

Evidence-Based Management Of Accidental Hypothermia In The Emergency Department

Abstract

Accidental hypothermia is defined as an unintentional drop in core body temperature below 35°C. It can present in any climate and in any season, as it is not always a result of environmental exposure; underlying illnesses or coexisting pathology can play important roles. Although there is some variability in clinical presentation, hypothermia produces a predictable pattern of physiologic responses and clinical manifestations, and effective treatment has yielded many impressive survival case reports. Treatment strategies focus on prevention of further heat loss, volume resuscitation, implementation of appropriate rewarming techniques, and management of cardiac dysrhythmia. Rewarming may be passive or active and/or internal or external, depending on severity and available resources. This issue focuses on methods of effective rewarming and prevention of further morbidity and mortality.

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CME Objectives

Upon completion of this article, you should be able to:

1. Describe physiologic changes that can be expected with hypothermia.
2. Identify typical vital signs and examination findings in mild, moderate, and severe hypothermia.
3. Develop an evidence-based, systematic approach to treatment of a patient with mild, moderate, or severe hypothermia with or without hemodynamic instability.

Prior to beginning this activity, see "Physician CME Information" on the back page.

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Case Presentation

Emergency physicians in 3 different cities encounter 3 distinct patients with 1 thing in common: a low core body temperature.

Minneapolis, Minnesota: On a cold winter day, an emergency physician receives a call from EMS asking for advice: They were called to a nearby park where an unidentified middle-aged woman was found on the ground near a park bench. She has no palpable pulse, and there is an unknown downtime. On exam, her pupils are fixed and dilated, and her body feels cold to the touch. The paramedic is concerned that any resuscitation efforts would be futile and asks if any interventions should be made.

Portland, Oregon: A 22-year-old woman is brought to the ED after being rescued from a hiking expedition gone awry. The rescue team reports that she was lost on a mountain overnight without proper equipment or clothing. She was found lethargic, bradycardic, and hypotensive, but pulses were present. When she arrives in the ED, her condition is unchanged. You wonder what the best rewarming strategy would be.

Phoenix, Arizona: An 82-year-old man with multiple medical problems is transported to the ED from his nursing home due to altered mental status. Initial vital signs show that he is tachycardic, hypotensive, and has a rectal temperature of 33°C. There is no history of known cold exposure, and nursing home staff assures the doctor that he has been in bed for days with plenty of blankets. What is the differential diagnosis, and how should this patient be treated?

Introduction

Accidental hypothermia is defined as the unintentional drop in core body temperature below 35°C (95°F).¹ While accidental hypothermia is most common in cool climates during winter months, it can also occur in warm climates, in any season, and in individuals without a history of outdoor exposure. Accidental hypothermia can occur in a variety of populations, including those in an urban environment. Those at highest risk include homeless individuals, the very young and very old, and individuals with psychiatric disease, serious underlying medical conditions, traumatic injuries, or drug or alcohol intoxication.^{2,3} These groups often have impaired thermoregulation, but they also lack the ability to perform the behavioral adaptations to protect themselves from the cold, such as seeking shelter and putting on extra clothing.

The United States Centers for Disease Control and Prevention (CDC) reported that in the United States during the years of 1999 to 2011, there were an average of 1301 deaths from environmental cold exposure per year.⁴ Approximately half of the deaths attributed to hypothermia occur in patients over the age of 65. Inhospital mortality of patients with

moderate or severe hypothermia is as high as 40%.³ Despite the high mortality rate, there have been survivors with good neurologic outcomes who were resuscitated from extremely low temperatures, the lowest of which was 13.7°C.⁵ There have also been case reports of individuals surviving neurologically intact after prolonged cardiac arrest, the longest being in cardiac arrest for 8 hours and 40 minutes.⁶

In this issue of *Emergency Medicine Practice*, we will review the definition, pathophysiology, differential diagnosis, prehospital management, and emergency department (ED) evaluation and management of patients presenting with accidental hypothermia.

Critical Appraisal Of The Literature

The literature is full of extraordinary survival stories of patients with accidental hypothermia. These case reports and retrospective reviews have expanded our understanding of what the human body can endure. The sheer number of rewarming methods described in the literature provides the emergency clinician with seemingly countless options. Unfortunately, there is a paucity of randomized controlled trials comparing various treatments and rewarming techniques, likely due to the rarity of this condition. Ethical limitations preclude simulating severe accidental hypothermia in healthy individuals in the laboratory setting. Canine and porcine models offer some additional data, but clinical translatability is always a question. Because of the lack of quality clinical evidence, it is not possible to provide strong recommendations on management of patients with accidental hypothermia.

Searches of numerous evidence-based medicine sources were performed, including PubMed, MEDLINE®, Cochrane Database of Systemic Reviews, Database of Abstracts of Reviews of Effectiveness (DARE), and the National Guideline Clearinghouse, using the key terms *accidental hypothermia* and *accidental hypothermic arrest*. A systematic review published in 2014 describing the use of extracorporeal-assisted rewarming in the management of accidental deep hypothermic cardiac arrest was the sole review that met criteria for inclusion on DARE.⁷

Several sets of guidelines for the treatment of accidental hypothermia exist. In 2010, the American Heart Association and European Resuscitation Council both published guidelines on treatment of accidental hypothermia within the larger context of general guidelines for cardiopulmonary resuscitation (CPR).^{8,9} The State of Alaska Cold Injuries Guidelines were last updated in 2014 and include a section on accidental hypothermia.¹⁰ In 2013, the International Commission for Alpine Rescue-International Commission for Mountain Emergency Medicine (ICAR-MEDCOM) also developed recommendations for on-site medical treatment for acci-

dental hypothermia.¹¹

Additionally, in 2014, the Wilderness Medical Society developed practice guidelines for out-of-hospital care of accidental hypothermia.¹² These guidelines are based on the available literature as described above. Although the literature is not strong, the volume of data, available guidelines, and expert opinion do allow a treating physician to make a logical treatment plan for a patient with hypothermia according to available resources.

Etiology And Pathophysiology

Normal body temperature is maintained by a balance between heat production (ie, thermogenesis) and heat loss. If this thermoregulation cannot be maintained because of increased heat loss, decreased heat production, or overwhelming environmental conditions, hypothermia will manifest. There are 3 categories of hypothermia; a fourth category of profound hypothermia (< 24°C) has also been proposed.¹³ The 3 categories are:

1. Mild (core temperature 32°-35°C)
2. Moderate (28°-32°C)
3. Severe (< 28°C)

Heat loss occurs mainly via the skin and the lungs and occurs by 4 different mechanisms: conduction, convection, evaporation, and radiation. *Conduction* is the transfer of heat by direct contact with a cooler substrate. *Convective* heat loss occurs with water or air flowing over the skin and carrying heat away from the body. *Evaporation* is vaporization of water from a surface, as occurs when sweating. *Radiation* is infrared heat emission given off to the surrounding atmosphere. Heat loss depends on both the temperature gradient between the body and the environment and the amount of body surface area that is exposed. Under normal circumstances, the majority of heat is lost through radiation, but conductive and convective losses are generally key factors in the development of hypothermia.¹⁴

When core body temperature begins to fall, there are predictable physiologic responses. In mild hypothermia, the body first senses cold stress via the afferent fibers of cold receptors, and peripheral vasoconstriction occurs. The preoptic anterior hypothalamus also receives a signal and triggers shivering as well as the release of thyroxine and catecholamines, which aid in heat production. Shivering increases metabolic demand, which elevates the heart rate and increases cardiac output, respiratory rate, and overall oxygen consumption.

As the core body temperature progresses to moderate hypothermia, shivering ceases; this typically occurs when the core body temperature falls to between 30°C and 32°C. Catecholamine levels return to the prehypothermic state. With these changes,

there is a general slowing of the neurologic, respiratory, and cardiovascular systems. Changes in peripheral blood flow can result in perceived warmth of the body. This can result in individuals inappropriately removing their protective clothing, a phenomenon known as *paradoxical undressing*. The kidneys are also affected and produce a large amount of dilute urine, termed *cold diuresis*. This phenomenon is thought to be secondary to decreased release of antidiuretic hormone by the hypothalamus and well as initial increased renal blood flow from peripheral vasoconstriction. As hypothermia progresses, there is an eventual decrease in renal blood flow, and oliguria results.¹⁴

In severe hypothermia, cerebral blood flow significantly decreases, causing loss of cerebrovascular autoregulation, central nervous system depression, and, ultimately, coma. The respiratory rate decreases and hypoventilation progressively worsens. The initial tachycardia seen in mild hypothermia progresses to sinus bradycardia, and atrial and junctional dysrhythmias sometimes follow. If cooling continues, these systems continue to slow until there is eventual cardiorespiratory failure.

Differential Diagnosis

The differential of accidental hypothermia encompasses more than purely environmental exposure. Underlying illnesses or coexisting pathology can play a role in thermoinstability and can lead to the development and progression of hypothermia by decreasing heat production, increasing heat loss, or interfering with thermoregulation. Hypothermia secondary to such processes is sometimes referred to as *secondary hypothermia*. See **Table 1 (page 4)** for a list of causes of secondary hypothermia.

Prehospital Care

Several sets of guidelines exist for prehospital evaluation and treatment of patients with accidental hypothermia. These include a consensus of opinion article published by the International Commission for Mountain Emergency Medicine in 2003¹¹ and, more recently, evidence-based practice guidelines developed by an expert panel and published by the Wilderness Medical Society in 2014.¹² These treatment guidelines are helpful in directing care of any prehospital patient with suspected hypothermia.

Field Assessment

The suspected severity of hypothermia guides prehospital therapy, but core temperature measurement is often not feasible in the prehospital setting. Thus, prehospital providers should use the patient's level of consciousness, degree of shivering, and hemodynamic stability to assess patients with suspected

hypothermia.¹² The International Commission for Emergency Medicine described a staging system (sometimes called “the Swiss system”) to help estimate the degree of hypothermia based on clinical signs. The classifications of the degree of hypothermia and corresponding core temperatures are:¹¹

- Hypothermia (HT) I: clear consciousness with shivering (35°C to 32°C)
- HT II: impaired consciousness without shivering (< 32°C to 28°C)
- HT III: unconsciousness (28°C to 24°C)
- HT IV: apparent death (24°C to 13.7°C)
- HT V: death as a result of irreversible hypothermia (< 13.7°C?)

When using this system, the caveat is that the physiologic response to hypothermia is variable. Shivering has been observed down to 31°C and may not cease until 30°C.¹⁵ Additionally, there are case reports of patients being verbally responsive at 25°C and having signs of life at temperatures < 24°C.¹⁶

Prehospital Treatment

In hypothermic patients, prehospital providers should not forgo basic principles of prehospital care.

Table 1. Risk Factors For Thermostability And Secondary Hypothermia¹³

Decreased Heat Production

- Hypoglycemia
- Malnutrition
- Impaired shivering
- Extremes of age
- Endocrine disorders: hypothyroidism, hypopituitarism, adrenal insufficiency

Increased Heat Loss

- Skin disorders: burns, psoriasis, erythrodermas, dermatitis
- Vasodilation secondary to alcohol or other pharmacologic therapies
- Iatrogenic causes, including exposure and cold infusions

Interference with Thermoregulation

- Medications: anxiolytics, antidepressants, antipsychotics, opioids
- Peripheral neuropathies (eg, diabetic neuropathy)
- Spinal cord injuries
- Cerebrovascular accidents
- Central nervous system trauma
- Neoplasm
- Multiple sclerosis
- Parkinsonism

Miscellaneous

- Shock
- Infection
- Pancreatitis
- Uremia
- Vascular insufficiency
- Multisystem trauma
- Cardiopulmonary disease

Injuries should be stabilized. If a patient is obtunded, reversible causes of altered mental status should be considered and treated, if identified.

The initial treatment goal in all hypothermic patients is removal from the cold environment and prevention of further heat loss. Cold and wet clothing should be cut off the patient. Warm, humidified supplemental oxygen may prevent further heat loss and should be used, if available. Patients with moderate or severe hypothermia should be handled gently, as seemingly innocuous movements may precipitate fatal dysrhythmias.¹⁷ If the patient shows evidence of traumatic injury or has suspected moderate, severe, or profound hypothermia, active rewarming should be initiated. This can be accomplished by applying heat to the chest, axilla, and back. Volume resuscitation should be initiated with warm saline (40°-42°C). Patients undergoing active rewarming should be kept horizontal, if possible.

Hypothermic patients who are comatose or in cardiac arrest should be assumed to have severe or profound hypothermia. Airway management will likely be necessary, and prehospital personnel should intubate or place an advanced airway for airway protection, if possible. Prehospital providers should assess for pulses and initiate CPR at a standard rate of 100 compressions per minute if no pulses are palpable after 1 minute. Further Basic Life Support (BLS) and Advanced Cardiovascular Life Support (ACLS) care are discussed in the “Treatment” section, page 8. Delayed or intermittent CPR can be associated with good outcomes, but should be used only if evacuation efforts necessitate.¹⁸

Triage And Transport

Patients with identified trauma should be transported to a trauma center. Mildly hypothermic and moderately hypothermic patients should be transported to the nearest hospital. When possible, the hypothermic patient who is comatose or hemodynamically unstable should be transferred to a hospital with an intensive care unit and extracorporeal circulation capabilities.

Termination Of Resuscitation

There are no temperature cutoffs for resuscitation, as there are case reports of patients surviving neurologically intact with temperatures as low as 13.7°C in accidental hypothermia, and 9°C in the operating room.^{5,19} Guidelines recommend that prehospital providers initiate resuscitation in all cases of hypothermia unless there is an obvious lethal injury, the chest wall is too stiff for CPR, or the patient has been buried in an avalanche for more than 35 minutes and has snow impacted in the airway. In all other cases, evacuation, resuscitation, and transport should be initiated, provided that doing so does not endanger prehospital responders.²⁰

Emergency Department Evaluation

History

When a hypothermic patient arrives in the ED, the emergency clinician should complete a focused but thorough history including the duration and type of exposure, whether the patient was found indoors or outdoors, and any history of immersion or suspected hypoxic insults. If possible, obtain information on underlying medical conditions and current medications that may predispose the patient to hypothermia. Inquire about suspected trauma, alcohol or drug use, and potential ingestions or overdose. In a multicenter survey detailing 428 cases of accidental hypothermia in the United States, 44% of patients had a predisposing underlying illness, 18% had associated infection, 19% had associated trauma, and 6% had associated overdose.²¹

If the patient is transported by EMS personnel, the emergency clinician should also get a detailed prehospital history including initial mental status and vital signs, changes to clinical status during transport, and any interventions completed by prehospital personnel.

Physical Examination

Initial physical examination should focus on assessment of airway, breathing, and circulation, assessment of mental status, obtaining an accurate core temperature, and obtaining a full set of vital signs. After a primary survey is complete and appropriate interventions are made, the emergency clinician should complete a thorough secondary survey, looking specifically for evidence of trauma, toxidromes, underlying infection, or local cold-related injuries (such as frostbite).

A patient's physical examination will vary, depending on the degree of hypothermia. If a patient's mental status or vital signs are inconsistent with the degree of hypothermia, the emergency clinician should have a high suspicion for alternate diagnoses.

Mental Status

A patient's level of consciousness steadily decreases proportional to the degree of hypothermia. In mild hypothermia, confusion, dysarthria, ataxia, and impaired judgment are seen. As the patient progresses into moderate or severe hypothermia, stupor and then coma result. Individual response can vary, and some patients remain verbally responsive down to temperatures of 25°C.¹⁴

Vital Signs

Temperature

An accurate core temperature is essential in assessing a hypothermic patient. Most standard thermometers can only read down to 34°C, so a low-reading thermometer should be used. Esophageal probes inserted

into the lower third of the esophagus most closely reflect cardiac temperature and should be used in all intubated patients with hypothermia, if available. Bladder and rectal temperature probes can also be used, but they may be less accurate, particularly if a rectal probe is inadvertently placed in cold stool.

There are also considerations regarding temperature monitoring while rewarming a patient. Esophageal temperature probes placed in the proximal esophagus can read falsely high as a result of warm, humidified oxygen being used during rewarming. Bladder and rectal probes are less reliable if peritoneal lavage is being used as a means of rewarming. Also, rectal temperatures lag behind core temperature changes by up to 1 hour, reading higher than the esophageal temperature during cooling and lower than the esophageal temperature during rewarming, with the greatest inaccuracy occurring during the transition from cooling to warming.²² This transition generally occurs during ED evaluation, so isolated use of a rectal probe alone during rewarming is not ideal.

Pulse

In mild hypothermia, tachycardia is expected. As cooling continues, progressive bradycardia ensues. Studies of humans undergoing therapeutic hypothermia as well as laboratory animals undergoing cooling show that the heart rate is expected to be 50% of normothermic levels at 28°C and 20% of normothermic levels at 20°C.²³ Relative tachycardia beyond that point should prompt investigation into conditions such as hypoglycemia, hypovolemia, or toxic ingestion.

Blood Pressure

The catecholamine surge seen in mild hypothermia results in increased blood pressure due to increased cardiac output and peripheral vasoconstriction. With further cooling, heart rate and cardiac output decrease and blood pressure drops. Hypotension in moderate and severe hypothermia is further worsened by fluid shifts and hypovolemia secondary to cold diuresis. Significant hypotension can be expected once core temperature reaches 24°C.

Respiratory Rate

Patients with mild hypothermia are tachypneic, but respiratory rate and minute ventilation progressively decrease in moderate and severe hypothermia.

Pulse Oximetry

Oxygen saturation measurement by pulse oximeter may be difficult to obtain, given profound peripheral vasoconstriction. Anesthesia literature has shown that forehead probes are more accurate in mild hypothermia than finger probes, which can show significant lag time in reflecting hypoxia.²⁴ Arterial

blood gas (ABG) measurements can also be used to assess oxygenation, if needed.

Neurologic Examination

Pupils are generally dilated at core temperatures of $< 27^{\circ}\text{C}$ and are expected to be fixed and dilated at core temperatures $< 22^{\circ}\text{C}$. Fixed and dilated pupils at temperatures $> 22^{\circ}\text{C}$ should raise concern for inadequate cerebral perfusion. Reflexes are hyperactive down to 32°C , then progressively diminish. Loss of reflexes generally occurs by 26°C . Loss of corneal and oculocephalic reflexes generally occurs by 23°C .¹⁴

Other Physical Examination Findings

The remainder of the examination should consist of evaluation for traumatic injuries or other exposure injuries, such as frostbite.

Diagnostic Studies

A previously healthy patient with mild hypothermia and a clear history of environmental exposure may not require an extensive laboratory workup. In all other hypothermic patients, further diagnostic studies are indicated to assess for comorbid conditions as well as complications of hypothermia, including electrolyte derangements, rhabdomyolysis, and coagulation disorders. If secondary hypothermia is suspected, further testing to evaluate for infection, injury, or predisposing illness is also indicated.

Laboratory Studies

Fingerstick Glucose

As with any ED patient with altered mental status, a fingerstick glucose test should be obtained on arrival. Both hypoglycemia and hyperglycemia are associated with hypothermia.

Chemistry Panel

Sodium levels may be elevated due to dehydration, but in general, sodium, chloride, and magnesium concentrations are not significantly altered in patients with core temperatures above 25°C .²⁵ Elevated serum creatinine and blood urea nitrogen are common. Oliguric renal failure can occur secondary to dehydration, decreased cardiac output, or rhabdomyolysis. One case series of 79 patients with moderate or severe hypothermia found that 46% had acute kidney injury, with urine studies suggesting prerenal etiology. Of those with kidney injury, 97% had full recovery with rewarming and fluid therapy, and none required dialysis.²⁶

Rhabdomyolysis is frequently seen in hypothermia, and a creatine kinase level should be obtained in these individuals. Hyperkalemia can be seen as a result of acute renal failure or rhabdomyolysis. Electrocardiogram (ECG) changes associated with

hyperkalemia are blunted in hypothermia, so one should maintain a high suspicion even with a nondiagnostic ECG.²⁷

Lactate is often elevated due to hypoperfusion and decreased clearance. This can be trended to ensure it is clearing with rewarming and resuscitation. If not, secondary processes should be considered. Hepatic impairment and elevation of serum liver enzymes may occur due to decreased cardiac output and cellular damage. Hypothermia is also associated with pancreatitis.

Complete Blood Count

The hematocrit increases 2% for every 1°C drop in core temperature. A low or low-normal hematocrit in moderate to severe hypothermia should raise concern for baseline anemia or acute blood loss. In mild hypothermia, a leukocytosis may be present due to leukocyte demargination secondary to shivering. Thrombocytopenia and leukopenia can also be present in hypothermic individuals due to splenic and hepatic sequestration; this reverses with rewarming.²⁸

Coagulation Studies

Cold-induced coagulopathy is a known complication of hypothermia, but this is not usually reflected in coagulation studies, as the tests are run after blood is warmed to 37°C . In vitro animal studies suggest this coagulopathy is due to temperature-dependent enzyme reactions in the coagulation cascade and not depletion of circulating clotting factors. Because of this, the sole treatment is rewarming. Administering clotting factors does not improve outcome.²⁹

Fibrinogen should also be checked, as disseminated intravascular coagulation can also occur in moderate and severe hypothermia.

Blood Gases

Hypothermia can result in metabolic acidosis and/or respiratory alkalosis. The pH, partial pressure of carbon dioxide (PCO_2) and partial pressure of oxygen (PO_2) of blood samples vary with temperature, and blood gas analyzers warm blood to 37°C prior to analysis. However, because the ideal ABG values of a hypothermic patient are not known, expert opinion currently does not recommend adjusting ABGs for patient temperature.

Other Laboratory Testing

Blood alcohol level should be obtained if alcohol use is suspected. A urine toxicology screen can be helpful if altered mental status persists despite rewarming. If a patient fails to rewarm despite aggressive treatment, or if there is not a clear environmental exposure, the workup should be broadened to evaluate for secondary causes of hypothermia, including hypothyroidism, adrenal insufficiency, or sepsis.

Imaging Studies

Plain Films

A chest x-ray should be obtained to evaluate for aspiration pneumonia or pulmonary edema, with extra care to avoid significant jostling while obtaining this test. Lateral cervical spine films and pelvis films can be obtained in cases of suspected trauma, as the emergency clinician deems appropriate.

Ultrasound

Bedside ultrasound can be extremely helpful in assessing the hemodynamics of a hypothermic patient. In patients with severe hypothermia, bedside cardiac ultrasound can be helpful in confirming cardiac activity, as these patients often have pulses that are difficult to palpate. Cardiac ultrasound in conjunction with viewing the inferior vena cava gives valuable information regarding the patient's volume status. Thoracic ultrasound can also be used to assess for B lines suggestive of pulmonary edema. If there is suspected trauma or concern for necrotizing intra-abdominal process, an E-FAST (extended focused assessment with sonography in trauma) examination should be completed to evaluate for intraperitoneal free fluid.

Computed Tomography

Use of computed tomography (CT) in hypothermic patients is guided by clinical presentation. A head CT should be obtained in patients whose mental status is not consistent with that expected at measured core temperature or whose mental status does not clear with rewarming.

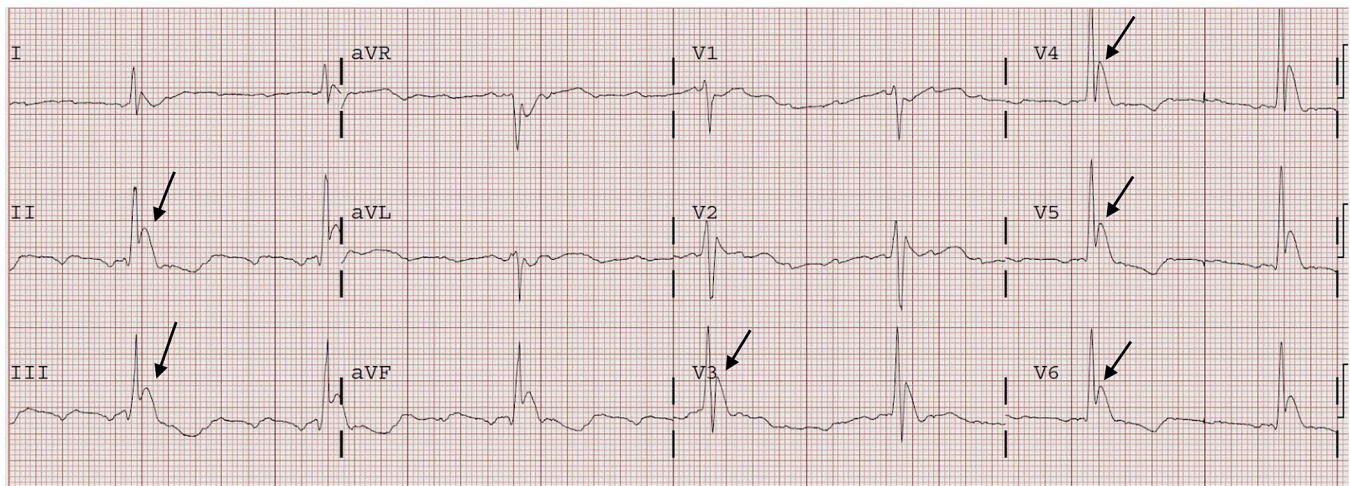
Other Diagnostic Studies

Electrocardiography

J waves, also called Osborn waves, are a well-known ECG abnormality in hypothermic patients. J waves manifest as positive deflection at the termination of the QRS complex with associated J-point elevation. (See Figure 1). They are generally present when core temperature is below 32°C, and their size is inversely related to core temperature.²⁷ Multiple observational studies, including a total of 150 patients with accidental hypothermia, showed that J waves were present in all patients whose body temperature was below 30°C.³⁰ J waves are expected to get smaller with rewarming, but they can persist even after normothermia is achieved. Although they are most commonly associated with hypothermia, J waves have been described in patients with subarachnoid hemorrhage, acute cardiac ischemia, and in normothermic patients.

In mild hypothermia, sinus rhythm predominates. In moderate hypothermia, atrial fibrillation with slow ventricular response becomes the most common rhythm, but sinus bradycardia, atrial re-entrant rhythms, and junctional rhythms can also be seen. Myocardial irritability may manifest with ectopic ventricular beats. As hypothermia becomes more severe, the risk of ventricular fibrillation and asystole increases. In moderate and severe hypothermia, slowing of the myocardial conduction, depolarization, and repolarization can result in PR prolongation, atrioventricular block, QRS widening and QTc prolongation.

Figure 1. Electrocardiogram Of A Hypothermic Patient With Prominent J Waves (Osborn Waves)



Arrows point to J waves (Osborn waves).

Image reprinted with permission of Stephen W. Smith, MD. Dr. Smith's ECG Blog, <http://hqmeded-ecg.blogspot.com/>.

Treatment

A patient who is brought to the ED after being found down, cold, and without signs of life has the potential to be fully resuscitated with good neurologic recovery despite extremely low core temperatures, prolonged CPR, or unknown down time. In hypothermic patients, many of the basic principles of resuscitation remain the same.

Airway Management

Hypothermic patients who are not spontaneously breathing or are failing to protect their airway should be intubated to assist with ventilation and protect against aspiration. Although there are reports of patients sustaining ventricular fibrillation arrests around the time of endotracheal intubation,^{31,32} case series suggest that this complication is rare. In a case series, 117 of 428 hypothermic patients required intubation and no dysrhythmias or other significant complication were reported.²¹ Rarely, cold-induced trismus can complicate endotracheal intubation in severely hypothermic patients. In such patients, placement of a supraglottic airway, fiber-optic intubation, or cricothyrotomy may be necessary.

The emergency clinician should also be aware that the pharmacokinetics of medications typically used for rapid sequence intubation are altered in hypothermia. Hypothermia results in altered metabolism and a longer duration of action of anesthesia and neuromuscular blocking agents.³³⁻³⁵ Administration of these medications may impede a clinician's ability to reliably assess a patient's neurologic examination during rewarming. If anesthesia and neuromuscular blocking agents are clinically required, lower doses and longer intervals between doses are recommended.

Volume Resuscitation

Hypotension is expected in moderate and severe hypothermia. These patients are often significantly hypovolemic secondary to dehydration from cold diuresis. Rewarming also reverses the peripheral vasoconstriction seen in hypothermic patients, and rewarming shock can occur if volume is not replaced.

Multiple large-bore intravenous (IV) lines should be established, if possible. If central venous access is needed to facilitate resuscitation, a femoral site is preferred to minimize risk of the wire irritating the myocardium and precipitating a dysrhythmia during placement.

Volume resuscitation with warm IV fluids (40°-42°C) should be initiated. Normal saline is an appropriate choice for volume expansion. Lactated Ringer's should be avoided, as hepatic metabolism of lactate is impaired in hypothermic patients. While many of these patients will have large fluid

requirements, note that these patients may also have depressed cardiac output and are susceptible to pulmonary edema during resuscitation.

Warm IV fluids are not expected to contribute significantly to the rewarming process, but they will prevent further cooling in patients with large fluid resuscitation requirements. If a fluid warmer is not available, 1 liter of normal saline can be placed in a conventional microwave oven for 2.5 minutes to warm the saline to 40°C. Fluids containing dextrose should not be warmed in this manner, as glucose caramelizes at 60°C. Fluids in glass bottles and blood products are also not safe to be warmed with this method.³⁶

Basic And Advanced Cardiac Life Support

A hypothermic patient often has a slow, weak, and irregular pulse that is difficult to detect. Cardiac ultrasound and cardiac monitoring can be used as adjuncts to identify organized cardiac activity. If none is detected, initiate CPR.

A definitive, evidence-based approach to hypothermic patients in cardiac arrest has not yet been established. Conventional wisdom suggests that physiologic changes associated with hypothermia alter cardiac response to typical BLS/ACLS therapies, including cardiac pacing, defibrillation, and administration of vasopressors and antiarrhythmics. Additionally, there is a theoretical risk of medications accumulating to toxic levels because of changes to hepatic metabolism. The 2010 American Heart Association guidelines on cardiac arrest in hypothermic patients do not make any specific recommendations on the use of vasopressors in hypothermic cardiac arrest, stating that the lack of human data and the relatively small size of recent animal studies do not provide enough evidence to recommend either withholding or administering vasopressors during cardiac arrest.⁹ It is reasonable to administer 1 round of vasopressors initially and recommence standard ACLS therapies when the patient's temperature reaches 30°C.^{37,38}

The timing of attempted defibrillation in patients with ventricular tachycardia and ventricular fibrillation is also uncertain. Early literature suggested that defibrillation was, generally, not successful until a patient was rewarmed to 30°C.³⁹ However, there are case reports of successful defibrillation in patients with temperatures as low as 24.2°C.⁴⁰ A study using hypothermic porcine models cooled to 30°C showed that, at this temperature, energy requirements and success rates of defibrillation of ventricular fibrillation were the same as normothermic pigs.⁴¹

Current guidelines recommend administering a single shock at maximal power for patients with ventricular tachycardia or ventricular fibrillation cardiac arrest, regardless of their initial core temperature. If this is unsuccessful, resume CPR. The

American Heart Association states it may be reasonable to repeat attempts concurrent with rewarming, but the European Resuscitation Guidelines recommend against further defibrillation until the core temperature reaches 30°C.^{8,9}

Managing Dysrhythmias

Hypothermia produces myocardial irritability and predisposes patients to dysrhythmias. Use extreme care when moving a patient, as even small movements have the potential to precipitate dysrhythmias. Dysrhythmias can also be seen during rewarming. Most dysrhythmias do not result in hemodynamic instability and resolve spontaneously with further rewarming.⁴² Significant electrolyte derangements should be corrected, if present, but no other specific interventions are generally required for atrial or junction rhythms.

Transcutaneous Pacing

The role of transcutaneous pacing is not yet known. Two case reports of successful use of transcutaneous pacing in severely hypothermic patients exist. In both cases, pacing was used to augment blood pressure in order to facilitate arteriovenous rewarming, with good outcome.⁴³

Rewarming Methods

There are many different methods available to re-warm hypothermic patients. The choice of rewarming method is dependent on a number of variables, including the severity of hypothermia, the presence of underlying illness, the presence or absence of cardiovascular instability, and the resources available. A detailed discussion of methods and indications for passive external rewarming, active external rewarming, and active internal rewarming follows.

Passive External Rewarming

Passive external rewarming is used in patients with mild hypothermia and as a supplemental means of rewarming in patients with moderate or severe hypothermia. Passive external rewarming is aimed at eliminating further loss of heat and using the body's intrinsic means to produce heat to bring the core body temperature to a normal level.

To initiate passive external rewarming, the individual should be removed from the cold stress. Wet clothing should be removed, as this leads to further heat loss. The patient should be placed in a warm and dry environment. Adequate insulation, usually with warm blankets, should be provided. If available, humidified air can also be provided. The body's intrinsic shivering mechanism can be extremely effective in rewarming, and a case report of a healthy male cooled to 31.2°C showed a 5-fold increase in heat production from shivering.¹⁵ The rewarming rate for passive external rewarming ranges

from 0.5°C to 2°C per hour.⁴⁴ If the patient fails to rewarm, this could be a sign that there is underlying infection, depleted energy reserve, or another disorder that is impeding thermoregulation.⁴⁵ If the patient fails to rewarm adequately or if cardiovascular instability is present, then some form of active rewarming should be used.

Active External Rewarming

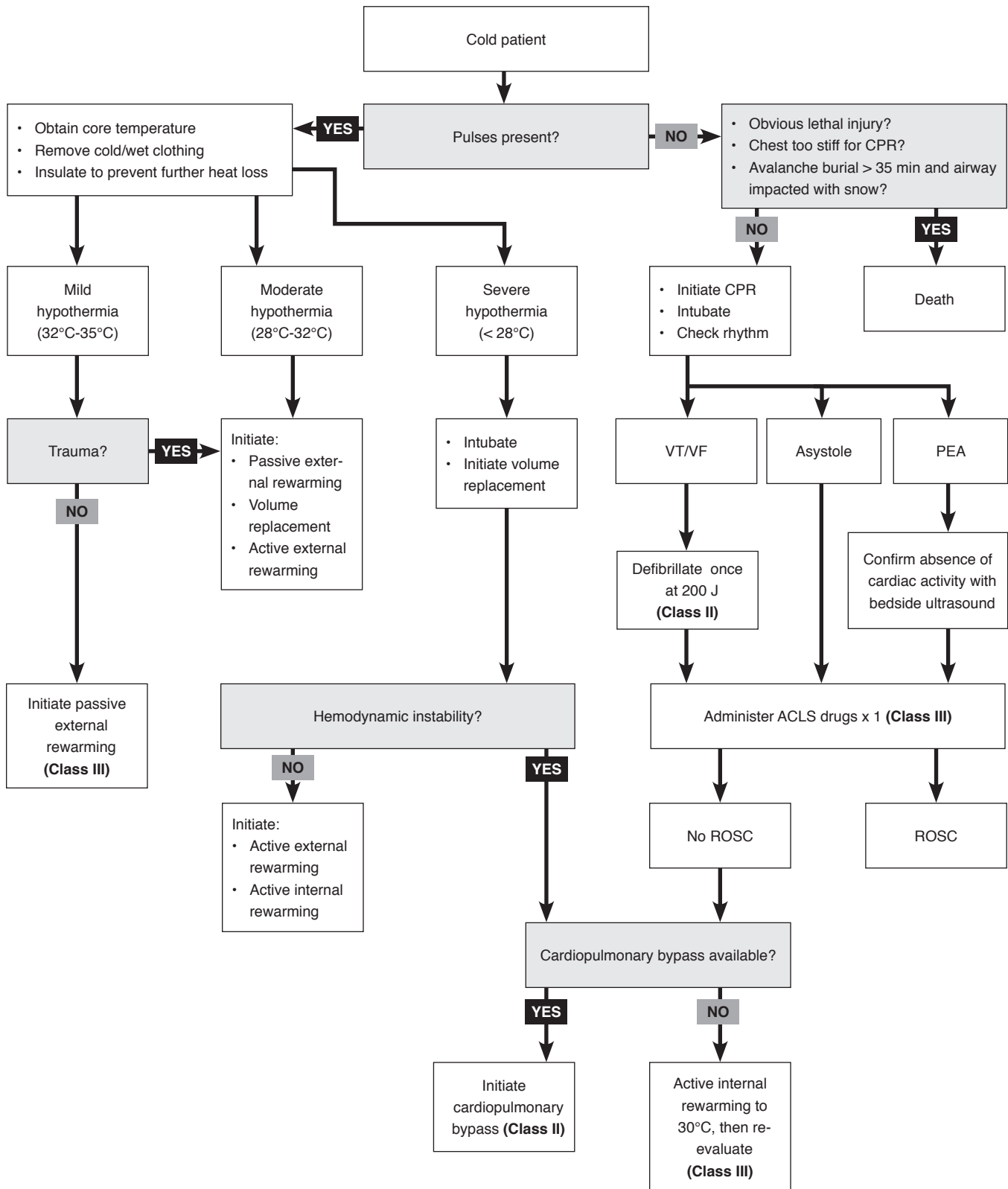
Active external rewarming uses exogenous heat applied to the body surface to rewarm. This method is appropriate in patients for whom passive rewarming has failed or for patients with moderate or severe hypothermia without cardiovascular compromise. This can be done through several different methods, including forced-air rewarming devices, external temperature control systems, warm water immersion, heating blankets, and radiant heat. Active external rewarming raises the core temperature more rapidly than passive rewarming alone.⁴⁶

Caution must be taken when using active external rewarming. Peripheral vasoconstriction makes the skin more susceptible to thermal injuries, and there have been case reports of full thickness burns from both warm chemical packs and forced air heating systems.⁴⁷ In moderately and severely hypothermic patients, the emergency clinician should also take care to rewarm a patient's trunk prior to warming the extremities. Rewarming the extremities reverses peripheral vasoconstriction and cooled, acidic blood that is pooled in the extremities returns to the core, potentially causing further drop in core temperature and pH, called *core afterdrop*. Additionally, peripheral vasodilation increases intravascular space, pulling blood away from central circulation, potentially leading to hemodynamic instability and sometimes resulting in ventricular fibrillation. This phenomenon is discussed further in the "Controversies" section, page 13.

Forced-Air Rewarming Device

An experimental human model found that a forced-air rewarming device rewarmed nonshivering humans at a rate of 2.4°C per hour compared to 0.4°C per hour for warm blankets alone.⁴⁸ Multiple randomized controlled trials have demonstrated that convective rewarming with forced air was more rapid than resistive rewarming with heated blankets.^{44,49} The literature also includes a case series of 5 severely hypothermic patients, including 2 in cardiac arrest, who underwent rewarming with forced air rewarming devices only. All 5 patients survived without neurologic sequelae.⁵⁰ In a larger cohort with 36 patients presenting with vital signs in the setting of severe hypothermia, 92% were successfully rewarmed using forced air. All 19 patients who were hemodynamically stable were rewarmed successfully; of the remaining 17 with hemodynamic instability, 14 were rewarmed successfully.⁵¹ Based on

Clinical Pathway For Managing Accidental Hypothermia



Abbreviations: ACLS, Advanced Cardiac Life Support; CPR, cardiopulmonary resuscitation; PEA, pulseless electrical activity; ROSC, return of spontaneous circulation; VF, ventricular fibrillation; VT, ventricular tachycardia.
 For classes of evidence definitions, see page 11.

these studies, forced air rewarming devices applied to a patient's core are a viable option for rewarming hemodynamically stable hypothermic patients.

External Temperature Control System

There are case reports that describe rewarming hypothermic patients with a device called Arctic Sun™ (Medivance, Inc., Arctic Sun™ Temperature Management System, Louisville, CO, USA), a system usually used to induce therapeutic hypothermia. The system circulates warm water through gel pads placed on areas of the body with large surface areas (mainly the trunk and thighs). Three case reports exist showing rewarming rates from 0.63°C to 2.5°C per hour, with 1 patient rewarmed from an initial temperature of 22°C.⁵²⁻⁵⁵ If readily available, external temperature control systems such as the Arctic Sun™ are another alternative for noninvasive active external rewarming.

Warm Water Immersion

Warm water immersion is efficacious at raising the temperature rapidly; however, the logistics of warm water immersion as well as the inability to use appropriate cardiac monitors make this an impractical option in the ED.

Active Internal Rewarming

Active internal rewarming delivers exogenous heat internally using methods ranging from minimally invasive (ie, warm IV fluids and heated inspired air), to highly invasive techniques, (ie, coronary bypass surgery and extracorporeal membrane oxygenation). As discussed earlier, warmed IV fluids do not significantly raise core temperature, but they can prevent further heat loss.

Heated Inspired Air

Humidified, heated oxygen at 42°C to 46°C provided via a face mask or endotracheal tube has been shown to raise the core temperature minimally, if at all. The true benefit of heated inspired air is likely in limiting further heat loss via the respiratory tract.

Expert opinion recommends that this method should not be the sole means of rewarming.⁵⁶

Gastric And Bladder Lavage

There is a paucity of literature to suggest that gastric or bladder lavage is helpful in rewarming a hypothermic patient. The surface area of the bladder and stomach are not thought to be large enough to produce significant changes in the core temperature, and there is a risk of aspiration with gastric lavage.

Peritoneal Lavage

The data on peritoneal lavage are limited to case reports, in which the rate of rewarming has been reported to be 2°C to 4°C per hour. There is a hypothetical benefit to rapidly rewarming the liver in order to restore its metabolic processes and aid in clearance of toxins, but this remains theoretical.⁵⁷ Peritoneal lavage can be accomplished by placing a catheter in a fashion similar to that used for a diagnostic peritoneal lavage. A bolus of 10 to 20 mL/kg of warmed normal saline (40°-42°C) is then infused into the peritoneal cavity, left for 20 minutes, and then allowed to drain. This can be repeated until rewarming is complete.¹³

Thoracic Cavity Lavage

Thoracic cavity lavage can be performed with either a closed or open technique. These methods of rewarming have not been compared, and current data are from retrospective case series and reports.^{58,59}

To perform closed thoracic cavity lavage, a large-bore chest tube is placed in the second to third intercostal space at the midclavicular line. On the same side of the hemithorax, a second chest tube is placed in the fifth to sixth intercostal space in the midaxillary line. Warm fluid (40°-42°C) is infused into the anterior chest tube and then drained through the posterior chest tube. According to various case reports, the rate of rewarming has ranged from 3°C to 6°C. When the patient is adequately rewarmed, the anterior chest tube can be removed and the posterior chest tube is left in place for continued drainage.

Class Of Evidence Definitions

Each action in the clinical pathways section of *Emergency Medicine Practice* receives a score based on the following definitions.

Class I

- Always acceptable, safe
- Definitely useful
- Proven in both efficacy and effectiveness

Level of Evidence:

- One or more large prospective studies are present (with rare exceptions)
- High-quality meta-analyses
- Study results consistently positive and compelling

Class II

- Safe, acceptable
- Probably useful

Level of Evidence:

- Generally higher levels of evidence
- Nonrandomized or retrospective studies: historic, cohort, or case control studies
- Less robust randomized controlled trials
- Results consistently positive

Class III

- May be acceptable
- Possibly useful
- Considered optional or alternative treatments

Level of Evidence:

- Generally lower or intermediate levels of evidence
- Case series, animal studies, consensus panels
- Occasionally positive results

Indeterminate

- Continuing area of research
- No recommendations until further research

Level of Evidence:

- Evidence not available
- Higher studies in progress
- Results inconsistent, contradictory
- Results not compelling

This clinical pathway is intended to supplement, rather than substitute for, professional judgment and may be changed depending upon a patient's individual needs. Failure to comply with this pathway does not represent a breach of the standard of care.

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Though sterile saline is preferred, there have been reports of using both sterile saline and warmed tap water without a higher incidence of infection in patients in whom tap water was used. Care should be taken when placing the left-sided thoracostomy tubes, as any jostling of the heart has the potential to induce ventricular fibrillation.¹³

To perform open thoracic cavity lavage, the emergency clinician completes a left lateral thoracotomy, irrigates the mediastinum with warm fluid, and initiates internal cardiac massage. Given that this is a highly invasive procedure, this has traditionally been reserved for hypothermic patients in cardiac arrest. Mediastinal irrigation preferentially rewarms the myocardium, which leads to rapid rewarming and may lead to more rapid defibrillation in patients in cardiac arrest. A case series of 11 patients with hypothermic cardiac arrest reported a survival rate of 71% (5/7) in patients receiving ED thoracotomy with mediastinal irrigation and internal cardiac massage. Of those patients, 3 went on to have continued rewarming via cardiopulmonary bypass, and all survivors had good neurologic outcome. The 4 remaining patients seen over the study period went directly to the operating room for initiation of cardiopulmonary bypass, but none survived.³⁷ While this does not indicate superiority of open thoracic cavity lavage versus cardiopulmonary bypass, it does indicate that it is a viable alternate rewarming method for hypothermic patients in cardiac arrest, particularly if cardiopulmonary bypass is not available.

Endovascular Temperature Control Systems

Endovascular temperature control systems are typically used to induce therapeutic hypothermia after a cardiac arrest. These systems are inserted into the femoral vein in the fashion that a central line would be inserted. The catheter contains a closed-loop circuit through which temperature-controlled water is circulated, warming or cooling the blood as it flows around the catheter. This technique has been reported to be successful, with rewarming rates of 0.74°C to 5°C per hour.⁶⁰⁻⁶²

Extracorporeal Rewarming Techniques

Several extracorporeal rewarming techniques have been used for rewarming in cases of moderate and severe hypothermia, including hemodialysis, venovenous rewarming, continuous arteriovenous rewarming, and cardiopulmonary bypass.

Hemodialysis

There have been case reports describing the use of hemodialysis for rewarming hypothermic patients. Temporary dialysis catheters are readily available and relatively easy to place.⁶³ Warming rates are 2.15°C to 3.3°C per hour.⁶² An advantage of hemodialysis is that it can concurrently correct metabolic

derangements associated with severe hypothermia that can occur during rewarming.

Extracorporeal Venovenous Rewarming

Extracorporeal venovenous rewarming requires a central venous catheter and a second large peripheral or central IV catheter. Blood is removed by the central venous catheter, runs through the external rewarming circuit, and is returned via the second line. Rewarming occurs at a rate of 2°C to 3°C per hour, which is similar to that of hemodialysis.

Continuous Arteriovenous Rewarming

In continuous arteriovenous rewarming, a femoral arterial catheter and a contralateral femoral central venous catheter are placed. The patient's blood pressure propels blood through an external warming system, effectively creating an arteriovenous fistula. A systolic blood pressure of 60 mm Hg is required.⁶⁴ Rewarming occurs at a rate of 3°C to 4°C per hour. This system does not require systemic anticoagulation, making it a good choice for patients with concurrent trauma.

Cardiopulmonary Bypass And Venoarterial Extracorporeal Membrane Oxygenation

Cardiopulmonary bypass (CPB) and venoarterial extracorporeal membrane oxygenation (VA-ECMO) are generally reserved for hypothermic patients in cardiac arrest, or patients who have significant hemodynamic instability, severe rhabdomyolysis with hyperkalemia, frozen limbs, or have failed to rewarm with alternate rewarming techniques. Rewarming rates have been reported from 7°C to 10°C per hour.⁶⁵ CPB and VA-ECMO offer circulatory support, and individuals placed on CPB or VA-ECMO for rewarming have the benefit of cardiopulmonary support after return of spontaneous circulation, which is often needed, given the high rate of cardiopulmonary dysfunction after rewarming. In most cases, the need for systemic anticoagulation while using these modalities does not preclude their use in rewarming hypothermic individuals.

The degree of benefit of extracorporeal rewarming techniques as compared to standard invasive rewarming techniques is not fully known. There is a single retrospective study comparing portable and percutaneous CPB (PPCPB) and conventional rewarming methods. The study compares outcomes from the 9 years before and after the institution of PPCPB in a single tertiary care center as the standard method of rewarming patients with deep accidental hypothermia. Survival rates were significantly higher in patients treated after the institution of PPCPB for rewarming compared to conventional rewarming methods (46.7% vs 84.2%, $P < .05$, $n = 68$). The difference was especially pronounced in patients presenting in cardiac arrest (14.3% vs 88.3%, $P < .05$, $n = 13$). While there are potentially confounding variables

(namely, overall improvement in critical care practices over the 18-year duration of the study), the results are suggestive of some degree of benefit. In the same study, no direct complications of PPCPB occurred in the 38 patients rewarmed with PPCPB.⁶⁶ A systematic literature review of extracorporeal-assisted rewarming in hypothermia also suggested the relative safety of this method, reporting only 3 major complications in 247 reported cases, with a complication rate of 1.2%.⁷ While publication bias may play a role, successful applications of CPB and ECMO for other indications confirm its relative safety.

CPB and VA-ECMO are now recognized as effective and safe methods of rewarming individuals with accidental hypothermia, but these modalities are both invasive and highly resource-intensive. There are ongoing investigations to attempt to identify specific groups of patients who are likely to have good functional outcomes. Thus far, multiple reviews have shown that asphyxia prior to hypothermic arrest (as seen in most avalanche and drowning victims) is a poor prognostic factor.⁶⁷ Elevated serum potassium level is felt to be a marker of cell lysis and frequently indicates hypoxic insult prior to hypothermia. Patients with elevated serum potassium generally have worse outcomes than patients with normal potassium.⁶⁸ Presenting rhythm of asystole, advanced age, underlying illness (including infection), and elevated serum lactate may also be poor prognostic factors.⁶⁷

Other Treatment Considerations

Hypothermic patients are at high risk for cardiovascular collapse in the ED. Hemodynamic monitoring during resuscitation is paramount. Electrolytes may also fluctuate with rewarming, so electrolytes (particularly potassium) should be checked frequently.

Failure To Rewarm

If a patient fails to rewarm despite appropriate rewarming therapies, underlying medical causes should be considered, including hypoglycemia, infection, profound hypothyroidism, and adrenal insufficiency. One prospective observational trial of hypothermic patients in the ED showed that rewarming at a rate $< 0.67^{\circ}\text{C}$ per hour was a strong predictor of infection. These individuals should be empirically treated for infection.⁴⁵ Empiric treatment for adrenal insufficiency and hypothyroidism can be considered, but there are no data to support this.

Special Circumstances

Hypothermia In Trauma Patients

Hypothermia is associated with decreased survival in patients with multisystem trauma.⁶⁹ Patients with hemorrhagic shock are often acidotic and coagulopathic, leading to what is referred to as the “lethal

triad” of acidosis, coagulopathy, and hypothermia. These patients are at extremely high risk for multisystem organ failure and death.⁷⁰ A randomized prospective study of 57 trauma patients with hypothermia showed that those who underwent rapid rewarming had improved mortality. Patients who failed to rewarm had a 100% mortality.⁷¹ Another study found that the average temperature of patients with penetrating trauma on arrival to the ED was 34.8°C , suggesting that some degree of hypothermia in trauma victims is more common than previously recognized.⁷² For these reasons, care must be taken to recognize and aggressively treat hypothermia in patients with traumatic injuries.

Controversies

Core Afterdrop

There is much discussion surrounding the phenomenon of core afterdrop, which is the decrease in core temperature secondary to increasing blood flow to cold extremities. This causes the return of cold, acidic blood to central circulation, in turn causing further drop in core temperature and worsening acidosis. Peripheral vasodilation also contributes to hemodynamic instability, and all of these factors put the patient at increased risk of fatal dysrhythmias during the rewarming process. Patients with moderate-to-severe hypothermia are particularly sensitive to even a small temperature drop, and this can lead to circulatory collapse.

The etiology, severity, and clinical significance of core afterdrop have been debated. Some believe that core afterdrop is caused by active external rewarming, and, more specifically, rewarming the extremities in conjunction with the core. Others suggest that core afterdrop is inevitable regardless of rewarming method, as temperature will temporarily decrease in any object with a warm core and cool periphery, due to conductive properties.⁷³ Studies on afterdrop are conflicting, and this is an area in need of further research. In the meantime, we recommend initially limiting the movement or warming of extremities so as to limit the potential for an afterdrop effect.

Disposition

Patients with mild hypothermia who are successfully rewarmed, have no other underlying pathology, and have access to appropriate shelter can be discharged from the ED. All other hypothermic patients should be admitted to the hospital for ongoing treatment and monitoring, and many will require ICU-level care.

When determining disposition and the level of care required in the hospital, note that successful rewarming does not eliminate a hypothermic patient's risk of further morbidity and mortality. Previously

hypothermic patients remain at risk for complications, including pulmonary edema, pneumonia, cardiac dysrhythmias, post-rewarming hypotension, seizures, prolonged coma, cerebral ischemia, sepsis, acute renal and hepatic failure, pancreatitis, rhabdomyolysis, and disseminated intravascular coagulation. In a retrospective cohort study of 84 hypothermic patients, the majority of complications occurred more than 24 hours after initial presentation, and more deaths occurred after rewarming rather than during the rewarming period.⁷⁴ For these reasons, even if a patient is successfully rewarmed in the ED, all moderately and severely hypothermic patients should be admitted to the hospital for further monitoring.

Summary

Hypothermia can affect any person regardless of age, location, or time of year. Individuals at highest risk include those without adequate protection from cold exposure as well as those without the intrinsic

reserves to adequately maintain thermoregulation. Clinical presentation will vary depending on the severity of hypothermia. Knowledge of expected clinical findings is critical in helping to identify concurrent injuries and illnesses in hypothermic patients.

In treating a hypothermic patient, many of the basic principles of resuscitation are the same, but modifications to traditional BLS/ACLS algorithms are recommended by existing guidelines. There is a large volume of literature surrounding rewarming in patients with accidental hypothermia, but no definitive studies have been conducted. Generally, mild hypothermia can be treated with passive rewarming. There are multiple viable options for treating patients with moderate or severe hypothermia who are hemodynamically stable; rewarming choice ultimately depends on available resources and response to initial therapies. Cardiopulmonary bypass has had great success with rewarming and supporting critically ill hypothermic patients, including those in cardiac arrest. While these patients often require tremendous time and resources, the literature is clear

Risk Management Pitfalls For Accidental Hypothermia (Continued on page 15)

1. **“I work in Florida, not Alaska. I didn’t think I’d ever see a hypothermic patient.”**

While most cases of accidental hypothermia occur in colder climates during the winter months, hypothermia can occur anywhere, including mild climates. All emergency clinicians should have the skills to identify and treat these patients.

2. **“The nurse couldn’t get a temperature.”**

Normal thermometers only read down to 34°C. If a thermometer is not reading appropriately, it may be because the patient’s core body temperature is below that level. A low-reading thermometer should be used to obtain a core body temperature and assess for hypothermia.

3. **“I couldn’t feel a pulse, so we started CPR.”**

Pulses are extremely difficult to palpate in hypothermic patients. Additionally, initiating CPR in hypothermic patients with a perfusing rhythm runs the theoretical risk of precipitating a nonperfusing dysrhythmia that is refractory to treatment. If possible, bedside cardiac ultrasound or cardiac monitoring should be used to evaluate for organized cardiac activity. If that is not available, the emergency clinician should palpate for a pulse for a full minute before initiating CPR.

4. **“I started rewarming the patient and then admitted him to the ICU. As the patient was going upstairs, he arrested in the elevator.”**

A moderately or severely hypothermic patient’s clinical status is extremely tenuous. Dysrhythmias and cardiovascular collapse can occur at any time, often after rewarming has been initiated. Strongly consider limiting any transport within the hospital until the patient is rewarmed to 30°C to 32°C (with the clear exception of transport to the operating room for cardiopulmonary bypass). Patients who must be transported prior to rewarming will need ongoing cardiac monitoring and, ideally, should be transported in the company of the treating physician.

5. **“I put warm blankets on him and started IV fluids. I don’t know why his temperature hasn’t improved.”**

If passive external rewarming fails in mild hypothermia, turn to more aggressive rewarming measures, but also begin to investigate reasons why the patient is not rewarming as expected. Underlying infection is a common cause of slowed or failed rewarming, and individuals who fail to rewarm should be treated empirically with antibiotics.⁴⁵

on one point—incredible recoveries are possible. This fact alone makes the resuscitation of hypothermic patients a compelling part of the practice of emergency medicine.

Case Conclusions

After hearing the paramedic's story, the emergency clinician had a high suspicion for hypothermia leading to cardiac arrest. The physician reviewed contraindications to initiating resuscitative efforts with the paramedic and ultimately agreed that the paramedic should proceed with attempted resuscitation. While awaiting the patient's arrival in the ED, the physician contacted the hospital cardiovascular surgeon, as she believed this patient would likely benefit from cardiopulmonary bypass rewarming. When the medics arrived, they reported that the patient was in ventricular fibrillation when she was placed on the monitor. They attempted defibrillation at 200 Joules once, gave 1 mg of epinephrine, and continued CPR. On the patient's arrival, she was intubated without difficulty. An

esophageal temperature measured 26°C. At pulse check, cardiac ultrasound was performed, and it confirmed ongoing ventricular fibrillation. CPR was restarted, and the patient was transported to the OR for cardiopulmonary bypass. After rewarming was complete, she was weaned off cardiopulmonary bypass and she ultimately survived, with good neurologic outcome. Prior to discharge, she was discovered to be homeless, and housing and shelter resources were arranged.

The hiker in Oregon arrived to the ED with vital signs still present. Given her low Glasgow Coma Scale score, the physician intubated her for airway protection. After the intubation, an esophageal temperature was measured at 28°C. Given that she was severely hypothermic, active internal rewarming was initiated with an endovascular temperature control system that was readily available at that hospital but normally used in therapeutic hypothermia after cardiac arrest. The physician chose internal rewarming to prevent core afterdrop and out of concern that the patient would be at higher risk of having a cardiac arrest if other methods were used. The patient was admitted to the ICU, and was rewarmed over 4 hours without complica-

Risk Management Pitfalls For Accidental Hypothermia (Continued from page 14)

6. **“His pupils were fixed and dilated, so I thought he would have a bad outcome.”**
Fixed and dilated pupils can be seen at temperatures below 27°C and are expected by the time a patient reaches a core temperature of 22°C.¹⁴ While alternate causes of decreased cerebral perfusion should be considered, it is possible that this finding is due solely to hypothermia, and is not necessarily indicative of a poor neurologic outcome.
7. **“I didn't think he needed fluids because his heart rate was normal.”**
“Normal” vital signs in a hypothermic patient are, typically, not normal. In a moderately hypothermic patient, bradycardia is expected. The presence of a normal heart rate should be perceived as relative tachycardia, and an etiology should be sought and the patient treated. Hypovolemia is often present in hypothermic individuals and should be treated with warm IV fluids.
8. **“I didn't see any evidence of hyperkalemia on his ECG.”**
Typical ECG changes seen with hyperkalemia are blunted in hypothermia. Acute renal failure and rhabdomyolysis are common in hypothermic patients and can lead to severe hyperkalemia. Despite a nondiagnostic ECG, keep a high index of suspicion for hyperkalemia both on presentation and during their ED course, as potassium levels can fluctuate rapidly during rewarming.
9. **“Just after I examined the patient's extremities for frostbite, he had a ventricular fibrillation arrest.”**
Extreme care should be taken when moving and examining a patient with moderate or severe hypothermia. Movement of a patient's extremities may increase the return of cold blood to central circulation, causing a further drop in temperature and placing a patient at further risk for hemodynamic instability and cardiac arrest. While this should not prevent you from completing necessary tasks (eg, intubation), the treatment team should try to minimize any extraneous movement or jostling until a patient is rewarmed.
10. **“The patient was in asystole and didn't respond to multiple rounds of epinephrine, so we called the code.”**
The adage, “a patient is not dead until he is warm and dead” still holds true. Resuscitation of a hypothermic cardiac arrest patient should be continued until the patient is adequately rewarmed, as individuals with extremely low core temperatures who are given prolonged CPR can have good neurologic outcomes. Ventricular fibrillation may be refractory to defibrillation until a patient is sufficiently rewarmed. If a patient remains pulseless at 32°C, resuscitation efforts may then be terminated.

tions. Her course was complicated by acute kidney injury and aspiration pneumonia, but she was ultimately discharged from the hospital without neurologic sequelae.

The elderly patient in Phoenix was worked up for secondary causes of hypothermia, including infection. The workup included a CBC, chemistry panel, TSH, urinalysis, ECG, blood cultures, and a chest x-ray. Bedside ultrasound revealed a flat, collapsing inferior vena cava, moderately decreased cardiac contractility, but no B lines on thoracic ultrasound to suggest pulmonary edema. After going through his paperwork, a valid DNR/DNI (Do Not Resuscitate/Do Not Intubate) order was discovered. The patient was covered with a forced air rewarming device and given warm IV fluids. Antibiotics were ordered empirically, and his urinalysis showed significant pyuria, and nitrite and leukocyte esterase were positive. He also had acute-on-chronic kidney injury. He was admitted to the ICU. The ICU team had difficulties rewarming him, and his volume status was difficult to manage given his pre-existing cardiac and renal dysfunction. His respiratory and mental status declined, and in keeping with his wishes, he was not intubated. He expired on hospital day 3.

Time- And Cost-Effective Strategies

- The ideal rewarming technique should be determined on a case-by-case basis; the most expensive methods may not always be indicated. While it is generally accepted that CPB is the ideal method of rewarming for patients in cardiac arrest, this is not always available. If this is not available and transfer is not possible due to prolonged transport times to the closest CPB center or the severity of the patient's condition, other methods should be used, including thoracic cavity lavage, peritoneal lavage, or other active internal rewarming techniques. Elderly patients with multiple comorbidities may not be able to tolerate more-invasive therapies for accidental hypothermia. In these patients, less aggressive and, often, less costly therapies may be indicated.
- The most effective means of limiting the time and resources spent on accidental hypothermia is preventing it from occurring. At-risk populations, including the elderly, should be educated on the importance of keeping warm in the winter. Most cities have resources available for those with housing insecurity, and this information can be disseminated in locations such as food banks, community centers, and the ED. Individuals engaging in cold weather recreational activities outdoors should also be educated on appropriate clothing, survival skills, and emergency planning. Such educational programs could save tremendous amounts of healthcare dollars each year.

References

Evidence-based medicine requires a critical appraisal of the literature based upon study methodology and number of subjects. Not all references are equally robust. The findings of a large, prospective, randomized, and blinded trial should carry more weight than a case report.

To help the reader judge the strength of each reference, pertinent information about the study are included in bold type following the reference, where available. In addition, the most informative references cited in this paper, as determined by the authors, will be noted by an asterisk (*) next to the number of the reference.

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1. Severe hypothermia is defined as a temperature below:
 - a. 13.7°C
 - b. 20°C
 - c. 28°C
 - d. 30°C
2. When should prehospital providers NOT initiate resuscitation for a patient with suspected hypothermic cardiac arrest?
 - a. If the core temperature is < 13.7°C
 - b. If the chest wall is too stiff for CPR
 - c. If the pupils are fixed and dilated
 - d. All of the above
3. What location in the body is most accurate for measuring core temperature?
 - a. Upper third of the esophagus
 - b. Lower third of the esophagus
 - c. Rectum
 - d. Bladder

4. At 28°C, the heart rate is expected to be what percentage of the normothermic heart rate?
 - a. 10%
 - b. 20%
 - c. 50%
 - d. 80%

5. Hematocrit is expected to increase by what percentage for every 1°C drop in temperature?
 - a. 1%
 - b. 2%
 - c. 3%
 - d. 4%

6. Which ECG abnormality can be seen in patients with hypothermia?
 - a. Atrial fibrillation with slow ventricular response
 - b. Prolonged QT interval
 - c. J waves (Osborn waves)
 - d. All of the above

7. If a patient is in hypothermic ventricular fibrillation cardiac arrest, defibrillation at 200 J should be attempted when their temperature rises above:
 - a. 24°C
 - b. 30°C
 - c. 32°C
 - d. It should be attempted once in any patient with ventricular fibrillation, regardless of initial temperature

8. Passive external rewarming, alone, is appropriate for patients with:
 - a. Mild hypothermia
 - b. Moderate hypothermia
 - c. Severe hypothermia
 - d. Any of the above, as long as there is hemodynamic stability

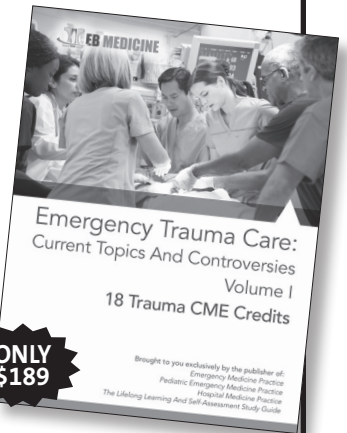
9. Which method of active internal rewarming warms the fastest?
 - a. Humidified inspired air
 - b. Warm intravenous fluids
 - c. Hemodialysis
 - d. Thoracic cavity lavage

10. Which of the following is a possible complication that can occur after a patient with accidental hypothermia is rewarmed?
 - a. Pulmonary edema
 - b. Rhabdomyolysis
 - c. Disseminated intravascular coagulation
 - d. All of the above

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