examples of recovery, after long-continued torpor, even in men.”

Dr. Kellie explained the progression to torpor:

In passing into this state, the irritability of the sanguiferous [circulatory] system seems first affected; the pulsations of the heart and arteries are languid and less frequent; the respiration, next affected, is performed more slowly; the

internal heat falls below the natural standard; the functions of digestion are suspended; the powers of voluntary motion and of sensation gradually sink, and at length the torpor becomes complete.

This clinical description is mostly accurate, although the declines in neurologic and cognitive function accompany the continued decreases in cardiac output, heart rate, and respiratory rate.

Dr. Kellie thought that rewarming presents a mirror image of cooling: “In tracing the progress of resuscitation, we remark that the functions are revived nearly in the order in which they became torpid; the circulation and respiration first, and, gradually after, the activity of muscular motion, is restored.” This is not strictly true. One exception is that during cooling, there is a cold diuresis that may cause or exacerbate hypovolemia.⁸ W.D. was likely hypovolemic from decreased food and fluid intake and may also have had diuresis caused by cold. His tachycardia during rewarming may have been exacerbated by hypovolemia.

CENTRAL NERVOUS SYSTEM AND RESPIRATION

Dr. Kellie expressed the opinion that, if torpor were the direct result of cold, it would “in no case take place till, the heat of the brain and nerves was reduced beneath the natural standard.” Instead, he thought that torpor must be caused by “changes produced on the blood during the pulmonary circulation. Whatever impedes the respiratory changes of the circulating fluid debilitates or destroys the powers of muscular motion.”

Cerebral function starts decreasing at brain temperatures below about 33°C and continues to decrease with further cooling.⁷ The electroencephalogram shows only minor changes until core temperature drops below 33.5°C.⁹ Clinical manifestations include irritability, confusion, apathy, dysarthria, ataxia, and decreased mental status progressing to coma, usually at a core temperature between 30 and 28°C. These changes are caused by the direct effect of brain tissue cooling. They can generally be reversed with rewarming, except when hypothermia has been associated with asphyxia. Cerebral metabolism decreases by 6% for every decrease in brain temperature of 1°C or about 50% for each decrease of 10°C.¹⁰ Decreased metabolism protects the brain from ischemia, allowing tolerance to prolonged periods of decreased or absent blood flow during hypothermia.

CARDIOVASCULAR SYSTEM

Although decreasing core temperature initially causes tachycardia and increased blood pressure, continued cooling below about 33°C causes pulses to become progressively weak and slow.¹¹ Based on Dr. Kellie’s

examination, W.D. was initially bradycardic with an irregular pulse. The irregularity was likely caused by atrial fibrillation, a common occurrence during cooling.

When Dr. Kellie arrived, W.D.'s body was pale except for the face. Dr. Kellie thought that "[T]he terminations of the sanguiferous system on the surface of the body have their action immediately diminished by the local abstraction of caloric [loss of heat]." Although the circulatory system is a circuit that does not have terminations, Dr. Kellie's understanding was consistent with modern knowledge that hypothermia causes peripheral vasoconstriction with centralization of blood flow.

Dr. Kellie believed that "though the temperature of the heart itself be no way affected its irritability is instantly diminished by abstraction of caloric from the extreme branches of the system." He was incorrect that the temperature of the heart was not affected, but correct that loss of heat from the periphery causes cooling of blood returning to the heart. The word "irritability," as used by Dr. Kellie, refers to the automaticity of the electrical system of the heart. Modern usage is that the heart becomes more irritable, meaning "unstable," with cooling. Dysrhythmias are more likely at lower core temperatures.¹²

As core temperature falls below 33°C, cardiac function decreases. Hypothermia interferes with electrical activity, causing bradycardia and other dysrhythmias, with decreased automaticity of the sinus node, a decrease in transmembrane resting potential, and prolongation of the action potential.¹³ As the heart cools to 28°C, the risk of life-threatening dysrhythmias, especially ventricular fibrillation, increases.¹⁴ Ventricular fibrillation arrest can be caused by cooling alone but can also be provoked by movement or rough handling.¹⁵ Cooling can also cause asystole rather than ventricular fibrillation.¹²

RESPIRATORY SYSTEM

Dr. Kellie stated that respiration is "completely suspended" in hibernating amphibians and markedly diminished by cold in "higher orders" of animals. He used the example of people "remaining long torpid, deeply buried under snow" as proof that decreased respiration causes decreased cerebral function. We now know that respiratory rate and tidal volume decrease in response to diminished brainstem activity. Cold is a direct cause of decreased ventilatory drive.¹⁶ Dr. Kellie observed that cold causes a greater decrease in respiration than in cardiac activity. W.D.'s "respiration was obscure and insensible, though the pulse was distinctly perceptible, even at the wrist."

DIAGNOSIS AND STAGING OF HYPOTHERMIA

Dr. Kellie knew that W.D. had been exposed to cold. The differential diagnosis of unconsciousness includes

intoxication and injury. Dr. Kellie excluded intoxication by history and by smelling W.D.'s breath. He excluded injury with a thorough physical examination. He concluded that "the symptoms had arisen from the operation of the cold" after hours of exposure to "the diminished temperature of the atmosphere ... assisted by moisture" from the rain that had fallen. Dr. Kellie added that W.D. had "suffered from fatigue" and lack of nourishment, both contributing factors to accidental hypothermia.¹⁷

If there are no coexisting conditions, such as intoxication, injury, exhaustion, or decreased reserves of energy caused by inadequate nutrition, the severity of hypothermia can be estimated by clinical signs using the Wilderness Medical Society system or the Swiss system. In the Wilderness Medical Society system, unconsciousness indicates severe or profound hypothermia with an estimated core temperature below 28°C.¹⁸ In the Swiss system, unconsciousness without apparent death (HT III) correlates with a core temperature of 28 to 24°C.¹⁹ If exhaustion and lack of nourishment contribute to unconsciousness, estimates of core temperature using the Wilderness Medical Society or Swiss system may not be accurate.

TREATMENT

It is likely that W.D.'s wet clothes were removed before Dr. Kellie arrived because Dr. Kellie describes the appearance of the trunk and extremities as well as that of the face. Removal of the wet clothes would have limited heat loss (Table 2). Evaporation from wet clothes increases the rate of heat loss fivefold, compared to dry clothes.²⁰

Dr. Kellie's goals of treatment were to provide exogenous heat to warm the tissues and stimulate cardiorespiratory activity. Rewarming with exogenous heat increases core temperature, causing stimulation of ventilation and circulation. W.D. was placed supine near a fire and wrapped in warm blankets. The fire would have provided radiant heat to the side of the body facing the fire, decreasing heat loss from the blankets, and would have also decreased heat loss by warming the room (Table 2). The small heat content of the blankets not facing the fire would have dissipated quickly, much of it to the surrounding air, at least from the outermost blanket, but these blankets would have provided insulation limiting further heat loss. Massage of the extremities had the potential to be harmful by causing peripheral vasodilation of the skin with increased return of cold blood to the heart, lowering core temperature after removal from the cold (afterdrop).

Dr. Kellie advocated rapid rewarming for accidental hypothermia. He contrasted rapid rewarming with

Table 2. Treatment of WD in 1805 with current concepts in 2021

<i>Treatment</i>	<i>Current concepts</i>
W.D. evacuated from the scene to a warm environment	Effective first step
Wet clothes removed in a warm environment	Effective at decreasing heat loss; if transport time is short, wet clothes should not be removed until the patient is in a warm environment
W.D. placed near fire	Radiant heat source for parts of body facing the fire; decreases heat loss from warm blankets by providing radiant heat and by warming the room
Warm bricks applied to feet	Appropriate attempt to provide heat, but likely ineffective; no core warming; may cause burns to feet if bricks are too hot
Massage with warm flannels (blankets)	Limited heat transfer; risk of tissue damage if tissue frozen (not applicable in this case); risk of ventricular fibrillation because of movement, if core temperature <28°C
Warm blankets	Appropriate attempt to provide heat, but relatively ineffective; low heat content, but would provide insulation, protecting against further heat loss
Smelling salts (ammonia)	Only useful to evaluate unresponsiveness; likely no effect on hypothermia
Teaspoons of brandy	Alcohol is generally contraindicated because it can produce vasodilation, leading to increased heat loss; in this case, the amount of alcohol was likely too small to cause significant vasodilation

gradual rewarming of a frostbitten limb that was thought to be necessary to prevent “a violent reaction” or injury. He observed that in spite of the means employed to rewarm W.D., “the temperature was very slowly restored, the surface and limbs long felt as cold as ever.” The slow pace of rewarming is not surprising. The amount of active heating was likely less than that provided by modern methods of active warming, such as forced-air warming and chemical, electric, or water-filled heating pads. Regardless of the amount of heat donated by the fire and warm blankets, transfer of heat to the core would have been limited, at least initially, because of vasoconstriction. The pallor and cold skin of the body, except for the face, suggests peripheral vasoconstriction.

Dr. Kellie and his assistants used venesection (bloodletting) diagnostically rather than therapeutically. Dr. Kellie wrote, “As to blood-letting, I regard the practice as useless, while the body is cold, and the circulation and respiration languid.” The drainage of a small amount of blood is unlikely to have had any appreciable effect on resuscitation. Bloodletting, to see if W.D. would bleed, was superfluous in the presence of vital signs, even though they were diminished.

W.D.’s response to inhaled smelling salts was to grimace. This suggests that he was not deeply comatose. Fatigue and nutritional depletion may have contributed to the decreased level of consciousness. Inhaled smelling salts may stimulate ventilation.²¹ Irritation of the chest and epigastrium when Dr. Kellie applied ammonium water by “rubbing it forcibly in” with his hand seemed also to stimulate W.D.’s breathing. This maneuver was similar to a sternal rub, a noxious stimulus in which the examiner’s knuckles are rubbed against the sternum.

A sternal rub is very uncomfortable for a conscious patient. Topical application of ammonium water to the chest and upper abdomen likely had no direct effect on ventilation. It is likely that forcible rubbing acted as a general stimulant to increase the level of consciousness, stimulating respiration.

Shortly afterward, rubbing ammonium water in the epigastric area seemed to cause not only “the usual full inspirations, but a writhing motion of the neck and shoulders, which could now also be reproduced by [smelling salts] applied to the nose.” The pulse became stronger, more regular, and more rapid. W.D. seemed more alert, although he still had a decreased level of consciousness.

Eventually, W.D. was able to swallow a few teaspoons of warm brandy and water. Although giving fluids or food to a patient with a decreased level of consciousness risks aspiration, the amounts that Dr. Kellie administered were likely quite small. Stimulation of the lips and tongue may have allowed reflex swallowing.

Modern methods of external rewarming include chemical or electrical heat packs and heated forced air. Unlike warm bricks, forced-air warming and heat packs provide significant heat to the chest, the back, and the axillae, where heat can be effectively transferred to the core.¹⁸ Massage with warm blankets was likely of little benefit. The only evidence-based medical use of smelling salts is to place them near the nose to see if a patient is feigning unconsciousness.²¹ The composition of modern smelling salts can vary, but they still usually consist of ammonium carbonate dissolved in water. It is very difficult for a conscious patient to suppress a reaction to this noxious stimulus. The fact that WD winced when ammonia was placed near his nose most

likely indicated that he was not deeply comatose. The practice of venesection has survived but is now mostly limited to withdrawing small samples of blood for laboratory analysis, a purpose that is still diagnostic rather than therapeutic. Administration of small amounts of warm brandy and water were unlikely to have been helpful or harmful. Current practice is to administer isotonic fluids, usually intravenously.

Conclusions

W.D. was hypothermic when found by passersby. Although he appeared dead, he was rewarmed by Dr. Kellie and his assistants over 200 y ago, using simple methods. Some of the methods, such as vigorous rubbing, use of smelling salts, and administration of brandy, are obsolete. Other methods have survived as fundamental elements in the treatment of accidental hypothermia. These include keeping the victim horizontal, gentle handling, removal from the cold environment, providing insulation, and rewarming. The methods of rewarming included heat from a fire, warm blankets, and applying warm bricks to the feet. Only radiant heat from a fire may have been as effective as modern methods, such as heat packs and forced air warming.

Some of Dr. Kellie's understanding of pathophysiology and thermodynamics has long since been disproved, but many of his observations were surprisingly accurate. One concept that has not changed is the critical importance of attempting resuscitation, even if it seems to be futile. Don't give up!

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Supplemental Material(s)

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