Hypothermia can occur not only in persons exposed to extreme cold, but also in the elderly and infirm, and in patients with medical conditions that impair the ability to maintain an adequate body temperature. Stages of hypothermia are classified as mild, moderate, and severe (Table 1). Treatments for hypothermia have been described since the time of Hippocrates (470-410 BC).2 In the ensuing centuries, hypothermia has continued to occur at significant rates in the winter months and in northern regions, with mortality rates up to 40% when body temperature is less than 34°C.3 Hypothermia can be either primary or secondary. Primary hypothermia occurs in otherwise healthy persons who are inadequately clothed and exposed to severe cold. In secondary hypothermia, another illness predisposes the person to accidental hypothermia.4 The elderly and infirm are at increased risk for secondary hypothermia, and conditions such as ethanol intoxication, diabetes, sepsis, uremia, hypoglycemia, and malnutrition can also impair the ability to maintain an adequate body temperature in a cold environment.5

Rewarming a hypothermic patient is not a casual endeavor, because rewarming too rapidly can precipitate a condition known as “afterdrop.” Afterdrop is defined as a precipitous reduction in core temperature, when rewarming patients.

Patients with profound hypothermia can be safely rewarmed by using a slow rate and by warming the core before warming the periphery.

Learn about intravascular rewarming, a method of restoring normal core body temperature while avoiding hazardous afterdrop.

PRIME POINTS

- How to avoid “afterdrop,” a precipitous reduction in core temperature, when rewarming patients.
- Patients with profound hypothermia can be safely rewarmed by using a slow rate and by warming the core before warming the periphery.
- Learn about intravascular rewarming, a method of restoring normal core body temperature while avoiding hazardous afterdrop.
reduction in core temperature due to redistribution of body heat to improperly warmed peripheral tissues, with rapid shunting of cold blood from the periphery to the core as the direct result of vasodilatation. Afterdrop can cause a further decrease in core temperature, even after a person with hypothermia is removed from the cold. Rewarming a patient with heating pads or by placing frozen extremities in warm water before thermal stabilization of the body core can cause a bolus of cold, hyperkalemic, acidic blood to return from the periphery to the heart, resulting in a profound, biochemical injury that leads to severe hypotension and dysrhythmias. Rewarming the core at a prescribed rate is important, because hypothermia alone may not be fatal if the body temperature is greater than 25°C. Shock and metabolic derangements can also be precipitated by hurried rewarming or by warming the periphery before the core. The following case study describes a novel method of rewarming a patient who had hypothermia.

CASE STUDY

An 81-year-old man with a history of hypertension, congestive heart failure, and chronic renal insufficiency was noted by his family to be nonresponsive. Paramedics called to the home found the patient’s skin cold and dry; he had a blood pressure of 70 mm Hg by palpation, a heart rate of 49/min, a respiratory rate of 14/min, and an oxygen saturation of 98%. The patient was given 0.5 mg of atropine as an intravenous bolus and fluids intravenously and was transported to the local tertiary care hospital.

When the patient arrived in the emergency department, physical examination revealed a cachectic elderly man with cool dry skin and a score of 11 on the Glasgow Coma Scale. Vital signs were as follows: heart rate, 52/min; respiratory rate, 14/min; blood pressure, 104/69 mm Hg; and body temperature, 26.6°C rectally. Further examination revealed irregularly irregular bradycardia, mild suprapubic tenderness, and decreased deep tendon reflexes. Samples of blood, urine, and sputum were obtained for culture, and empirical antibiotics were started per sepsis protocol. A urinary catheter was placed to monitor core temperature and urine output. Admission laboratory values included a potassium level of 7.6 mmol/L, a creatinine level of 7.2 mg/dL (to convert to micromoles per liter, multiply by 88.4), and a serum urea nitrogen level of 95 mg/dL (to convert to millimoles per liter, multiply by 0.357). An electrocardiogram obtained at admission did not show classic J waves, also called Osborne waves (Figure 1), which are common in hypothermia, but did show atrial fibrillation with bradycardia and 160° right axis deviation.

Despite fluid replacement, the patient’s blood pressure declined again, to 70/40 mm Hg, and he

Table 1 Stages of hypothermia

<table>
<thead>
<tr>
<th>Stage</th>
<th>Temperature range, ºC</th>
<th>Level of consciousness</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mild</td>
<td>34-35</td>
<td>Alert, but uncomfortable</td>
</tr>
<tr>
<td>Moderate</td>
<td>31-33</td>
<td>Confusion and apathy, slow and slurred speech</td>
</tr>
<tr>
<td>Severe</td>
<td>&lt;31</td>
<td>Gradual loss of consciousness</td>
</tr>
</tbody>
</table>

a Data from Search and Rescue Society of British Columbia.1

Discussion

Medical publications consistently report that slow, rather than rapid, rewarming contributes to favorable outcomes for patients. Patients with severe hypothermia must not be exposed to extremes of heat and should be rewarmed as safely as possible at a “successful rate,” with the core warmed before the periphery. A review of the literature indicates that patients have been successfully rewarmed at rates from 1ºC/h to 2.95ºC/h without

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experiencing permanent organ damage. Rewarming at the fairly rapid rate of 2.95°C/h described by Plaisier10 may be an outlier, because most investigators11-13 recommend a rewarming rate of 1°C/h. Patients who are successfully rewarmed but do not survive to hospital discharge are those with multiple preexisting comorbid diseases.12

In patients who had undergone cardiac bypass, the group with the slowest rewarming, about 1.09°C/h, had better cardiac index and peak velocity, lower blood lactate levels, less afterdrop in core and foot temperatures, and shorter intensive care unit stays than did patients who were rewarmed more rapidly.6,14 In addition to the cardiovascular effects, early research indicates that rewarmin that is too rapid has a deleterious effect on the nervous system; specifically, rewarming faster than 1°C every 40 minutes induces secondary damage in the neural axon, an effect not seen with slow rewarming.11

Rewarming Methods

Several methods of rewarming are available. Otherwise healthy patients with core temperatures greater than 32.2°C can be successfully rewarmed via spontaneous or passive rewarming. In passive rewarming, the patient is simply covered with an insulating material and removed from the cold. However, patients with core temperatures less than 32.2°C and patients with unstable cardiovascular conditions, endocrinologic or metabolic insufficiency, or an inadequate rate of rewarming require active rewarming.15(p73) Some of the more commonly used methods for active rewarming are forced air warming and active core rewarming (which includes airway warming, peritoneal dialysis, heated irrigation, and extracorporeal blood rewarming; Table 2).

Forced Air Warming. Heating blankets that use forced air warming transfer heat efficiently. They have the advantage of being readily available and easy to use in hospitals. However, concerns arise as to the potential for thermal injury to vasoconstricted, hypoperfused tissue, as well as a variable and unpredictable rate of rewarming.16

Active Core Rewarming. For several reasons, active core rewarming is recognized as the most efficient method of safely rewarming patients who have severe hypothermia. Core organs account for 8% of body weight protocol. Hyperkalemia was treated with a 1-g intravenous bolus of calcium chloride, 60 g of sodium polystyrene sulfonate (Kayexalate) per rectum, a 25-mL intravenous bolus of 50% dextrose in water, and 10 units of regular human insulin intravenously. Because of the patient’s profound hypothermia, the resident physician used the ICY catheter (designed for intravascular cooling to maintain mild hypothermia in postoperative neurological patients; Alsius Corporation, Irvine, California) to warm the patient gradually. The ICY catheter was placed via the femoral vein, and intravascular warming was initiated with the goal temperature set at 37.5°C. The patient was warmed initially at a rate of 1.5°C/h until a temperature of 33°C was reached and cardiovascular stability was achieved. At that point he was transferred to the medical intensive care unit, where a goal temperature of 37°C was achieved at a steady rate within 12 hours after admission, at a rate of 0.8°C/h. The patient did not experience cardiovascular afterdrop, and normal sinus rhythm resumed 90 minutes after rewarming was initiated (Figure 2). The patient underwent dialysis the evening of admission and had no further dysrhythmias or hypotension. He was successfully extubated 2 days after admission and maintained normothermia throughout the rest of his hospital stay.
### Table 2: Methods of rewarming

<table>
<thead>
<tr>
<th>Method</th>
<th>Application</th>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spontaneous (passive)</td>
<td>Removal of patient from cold and covering with insulating material</td>
<td>Readily available, inexpensive</td>
<td>Inadequate rate of rewarming in patients with temperatures less than 32.2°C</td>
</tr>
<tr>
<td>Forced air warming</td>
<td>Heating blankets</td>
<td>Readily available and easy to use in hospitals</td>
<td>Potential for thermal injury, rate of rewarming varied and unpredictable</td>
</tr>
<tr>
<td>Airway rewarming</td>
<td>Via endotracheal intubation</td>
<td>Readily available, because most patients with severe hypothermia receive mechanical ventilation</td>
<td>Amount of heat delivered is small, and affects limited surface area</td>
</tr>
<tr>
<td>Heated irrigation</td>
<td>Infusion of warmed fluids into thorax, peritoneum, or bladder</td>
<td>Fairly inexpensive and variable</td>
<td>Thoracic and peritoneal lavage are complex; bladder lavage has limited dwell time</td>
</tr>
<tr>
<td>Extracorporeal blood rewarming</td>
<td>Via cardiopulmonary bypass, hemodialysis, arteriovenous or venovenous rewarming</td>
<td>Very effective, rapid warming</td>
<td>Costly, can cause too-rapid rewarming with complications of hemolysis, pulmonary edema, and acute tubular necrosis</td>
</tr>
<tr>
<td>Intravascular rewarming</td>
<td>Via closed-loop indwelling catheter</td>
<td>Allows setting of goal temperature and regulating rate of rewarming</td>
<td>Limited availability at present time</td>
</tr>
</tbody>
</table>

**Figure 2** Effect of intravascular rewarming on heart rate and mean arterial pressure.
but contribute 56% of bodily heat production in normothermia and an even greater percentage in hypothermia. When warming efforts are directed to the core, rewarming occurs at a more efficient rate and the risk of rewarming collapse (as occurs when the periphery is warmed first) is minimized.1

Airway Warming. Airway rewarming is a valuable adjunct to other rewarming methods. Most patients who have severe hypothermia are intubated, so ventilator adjustments can be made to provide humidified, warmed air to preserve heat and humidity ordinarily lost with breathing. Although most ventilators can deliver humidified oxygen at temperatures up to 40°C, the amount of heat delivered by this method is small because of the limited surface area of the lungs for heat exchange. However, patients with hypothermia who are intubated can be assured of adequate oxygenation and airway humidity.17

Heated Irrigation. Published reports have described patients being successfully rewarmed by use of a variety of heated irrigation methods, ranging from gastric and bladder lavage with warm fluids to peritoneal dialysis and thoracic lavage. In all these methods, rewarming is limited by surface area exposed to the warming solution, infusion flow rate, and dwell time. Thoracic lavage with a median rewarming rate of 2.95°C/h has shown the most promise of these techniques but is limited by its complexity; it requires the placement of 2 large-bore thoracostomy tubes. Peritoneal dialysis with dialysate warmed to 40°C to 45°C at a rate of 6 to 10 L/h increases body temperature by 1°C/h to 3°C/h. Gastric and bladder lavage are limited because of the limited surface area involved, but those methods can be used in conjunction with other warming methods.17

Extracorporeal Blood Rewarming. Extracorporeal blood rewarming is effective and can be accomplished with cardiopulmonary bypass, hemodialysis, arteriovenous rewarming, and venovenous rewarming. All these methods are limited because rewarming too rapidly can result in severe complications such as hemolysis, pulmonary edema, and acute tubular necrosis. Because of the severity of complications, extracorporeal rewarming is not recommended for patients with no evidence of cardiac arrest and asystole.18,19

Intravascular Rewarming. Intravascular rewarming via a closed-loop indwelling catheter is a novel approach to rewarming that was used successfully at a large tertiary teaching hospital in the Midwest. The ICY catheter (Figure 3) used to rewarmin the severely hypothermic patient described in the preceding case study was originally developed to provide core temperature cooling in neurosurgery patients and patients after cardiac arrest. The catheter is part of the CoolGard system developed by Alsius Corporation, which includes a temperature monitor, a temperature control unit, a heat exchange unit, and a roller pump20 (Figure 4). Feedback from a bladder thermister regulates the temperature of sterile saline that is circulated through the closed
catheter membranes to facilitate steady achievement and maintenance of desired body temperature. This method has no danger of fluid overload because the warmed saline is fully contained within the catheter lumens. The goal temperature and rate of warming (or cooling) can be accurately dialed in on the system.

Use of Meperidine. Use of meperidine is contraindicated in all methods of rewarming because it inhibits shivering, which attenuates the rate of rewarming. In addition, shivering provides a physiological benefit in decreasing afterdrop in rewarmed patients.

Nursing Implications for Intravascular Rewarming

Intravascular rewarming involves placement of a central catheter, so sterile technique must be observed when the catheter is placed, and a radiograph should be obtained to verify correct placement. Like all central catheters, the catheter must be replaced after 7 days. Although some intravascular temperature modulation catheters are manufactured for insertion in the subclavian vein, use of the femoral vein approach is essential for rewarming patients with hypothermia, because a hypothermic heart that is being rewarmed is irritable, and placement of a subclavian catheter could predispose patients to lethal dysrhythmias.

Conclusion

Patients with profound hypothermia can be safely rewarmed as long as rewarming proceeds at a slow rate, generally no faster than 1ºC/h to 2ºC/h, with warming of the core before the periphery. Use of intravascular rewarming via a technique such as use of the ICY catheter and CoolGard system is one method of restoring normal core body temperature in patients while avoiding hazardous afterdrop.

Financial Disclosures

None reported.

References

Facts

- Hypothermia occurs not only in persons exposed to extreme cold but also in the elderly and infirm and in patients with impaired ability to maintain adequate body temperature.
- Rewarming too rapidly can cause “afterdrop,” a precipitous reduction in core temperature due to redistribution of body heat to improperly warmed peripheral tissues, with rapid shunting of cold blood from the periphery to the core as the direct result of vasodilatation.
- Patients with profound hypothermia can be safely warmed by using a slow rate, generally no faster than 1°C/h to 2°C/h, with warming of the core before the periphery.
- Intravascular rewarming is one method of restoring normal core body temperature while avoiding hazardous afterdrop.


This article and an online version of the CE test may be found online at http://ccn.aacnjournals.org.
1. Which of the following describes the moderate stage of hypothermia?
   a. Temperature < 31°C with gradual loss of consciousness
   b. Temperature 31°C to 33°C with confusion and apathy, slow and slurred speech
   c. Temperature 34°C to 35°C with an alert but uncomfortable patient
   d. Temperature 31°C to 33°C with gradual loss of consciousness

2. Which of the following is true about secondary hypothermia?
   a. A medical condition that impairs the ability to maintain an adequate body temperature
   b. Occurs in an otherwise healthy person who is inadequately clothed and exposed to severe cold.
   c. Another illness such as ethanol intoxication, sepsis, hypoglycemia, or malnutrition predisposes the person to accidental hypothermia.
   d. Results from immersion in cold waters.

3. Which of the following describes the concept of afterdrop?
   a. A precipitous reduction in core temperature due to redistribution of body heat to improperly cooled peripheral tissues, with rapid shunting of cold blood from the periphery to the core as the direct result of vasodilatation
   b. A precipitous reduction in core temperature due to redistribution of body heat to improperly warmed peripheral tissues, with rapid shunting of cold blood from the periphery to the core as the direct result of vasodilatation
   c. A precipitous reduction in core temperature due to redistribution of body heat to improperly warmed peripheral tissues, with slow shunting of cold blood from the periphery to the core as the direct result of vasodilatation
   d. A precipitous reduction in core temperature due to redistribution of body heat to improperly warmed peripheral tissues, with rapid shunting of cold blood from the periphery to the core as the direct result of vasodilatation

4. Patients with profound hypothermia can be safely rewarmed at which of the following rates?
   a. 1°C to 2°C per hour
   b. 1.5°C to 3°C per hour
   c. 0.5°C to 1.5°C per hour
   d. 2°C to 3°C per hour

5. Removal of a patient from the cold and covering them with insulating material is what method of rewarming?
   a. Extracorporeal blood rewarming
   b. Heated irrigation
   c. Forced air warming
   d. Spontaneous (passive) warming

6. Which of the following is a disadvantage of forced air warming?
   a. Rewarming is limited to the surface area exposed, flow rate, and dwell time
   b. There is limited availability at the present time
   c. There is a potential for thermal injury and the rate of rewarming varies and is unpredictable
   d. This method is costly and can cause a too rapid rewarming

7. Which of the following is an advantage of intravascular rewarming?
   a. It is readily available, because most patients with severe hypothermia receive mechanical ventilation
   b. It is readily available and easy to use in hospitals
   c. It allows setting of goal temperature and regulation of the rewarming rate
   d. The amount of head delivered is small and affects a limited surface area

8. An infusion of warmed fluids into the thorax, peritoneum, or bladder is known as what method of rewarming?
   a. Extracorporeal blood rewarming
   b. Heated irrigation
   c. Forced air warming
   d. Spontaneous (passive) warming

9. Rewarming that uses a closed-loop indwelling catheter is known as what method of rewarming?
   a. Extracorporeal blood rewarming
   b. Heated irrigation
   c. Forced air warming
   d. Spontaneous (passive) warming

10. Which of the following is an advantage of airway rewarming?
    a. It is readily available, because most patients with severe hypothermia receive mechanical ventilation
    b. It is readily available and easy to use in hospitals
    c. It allows setting of goal temperature and regulation of the rewarming rate
    d. The amount of head delivered is small and affects a limited surface area

11. The rewarming method that utilizes heating blankets and is readily available and easy to use in hospitals is known as which of the following?
    a. Extracorporeal blood rewarming
    b. Heated irrigation
    c. Forced air warming
    d. Intravascular rewarming

12. Which of the following methods is accomplished by using cardiopulmonary bypass or hemodialysis?
    a. Extracorporeal blood rewarming
    b. Heated irrigation
    c. Forced air warming
    d. Intravascular rewarming

13. What percentage of bodily heat production is contributed by the core organs?
    a. 8%
    b. 27%
    c. 42%
    d. 56%

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Treatment of Severe Hypothermia With Intravascular Temperature Modulation
Marie Lasater

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