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Wilderness Medical Society Clinical Practice Guidelines for the Out-of-Hospital Evaluation and Treatment of Accidental Hypothermia: 2019 Update

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To provide guidance to clinicians, the Wilderness Medical Society convened an expert panel to develop evidence-based guidelines for the out-of-hospital evaluation and treatment of victims of accidental hypothermia. The guidelines present the main diagnostic and therapeutic modalities and provide recommendations for the management of hypothermic patients. The panel graded the recommendations based on the quality of supporting evidence and a balance between benefits and risks/burdens according to the criteria published by the American College of Chest Physicians. The guidelines also provide suggested general approaches to the evaluation and treatment of accidental hypothermia that incorporate specific recommendations. This is the 2019 update of the Wilderness Medical Society Practice Guidelines for the Out-of-Hospital Evaluation and Treatment of Accidental Hypothermia: 2014 Update.

Keywords: rewarming, resuscitation, wilderness medicine, cold, shivering

Introduction

Accidental hypothermia is defined as an unintentional drop in core temperature to 35°C or lower. Accidental hypothermia due to environmental exposure can occur during any season and in most climates, with cold and wet environments posing the greatest risk. Throughout history, it has been a disease of war and disasters, but those who work and recreate outside, especially in the wilderness, place themselves at risk for hypothermia.

In addition to occurring in wilderness environments, hypothermia is associated with urban homelessness, particularly with the use of alcohol and other intoxicating substances. Hypothermia can occur during resuscitation in emergency settings (iatrogenic hypothermia); is notably associated with trauma; and may be a feature of sepsis, diseases that decrease metabolic rate (including hypoendocrine states), and diseases that affect thermoregulation. Therapeutic hypothermia is beyond the scope of this review.

Hypothermia is the result of net heat loss from the body. Heat can be lost or gained by conduction, convection, and

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radiation and lost through evaporation. Conduction is direct transfer of heat from warmer to cooler objects that are in contact. Convection is transfer of heat to or from a gas or a liquid that is in motion. Radiation is transfer of heat in the form of electromagnetic energy between 2 objects that are visible to each other. Evaporation is loss of heat by vaporizing liquid (usually water from sweat or external sources) from the skin, clothing that is in contact with the skin, or respiration.

The human body attempts to maintain a core temperature at or near 37°C. The thermoregulatory control center in the hypothalamus receives input from central and peripheral thermal receptors. The integrated thermal signal triggers autonomic reflexes that control the initiation of cooling responses such as vasodilation or sweating (heat loss) or warming responses such as vasoconstriction (heat retention) or shivering (heat production).[1] Peripheral blood flow is also partly regulated by local skin temperature.

Humans originated in the tropics and have limited physiologic means to avoid developing hypothermia. Exercise and shivering can raise the metabolic rate to prevent hypothermia if nutritional reserves and insulation are adequate, but the benefit may be limited by environmental conditions. Prevention of hypothermia in humans mostly depends on behavior, chiefly wearing insulating clothing and using shelter.

Methods

The Wilderness Medical Society (WMS) convened an expert panel to develop evidence-based clinical guidelines for prevention and out-of-hospital diagnosis and treatment of victims of accidental hypothermia to update the previous WMS Practice Guidelines for the Out-of-Hospital Evaluation and Treatment of Accidental Hypothermia: 2014 Update.[2] Panelists were selected by the WMS based on clinical and/or research experience and generated a set of questions (Figure 1) to define the most significant areas of interest. As part of the update process, the current panel identified additional questions not previously considered. A literature search identified relevant articles with a key word search of the MEDLINE database. Keywords were hypothermia, accidental hypothermia, wilderness hypothermia, shivering, rewarming, core temperature, and resuscitation. The panel considered only peer-reviewed randomized controlled trials, observational studies, case series, and case reports related to evaluation and treatment of accidental hypothermia. Although all articles were considered, those published between 2013 and March 2019 were the focus of this review.

The panel assessed the level of evidence supporting each diagnostic and therapeutic modality. Conclusions from review articles were not used in the formulation of recommendations, but the guidelines cite review articles when necessary to provide background information.

Questions considered by the panel

FIELD ASSESSMENT

- How should the level of hypothermia be classified?
- What is the best way to measure core temperature?

PREHOSPITAL TREATMENT

- What is the best treatment for a cold patient who is not hypothermic or for a patient with mild hypothermia in the field?
- What is the safest way to handle a patient with moderate to severe hypothermia in the field?
- What is the best treatment for moderate to severe hypothermia?
- When should a hypothermic patient without signs of life be resuscitated?
- Are there specific considerations regarding hypothermia in a trauma patient?
- Are there specific considerations regarding burn prevention in an actively warmed patient?
- When should rescuers start cardiopulmonary resuscitation (CPR) on a hypothermic patient?
- When and how should a hypothermic patient be defibrillated?
- What is the best method for giving CPR to a hypothermic patient?
- What are recommendations for delayed, intermittent, and prolonged CPR?
- What is the best way to manage the airway in a severely hypothermic patient?
- What is the best way to obtain vascular access in a hypothermic patient?
- What is the best way to manage fluids in a hypothermic patient?
- What is the role of advanced life support (ALS) drugs in a hypothermic patient?
- Is there a role for transcutaneous cardiac pacing in a hypothermic patient?
- How should atrial dysrhythmias be managed during rewarming for a hypothermic patient?
- Is there a simple decision aid that can be used by any responders in the field?

TRANSPORT/TRIAGE

- How should the destination hospital be determined for a hypothermic patient?
- What is the role of extracorporeal life support in the hypothermic patient?
- How can serum potassium be used to determine if CPR should be continued on a hypothermic patient?

Figure 1. Questions considered by the authors for the development of these practice guidelines.

The panel used a consensus approach to develop recommendations regarding each evaluation technique and intervention and its role in management. The panel graded each recommendation based on the quality of supporting evidence and balance between the benefits and risks/burdens, according to the criteria of the American College of Chest Physicians (see online Supplementary Table).[3]

PATHOPHYSIOLOGY OF HYPOTHERMIA

The primary physiologic effects of tissue cooling are decreased resting metabolism and inhibition of central and peripheral neurologic function. During the initial stages of cooling of a neurologically intact victim, secondary responses to skin cooling predominate.[1] Shivering thermogenesis, triggered by skin cooling, results in increased metabolism due to the work of shivering and increased ventilation, cardiac output, and mean arterial pressure.[4] These physiologic parameters initially increase as core temperature decreases to approximately 32°C. The parameters then decrease with a further drop in core temperature.[1] Shivering ceases at and below a core temperature of approximately 30°C.[5] Once this occurs, metabolism decreases with further decreases in core temperature.

Clinical manifestations of accidental hypothermia relate predominantly to cerebral and cardiorespiratory effects. Brain activity begins to decline at a core temperature of approximately 33 to 34°C and continues to decline with further cooling.[6,7] Cooling of the brain leads to irritability, confusion, apathy, poor decision making, lethargy, somnolence, and eventually coma. Brain cooling decreases cerebral oxygen requirements.[8] This provides temporary protection during anoxic conditions such as cold-induced cardiac standstill and cold-water drowning. Cold stress reduces circulating blood volume due a combination of cold-induced diuresis, extravascular plasma shift, and inadequate fluid intake.[9] As the heart cools below 30°C, cardiac output decreases markedly, and bradycardia usually occurs. Abnormalities in electrical conduction lead to dysrhythmias such as premature atrial and ventricular contractions, atrial fibrillation, and ventricular fibrillation (VF).[10] Below 28°C, the heart is susceptible to VF, which can be triggered by acidosis, hypocarbia, hypoxia, or movement.[1] Decreased ventilatory response to carbon dioxide leads to hypoventilation and respiratory acidosis.[11]

FIELD ASSESSMENT

Classification of hypothermia

Most guidelines use a standard classification of hypothermia based on core temperature. Hypothermia is classified as mild at 35 to 32°C; moderate at 32 to 28°C; or severe at <28°C.[12–14] Some experts advocate a further category, profound hypothermia, at <24°C[12] or <20°C.[1] The chance of survival appears to be much lower in this range, probably because of a high likelihood of cardiac arrest. In cases of hypothermia secondary to cold water immersion, loss of airway protection and drowning may also contribute to causes of death. Although core temperature is used to classify hypothermia, individual variation to core temperature is wide, as is true of other physiologic parameters. Measuring core temperature is not always feasible in the out-of-hospital environment.[15]

Factors to guide treatment

The standard classification of hypothermia by core temperature correlates with the status of the thermoregulatory system. From 35 to 32°C (mild hypothermia) thermoregulatory shivering control is functional and increases as core temperature decreases.[16] With further cooling, shivering generally becomes less effective, although it can still be strong at 31°C.[5] Below 32°C (moderate hypothermia), thermoregulation becomes less effective and rewarming is possible only with addition of exogenous heat. As the core temperature decreases below 32°C, level of consciousness decreases. Below 28°C (profound/severe hypothermia), most patients are unconscious and not shivering, and the risk of VF or asystole is high.[17]

Recommendation. The key factors guiding hypothermia treatment are level of consciousness, alertness, shivering intensity, physical performance, and cardiovascular stability, which is based on blood pressure and cardiac rhythm (Figure 2). Core temperature can provide additional helpful information, but it is difficult to accurately obtain in the field, and the panel recommends that this should not be the sole basis for treatment (**Evidence grade:** 1C).

Simplified decision aid for field use

We have developed a simplified “Cold Card”[18] (Figure 3) corresponding to the more technical flowchart in Figure 2.

Recommendation. It is the recommendation of the working group that this decision aid be considered to facilitate evaluation and treatment of accidental hypothermia in the out-of-hospital setting for responders with varying levels of medical training.

Some patients are cold, but not hypothermic

Patients can be cold and shivering, but not hypothermic. Shivering is triggered by skin cooling as a mechanism for preventing hypothermia. A shivering patient with a core temperature >35°C is cold-stressed, but not hypothermic. If temperature measurement is not possible, clinical judgment may be helpful to distinguish whether a patient is

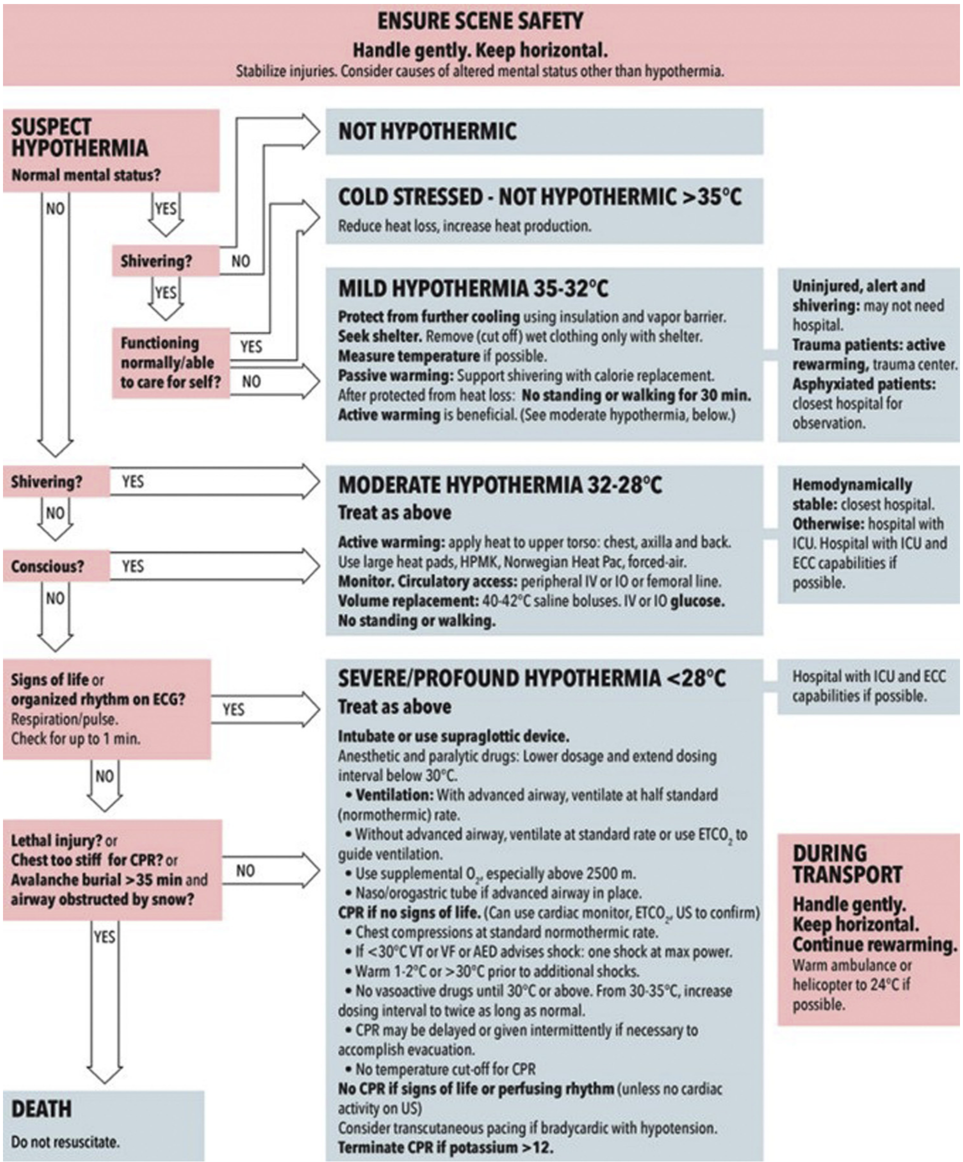


Figure 2. Recommendations for out-of-hospital evaluation and treatment of accidental hypothermia. *Abbreviations:* AED = automatic external defibrillator, CPR = cardiopulmonary resuscitation, ECC = extracorporeal circulation, ECG = electrocardiogram, $ETCO_2$ = end-tidal carbon dioxide, HPMK = Hypothermia Prevention Management Kit, ICU = intensive care unit, IV = intravenous, IO = intraosseous, O_2 = oxygen, PEA = pulseless electrical activity, US = ultrasound, VT = ventricular tachycardia, VF = ventricular fibrillation. From Zafren et al.[2] Reprinted with permission from the Wilderness Medical Society. ©2014 Wilderness Medical Society.

hypothermic or cold-stressed. For example, a patient who was not cold before being briefly immersed in cold water may be shivering but will not be hypothermic (Figures 2 and 3). Many alert, shivering patients who are well nourished and exhausted are not hypothermic.

Recommendation. It is the recommendation of the panel that a patient who is shivering but able to function well and care for him- or herself be closely observed because this patient is unlikely to be hypothermic. A patient who is shivering, becoming incapacitated, and having difficulty caring for him- or herself is likely to be hypothermic. If there is any doubt, assume that the patient is hypothermic and treat accordingly.

Alternate classification of hypothermia

The American Heart Association (AHA) 2010 Guidelines propose an alternate classification of hypothermia: mild (>34°C); moderate (34 to 30°C); and severe (<30°C).[19] Defibrillation is less likely to be successful at temperature below 30°C than above 30°C.

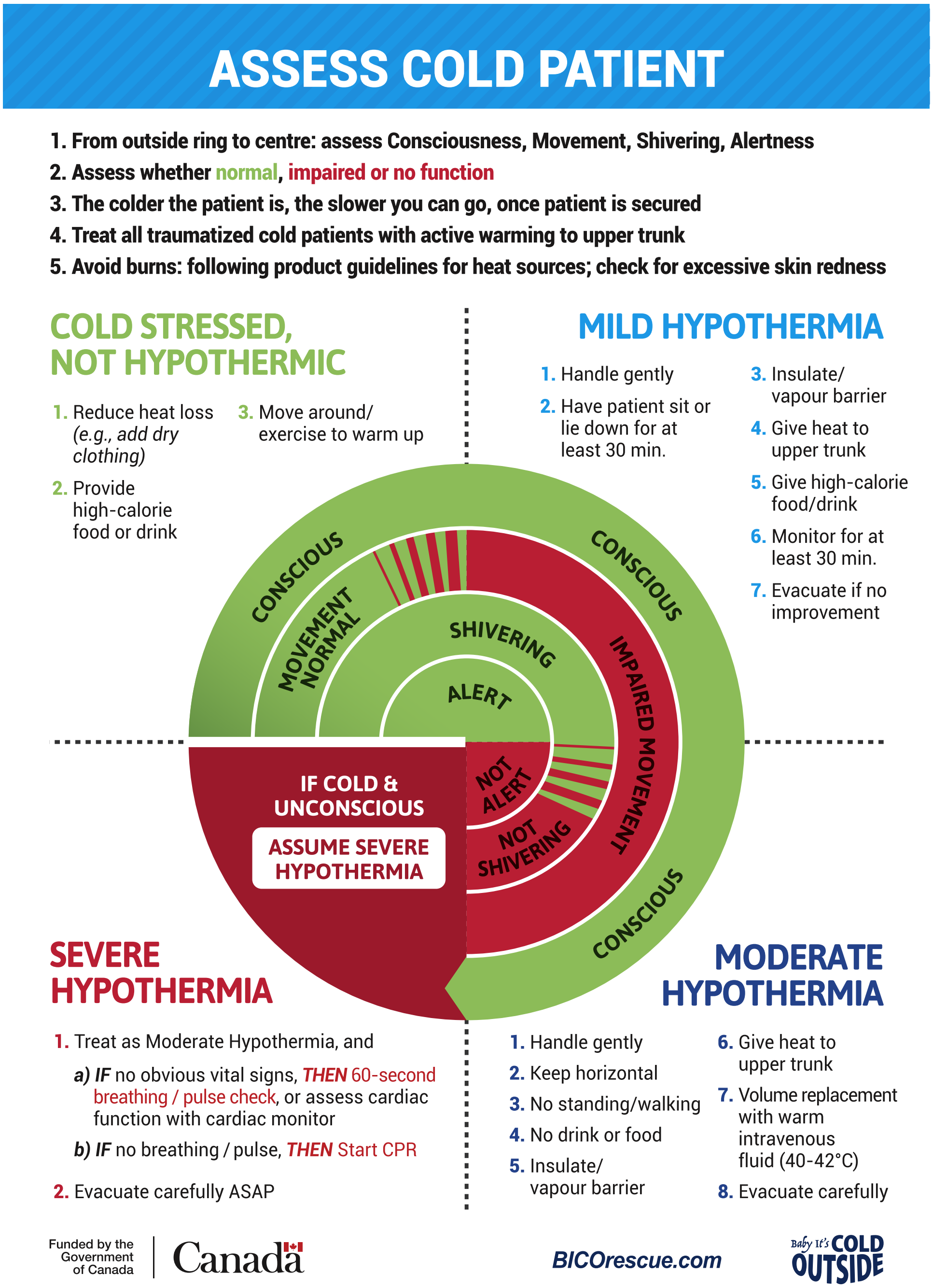


Figure 3. (A) Front of cold card — "assess cold patient". (B) Back of cold card — "care for cold patient." From Giesbrecht.[18] Reprinted with permission from the Wilderness Medical Society. ©2018 Wilderness Medical Society

Recommendation. The panel recommends that the AHA scheme should not be used as the standard classification for out-of-hospital treatment of hypothermia because it changes the widely accepted definition of hypothermia and emphasizes response to defibrillation rather than physiologic changes.

Field classification of hypothermia: the "Swiss" system

The "Swiss" hypothermia classification was developed to help rescuers estimate core temperature by observing clinical signs.[12] Because individuals have variability in response to cold, estimating core temperature on the basis

CARE FOR COLD PATIENT

SUGGESTED SUPPLIES FOR SEARCH/RESPONSE TEAMS IN COLD ENVIRONMENTS:

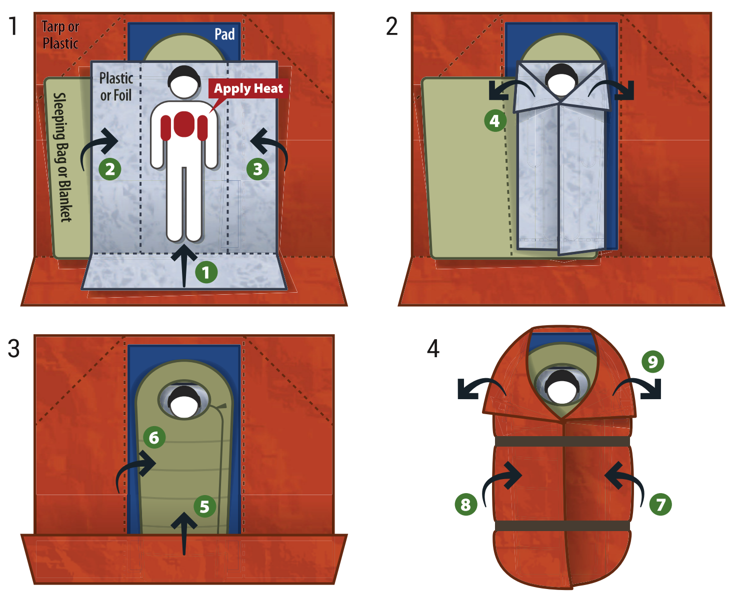
- **1** - Tarp or plastic sheet for vapour barrier outside sleeping bag
- **1** - Insulated ground pad
- **1** - Hooded sleeping bag (or equivalent)
- **1** - Plastic or foil sheet (2 x 3 m) for vapour barrier placed inside sleeping bag
- **1** - Source of heat ***for each team member*** *(e.g., chemical heating pads, or warm water in a bottle or hydration bladder),* or ***each team*** *(e.g., charcoal heater, chemical / electrical heating blanket, or military style Hypothermia Prevention and Management Kit [HPMK])*

INSTRUCTIONS FOR HYPOTHERMIA WRAP "The Burrito"

1. Dry or damp clothing: *Leave clothing on*

2. Very wet clothing:
- ***IF*** Shelter / Transport is ***less than*** 30 minutes away, ***THEN*** *Wrap immediately*
- ***IF*** Shelter / Transport is ***more than*** 30 minutes away, ***THEN*** *Protect patient from environment, remove wet clothing and wrap*

3. Avoid burns: follow product instructions; place thin material between heat and skin; check hourly for excess redness



Sources: BICOrescue.com; Zafren, Giesbrecht, Danzl et al. Wilderness Environ Med. 2014, 25:S66-85.

Figure 3 (*continued*).

of clinical signs is only an approximation. The stages of the "Swiss" hypothermia (abbreviated "HT") grading system with descriptions and estimated core temperature are as follows:

- HT I—clear consciousness with shivering: 35 to 32°C
- HT II—impaired consciousness without shivering: 32 to 28°C
- HT III—unconscious: 28 to 24°C
- HT IV—apparent death: 24 to 13.7°C
- HT V—death due to irreversible hypothermia: <13.7°C? (<9°C?)[12]

A limitation of this system is that individuals vary in physiologic response to hypothermia. Shivering may be maximal at 32 to 33°C but may continue at 31°C and may not cease until core temperature drops to approximately 30°C. A shivering patient with impaired consciousness should be treated for moderate, not mild, hypothermia. Temperature ranges for hypothermia stages should not be considered absolute but rather correlated with clinical observations. An analysis of reported cases of hypothermia revealed clinically significant temperature overlap with respect to hypothermia staging. The lowest recorded temperature was 28.1°C for HT I, 22°C for HT II, and 19.3°C for HT III.[20] It is advised that rescuers focus on the entire clinical picture rather than just shivering. Many case reports describe hypothermic patients with vital signs who had core temperatures below 24°C.[21–25] Individuals with core temperatures below 24°C are very susceptible to VF. Although the Swiss HT system can help guide rescuers in certain situations, we prefer to use the terms mild, moderate, severe, and profound hypothermia.

Recommendation. Rescuers should classify hypothermia as mild, moderate, severe, and profound on the basis of clinical observations, remembering that shivering can occur below 32°C, usually with altered mental status, and that patients can have detectable vital signs with core temperatures below 24°C. Furthermore, rescuers should be aware of core temperature overlap between classification categories[20,25] (**Evidence grade:** 1C).

Associated conditions complicating the field classification of hypothermia

In addition to hypothermia, many conditions can cause altered mental status and decreased level of consciousness. Conditions such as sepsis and severe trauma can decrease physiologic reserves and may decrease or abolish shivering.[26] Many drugs and medications[27] suppress shivering.[28]

Recommendation. Clinicians should consider causes other than hypothermia to explain altered mental status or lack of shivering that do not correlate with the measured core temperature or are associated with a history of minimal cold exposure (**Evidence grade:** 1B).

MEASUREMENT OF CORE TEMPERATURE

Esophageal temperature

The most accurate minimally invasive method of measuring core temperature is esophageal temperature, with the probe inserted into the lower third of the esophagus.[29] The degree of accuracy afforded by esophageal temperature monitoring is helpful to guide treatment of patients with moderate or severe hypothermia. Placement of an esophageal probe via the pharynx may cause vomiting and aspiration. The airway must be protected with an endotracheal tube or supraglottic device that allows passage of a gastric tube before placement of an esophageal probe. Heated humidified oxygen does not significantly raise the temperature measured by a properly inserted esophageal probe.[30–32] If the esophageal probe is not inserted into the lower third of the esophagus, an average of 24 cm below the larynx in adults,[1] use of heated humidified oxygen may result in a falsely elevated esophageal temperature. Esophageal probes that do not have markings can be measured visually against the patient and marked to ensure the correct depth of insertion. Field conditions will rarely allow for placement of an esophageal probe; however, transporting air or ground medical services that have this capacity should place a probe as soon as possible.

Recommendation. If available, an esophageal temperature probe should be placed in a patient whose airway has been protected and secured. Esophageal temperature is the preferred method of core temperature measurement (**Evidence grade:** 1C).

Epitympanic temperature

Epitympanic (ear canal) temperature, measured using a soft probe with a thermistor in proximity to the tympanic membrane, reflects carotid artery temperature.[33] Epitympanic thermometers should not be confused with the more common and much less accurate infrared “tympanic” thermometers. In patients with adequate cardiac output, epitympanic temperature reflects core temperature. Epitympanic temperature can be lower than esophageal temperature during low flow (decreased cardiac output) or no-flow (cardiac arrest) states.[28] In out-of-hospital settings care must be taken to insulate the ear canal from the environment. With cold ambient temperature, epitympanic temperature may be falsely low, especially if the external auditory canal is blocked by cerumen, filled with snow, or not adequately sealed and properly covered with an isolating “cap.”[33] Epitympanic temperature is much lower than esophageal temperature during initial cooling of the head in normothermic subjects. After 10 min of isolated head cooling, the mean difference between epitympanic and esophageal temperatures is about 1 to 2°C.[34] Epitympanic thermometers for use in the operating room are not suitable for field use; they are not designed for use in cold environments.

Recommendation. Use an epitympanic thermometer designed for field conditions with an isolating ear cap in a patient whose airway has not been secured by endotracheal intubation or a supraglottic airway, or in a patient with a secured airway if an esophageal probe is not available

(**Evidence grade:** 1C). Infrared tympanic thermometers should never be used to measure core temperature in a hypothermic patient[15] (**Evidence grade:** 1A).

Rectal temperature in the field

The use of rectal thermometers is not advisable before the patient has been removed from the cold environment because the patient must be further exposed, increasing heat loss and potentially worsening hypothermia.

Recommendation. Rectal temperature measurement should not be used unless the patient is in a warm environment (**Evidence grade:** 1C).

Rectal and bladder temperatures during rewarming

Rectal and bladder temperatures lag behind core temperature changes by as much as an hour and can give the false impression that the patient is still cooling.[4,9,35] Rectal and bladder temperature overestimate heart temperature during cooling and underestimate heart temperature during rewarming.

Recommendation. Monitor rectal or bladder temperature during rewarming of an unconscious patient only if an esophageal or epitympanic probe is not available. If rectal or bladder temperature is used for monitoring during rewarming, allow for inaccuracy due to the time lag behind core temperature changes (**Evidence grade:** 1A).

Oral temperature

Oral temperatures are useful only to rule out hypothermia. Nonelectronic thermometers are typically unable to measure temperatures below 35.6°C. If mercury or alcohol thermometers are used to diagnose hypothermia, they must be special "low reading" thermometers.[1]

Recommendation. Oral temperature measurement with a thermometer that cannot read below 35°C should not be used to diagnose hypothermia (**Evidence grade:** 1A).

"*Temporal artery*" *thermometer*

"Temporal artery" thermometers, used on the skin surface, do not provide accurate temperature measurements in hypothermia.[36]

Recommendation. Do not use a temporal artery thermometer in a possibly hypothermic patient (**Evidence grade:** 1C).

Zero-heat flux thermometer

A noninvasive heat flux or "double sensor" thermometer is currently under development.[37] This technology, which combines a skin temperature sensor with a heat flux sensor, correlates well with esophageal temperature in operative and intensive care unit settings.[38,39]

Recommendation. Because this technology has not been validated in field settings, no recommendation can be made at this time.

OUT-OF-HOSPITAL TREATMENT

Safety of the rescuers

Rescuer safety is the first priority during rescue. The scene may be unsafe to enter, or the safety officer in a rescue may allow only brief entry. Unless there are obvious fatal injuries, rescuers might need to move the patient to a safe place before deciding to resuscitate.

Recommendation. The decision to rescue or resuscitate a patient can only be made after the scene is secure and safe for the rescuers to enter and make an evaluation (**Evidence grade:** 1A). After rescuer safety has been assured, the priorities for out-of-hospital treatment of a hypothermic patient who is not in cardiac arrest are to avoid causing cardiovascular collapse during rescue, prevent further decrease in core temperature (afterdrop), and rewarm the patient in a safe manner. If a hypothermic patient is in cardiac arrest, rescuers should, if indicated, initiate resuscitation.

Core temperature afterdrop

Core temperature afterdrop refers to continued core cooling after removal from a cold environment. Afterdrop is caused by a combination of conductive heat loss from the warmer core to cooler peripheral tissue and convective heat loss from blood due to increased flow to cooler tissue and subsequent return to the central circulation and heart.[40–42] The convective component transfers more heat, and, unlike the conductive component, is affected by the method of rewarming. In a hypothermia victim, peripheral tissue is colder than the heart. Therefore, any action that increases blood flow to cold peripheral tissue (eg, hoisting or holding victim in a vertical position, allowing the victim to stand or walk, active or passive limb movement, immersion in warm water) will increase the volume of cold blood returning to the heart. This increases cardiac work and further decreases core temperature.

Afterdrop may be clinically important in victims who are at the threshold of moderate to severe hypothermia because they are susceptible to cardiovascular instability with a small further drop in core (heart) temperature. Afterdrop of as much as 5 to 6°C has been reported in hypothermic patients.[21,42–44] Therefore, care should be taken to prevent increased blood flow to the limbs during and after rescue.

Circumrescue collapse

Circumrescue collapse refers to light-headedness, collapse, syncope, or sudden death occurring in victims of cold-water immersion just before, during, or after rescue and removal from water.[45] Circumrescue collapse can be caused by mental relaxation and decreased catecholamine output causing life-threatening hypotension or by sudden onset of cardiac dysrhythmia, likely VF.[4]

The act of removing a victim from water decreases hydrostatic pressure,[4] which is normally greatest around the legs. Removing hydrostatic pressure allows blood to pool in dependent areas, causing decreased blood return with resultant hypotension or cardiovascular collapse. A cold heart may not be able to compensate for decreasing blood pressure by increasing cardiac output. Blood that does return from dependent areas will be cooled and will contribute to core temperature afterdrop. Afterdrop is increased if the victim has to perform work to assist in rescue (eg, having to climb a ladder onto a boat).[45,46] Mechanical stimulation of the heart during rescue and extrication—combined with hypotension, afterdrop, and acidosis—may precipitate fatal dysrhythmias.[47]

When rescue is imminent, mental relaxation in conscious patients may be associated with decreased catecholamine release, causing decreased blood pressure with loss of consciousness and subsequent drowning.[47] Circumrescue collapse has also been described in terrestrial rescue situations.[23,48]

Handling of a hypothermic patient during rescue

Keeping the patient in a horizontal position mitigates the effects of decreased hydrostatic pressure during rescue.[45] Avoiding physical effort protects against afterdrop.[46] Continued mental stimulus may help maintain catecholamine stimulus.

Recommendation. Rescuers should keep a hypothermic patient horizontal, especially during rescue from water or a crevasse (**Evidence grade:** 1B) and should limit physical effort by the patient during rescue (**Evidence grade:** 1B). A conscious patient should be encouraged to be attentive and focus on survival (**Evidence grade:** 1C).

Gentle handling to prevent ventricular fibrillation

Hypothermia lowers the threshold for VF, especially at core temperatures below 28°C.[1] Movement or significant warming of the extremities, as with warm water immersion, increases blood flow to colder tissues. Blood flows to the periphery, is cooled, and has the potential to cool the heart upon return to the core, increasing the risk of VF.[17,49,50] Additional blood return may also cause increased load on a heart that is already pumping ineffectively.

Recommendation. Handle a hypothermic patient gently and continue to keep the patient horizontal (**Evidence grade:** 1B). Avoid any disturbance, especially movement of the extremities that might precipitate VF (**Evidence grade:** 1B). In an effort to minimize movement, clothes should be cut off of a patient once in a warm environment (**Evidence grade:** 1B).

Protection from further heat loss

After rescue, the next priority for care of a hypothermic patient in the out-of-hospital setting is to maintain core temperature by preventing further heat loss.

Insulation protects from heat loss. Insulating materials include extra clothing, blankets, quilts, sleeping bags, insulated pads, and bubble wrap.[51,52] A sleeping bag should not be used like a blanket; rather the patient should be placed inside, and the enclosure should be completely zipped up. Multiple sleeping bags, if available, can be placed within each other to create a multilayered enclosure. Any available insulation (eg, spare parkas) should be incorporated within or outside the enclosure in such a way as to not compromise loft. Bubble wrap is an effective vapor barrier, but it provides less insulation than the other materials.[51,52] A large amount of heat can be lost to the ground by conduction.[53] Significant heat can also be lost from the head and neck due to necessary exposure of the face to allow breathing.[53,54]

Vapor barriers protect against convective and evaporative cooling (substantially reducing heat loss) and importantly also keep the insulation dry and more effective. Barriers can be made from bubble wrap, tarps, sheets of plastic, reflective blankets, or garbage bags with a hole cut out for the face. The vapor barrier(s) may be placed inside the insulation (to keep the insulation dry if the patient is packaged wet) and/or outside the insulation to protect the insulation from a wet environment.[52,55]

Extra insulation can compensate for the absence of a windproof layer or vapor barrier.[55] A combined method using 2 vapor barriers (1 against the patient and 1 outside the insulating layers) will protect the insulation from becoming wet from all sources.[52]

Recommendations. Protect from further cooling by using insulation and vapor barriers until the patient has reached a warm environment, such as the warmed interior of an ambulance. Remove wet clothes, preferably by cutting them off, only when the patient has been protected from the cold (**Evidence grade:** 1C). Insulate the patient from the ground (eg, with sleeping pads) to protect from conductive heat loss. Minimize heat loss from the head and neck by covering these areas as effectively as possible (eg, toque, watch cap, hood, jacket) (**Evidence grade:** 1C).

Protection from windy conditions

In windy conditions, a windproof layer, ideally a vapor barrier, provides substantial protection from convective heat loss.[51]

Recommendation. An outer windproof layer should be used to protect the patient from wind and especially from rotor wash when loading or unloading from a helicopter. If possible, add a second vapor barrier against the victim to protect the insulating layers (**Evidence grade:** 1C).

FIELD REWARMING

Once a hypothermic patient has been protected from further heat loss, the next priority is to rewarm the patient. The rewarming methods described in this section achieve the safe rewarming rate of 1 to 2°C·h^{-1} and minimize the risk of afterdrop. Afterdrop can lead to hemodynamic instability and VF. The risk of afterdrop is reduced by limiting limb movement and by keeping the patient horizontal. Most patients with altered consciousness will require active rewarming.

It is important to recognize that the optimal rate of rewarming may not be the fastest rate. Even profound hypothermia may require slow, controlled rewarming. Only patients with hemodynamic instability should be considered for rapid rewarming via extracorporeal life support (ECLS).

Shivering

Vigorous shivering can increase heat production by 5 to 6 times the resting metabolic rate and up to 50% of maximal metabolic rate ($\dot{V}O_{2\ max}$).[5,56] Shivering can raise core temperature by 3 to 4°C·h^{-1},[16,28,57] but it uses a large amount of energy, stresses the cardiovascular system, and causes patient discomfort.[17]

Recommendation. Shivering is an effective method of rewarming in a patient who is cold-stressed or mildly hypothermic. The patient must be adequately insulated from the environment to retain the generated heat (**Evidence grade:** 1A). An alert patient who is shivering, and who is not at risk for aspiration, should receive high-carbohydrate liquids and/or food. Liquids and food may be warmed but should not be hot enough to burn the esophagus (**Evidence grade:** 1C).

Delay exercise to protect against afterdrop

Once a patient is protected from further heat loss and has adequate energy reserves, the most effective means of rescue may be for the patient to walk. Allowing the patient to shiver and rewarm, while insulated and before exercise, should help minimize afterdrop.[46] This time period should last 30 min but will depend upon the situation. Standing upright increases blood flow to and from the legs, worsening afterdrop and potentially decreasing blood pressure.[29] Walking or other exercise generates additional heat, but if initiated immediately after rescue, may cause a greater afterdrop in core temperature than if the patient remains at rest.[46] There may be situations when immediate movement is necessary to relocate a patient to a safer environment. When this is necessary, close monitoring is prudent.

Recommendation. A shivering patient who may be hypothermic should be kept as warm as possible, given calorie replacement, and observed before exercising. After this period of observation, the alert patient may be allowed to stand. If the patient can stand without difficulty, exercise intensity should start low and increase gradually as tolerated. The patient should be closely monitored; if the condition worsens, the patient should stop exercising and be treated accordingly (**Evidence grade:** 1C).

Active external rewarming

Field methods of external rewarming are useful in both shivering and nonshivering patients. Active (exogenous) rewarming methods, such as large electric heat pads or blankets,[58] large chemical heat pads,[59,60] warm water bottles,[61] and the Norwegian charcoal-burning Heat Pac,[17,58,62] all provide significant external heat. In a shivering patient, the added heat attenuates shivering heat production. This results in a rate of core rewarming similar to that produced by shivering but has the advantages of increased comfort and decreased energy use with lower cardiac workload. In a nonshivering patient, added heat will warm the core, even if slowly, in a patient lacking capacity for endogenous heat production. The Heat Pac should be used with caution because it can generate potentially toxic levels of carbon monoxide (CO).[32]

To maximize total body net heat gain, active heating will be more effective in conjunction with insulation and vapor barrier(s) to create an effective hypothermia enclosure system. Five such systems were compared on normothermic subjects in -20°C conditions.[63] The systems (all including active heating and vapor barrier) included 3 commercial systems using heavy insulation enclosures, a user-assembled system using a 3-season sleeping bag, and the Hypothermia Prevention Management Kit (HPMK).[63] Initially evaluated for effectiveness between other rewarming systems,[64] the HPMK was commercially developed for the Department of Defense-Joint Trauma System (JTS) as a lightweight, compact kit designed for field use that combines an oxygen-activated self-heating liner with a vapor barrier. The HPMK was part of the JTS theater-wide strategy for battlefield casualties and has been used extensively in military operations to decrease mortality from trauma-induced hypothermia.[65–67] System effectiveness (net body heat gain) generally depended on the mass of the insulation enclosure.[63] The 3 commercial systems were heavy and bulky and therefore only applicable at a point of care or if they could be delivered by sled or vehicle. The user-assembled and HPMK systems could both be transported by backpack; however, the HPMK was smaller and lighter and therefore more portable, but at the expense of providing less net body heat gain. Therefore, factors such as mass, volume, effectiveness, and cost will affect the type of system used in the field. Search and rescue teams, which usually consist of 2 to 4 persons, could realistically carry a more-effective user-assembled system because the items can be separated and dispersed to multiple backpacks (Figure 3). Alternatively, the HPMK should be complemented by incorporating a sleeping bag (or blankets) over the heated liner and inside the vapor barrier.

Recommendations. Active sources of heat should be used (**Evidence grade:** 1B). Rewarming devices should be used in conjunction with vapor barriers and insulation (**Evidence grade:** 1B). The Heat Pac should only be used outdoors or with proper ventilation that is carefully monitored to prevent CO accumulation (**Evidence grade:** 1B). The single-package, small, and light HPMK is a practical system for transport in a single backpack and useful for military operations and should be used with an added layer of insulation if possible (**Evidence grade:** 1C).

Body-to-body rewarming

Body-to-body rewarming of a shivering patient with a warm person in a sleeping bag blunts the increase in shivering thermogenesis, resulting in rewarming rates no greater than shivering alone.[57,58] Body-to-body rewarming may make the cold patient more comfortable due to decreased shivering, but at the cost of delaying evacuation.

Recommendation. Body-to-body rewarming can be used in mild hypothermia to increase patient thermal comfort if enough personnel are available and it does not delay evacuation to definitive care (**Evidence grade:** 1B).

Applying heat to the axillae, chest, and back

External heat is most effective if concentrated on the axillae, chest, and back (in that order), which are the areas with the highest potential for conductive heat transfer.[53] Upper torso rewarming is more effective than extremity rewarming.[68] Some scenarios may. however, preclude applying heat to the chest (eg, cardiopulmonary resuscitation [CPR] in progress or treatment of chest injury). Applying heat to the head, although requiring more technique to insulate and apply the heat, has been shown to be equally effective in shivering and nonshivering subjects, thus providing an alternative warming approach in extenuating circumstances.[69]

Recommendations. Apply heat sources to the axillae, chest, and back. A large heat pad or blanket should be placed over the chest and, if large enough, extend into the axillae and under the back (**Evidence grade:** 1B). Additional heat can be applied to the neck if precautions are taken to prevent heat loss through any neck opening (**Evidence grade:** 1C). Avoid applying external heat to the extremities, although it is not necessary to insulate the arms from heat applied to the torso (**Evidence grade:** 1B). If application of heat to the chest is contraindicated (eg, CPR or some chest injuries), heat sources may be still be applied under the patient's upper back or to the head (**Evidence grade:** 1B). If applying heat sources to the back, rescuers must be able to observe for the development of burns on a regular basis (**Evidence grade:** 1C).

Protection of cold skin

Cold skin is very susceptible to injury from pressure or heat.[70] There have been reports of burns associated with use of a hot water bottle with lukewarm water applied directly to hypothermic skin,[71] the HPMK,[64] water-perfused warming blankets, a Heat Pac, and hot pads.[72] Burns have been reported both in controlled settings while researching rewarming methods and during rescue of hypothermic patients. It is important to visually inspect the heated skin at regular intervals (eg, 20 to 30 min) to observe for excess reddening or other signs of pending burns; in these cases, active heating should be stopped in the affected areas. This must be done segmentally and carefully to minimize heat loss. Heated pads should be applied with great caution to areas such as the back that are difficult to visualize or under constant pressure from body weight or immobilization systems.

Recommendation. Avoid localized pressure to cold skin. Apply heat sources according to manufacturer instructions; this often precludes direct contact with the skin by placing some thin insulating material between the skin and heat source to prevent burning the skin (**Evidence grade:** 1C). Skin should be assessed every 20 to 30 min for excess reddening or other signs of impending thermal burns when active heat sources are being applied (**Evidence grade:** 1C).

Do not use small chemical heat packs for rewarming

Small chemical heat packs (eg, those used for hand and foot warming) do not provide sufficient heat to affect core temperature. In addition, the high surface temperature of small chemical heat packs creates a risk of thermal burns.

Recommendation. Do not use small chemical heat packs for core rewarming of a hypothermic patient (**Evidence grade:** 1B). However, these small chemical heat packs can be used to prevent local cold injury to the hands and feet during treatment and transport (**Evidence grade:** 1C).

Heated humidified oxygen

Although heated humidified oxygen prevents respiratory heat loss, the respiratory tract allows limited heat exchange. Heated humidified oxygen is not effective as a solitary rewarming method,[30–32] but it can be used as an adjunct to other methods.[26] Heated humidified oxygen has the potential to cause facial burns.[32]

Recommendations. Heated humidified oxygen can be used in combination with other rewarming methods (**Evidence grade:** 2C), but it should not be relied on as the only rewarming method (**Evidence grade:** 1B).

Do not use warm showers or baths for rewarming

A warm shower or bath markedly increases peripheral blood flow, increasing afterdrop and potentially causing hypotension.[29,42] Using a warm shower or bath, even in a patient who is mildly hypothermic, may cause cardiovascular collapse. This method of warming may be considered for patients who are cold-stressed or after an initial period of rewarming for those with mild hypothermia.

Recommendation. A warm shower or bath should not be used for initial rewarming, even if a patient appears to be only mildly hypothermic (**Evidence grade:** 1C).

Distal limb warming

Distal limb warming in 42 to 45°C water to the elbows and knees is effective for warming alert, mildly hypothermic patients.[9] This method works by opening arteriovenous anastomoses in the hands and feet, causing increased return flow of warmed blood directly from the arms and legs to the core. This is an exception to the general rule that peripheral rewarming is contraindicated in hypothermic patients. Because the warmed superficial venous blood bypasses the cold arteries in the extremities, there is little countercurrent heat exchange. In the one laboratory study that used this method, the afterdrop was less than the afterdrop for shivering.[9] Distal limb rewarming in water was designed for use on watercraft and is difficult to apply for other out-of-hospital transport.

Recommendation. Distal limb warming to the elbows and knees in 42 to 45°C water can be used for rewarming a patient with mild hypothermia if the clinical setting is appropriate (**Evidence grade:** 1C).

Rewarming during transport

Continued rewarming is challenging during transport. A randomized, controlled study of care in helicopter and ground advanced life support units showed a small increase in core temperature with using large chemical heat pads but decreased core temperature with passive rewarming, reflective blankets, warm IV fluids, and warm IV fluids plus reflective blankets.[60]

Forced air warming, usually with an air-filled plastic baffled blanket with continuous heated airflow through perforations in the bottom of the blanket, is an effective way to rewarm a hypothermic patient.[30,73,74] In 1 study, afterdrop with forced air warming was less than with shivering.[75] Forced air warming is more effective and more practical than a liquid-filled heating blanket.

Recommendations. Forced air warming should be used during air or ground transport, if available (**Evidence grade:** 1A). If forced air warming is not available, use of other heat sources can be continued. Care must be taken to prevent CO buildup with the charcoal Heat Pac in a ground ambulance; this can be done by igniting the device outside the vehicle, bringing it inside only after initial smoke production subsides, ventilating the vehicle compartment, and monitoring CO (**Evidence grade:** 1C). A charcoal Heat Pac should not be used in an aircraft (**Evidence grade:** 1C).

Temperature in air or ground ambulances

The temperature in patient compartments should ideally be 28°C, which is the temperature at which unclothed resting normothermic humans will neither gain nor lose heat.[1] Warming the patient compartment will protect patients from further heat loss when exposed for monitoring or other procedures. However, an air temperature of 28°C is usually uncomfortably hot for pilots, drivers, and medical providers. A slightly cooler temperature of 24°C will limit heat loss and is better tolerated by ambulance personnel.

Recommendation. Patient compartments in ground and air ambulances should be heated to at least 24°C, if possible, to decrease further heat loss (**Evidence grade:** 1C).

Treatment of cold stressed patients who are not hypothermic

A cold patient who is alert and shivering but who has adequate energy reserves and is not hypothermic is at low risk for afterdrop or circumrescue collapse.

Recommendation. It is the consensus of the panel that a cold-stressed patient who is not hypothermic need not be kept horizontal. The patient may be allowed to remove his or her own wet clothing and to put on dry clothing without shelter, if necessary. The patient may be allowed to rest in a sitting position, to eat and drink to maintain energy reserves and hydration, and to move or keep moving, if necessary. These patients will need close monitoring to ensure they do not become hypothermic.

RESUSCITATION OF HYPOTHERMIC PATIENTS

Decision to resuscitate hypothermic patients without signs of life

Hypothermic patients have survived with normal neurologic function even after cardiac arrest.[23,76–78] Many of the usual indicators of death, such as fixed, dilated pupils and apparent rigor mortis, are unreliable in hypothermic patients.[76,77] Dependent lividity is an unpredictable indicator of death in hypothermia.

Recommendations. Fixed, dilated pupils, apparent rigor mortis, and dependent lividity are not considered contraindications to resuscitation of a severely hypothermic patient (**Evidence grade:** 1A for fixed, dilated pupils and apparent rigor mortis). Rescuers should attempt CPR and resuscitation unless contraindications exist (**Evidence grade:** 1A).

Contraindications to resuscitation of hypothermic patients

The dictum that "no one is dead until they are warm and dead" is based on the difficulty of diagnosing death in a hypothermic patient in the field. However, some patients really are cold and dead. General contraindications to attempted resuscitation in the field include obvious fatal injuries, such as decapitation, open head injury with loss of brain matter, truncal transection, incineration, or a chest wall that is so stiff that compressions are not possible.[79]

Recommendation. Do not attempt to resuscitate a patient with obvious fatal injuries or whose chest wall is too stiff for compressions (**Evidence grade:** 1A).

Indication for cardiopulmonary resuscitation

CPR is only indicated in cardiac arrest and is contraindicated if there are signs of life. In a hypothermic patient in the out-of-hospital setting, signs of life may be very difficult to detect. The heart rate can be very slow and pulses difficult to palpate. The traditional method of checking a pulse by trying to feel the pulse with a finger placed over the presumed location of an artery is limited by cold. Cold fingers have decreased sensitivity to tactile stimuli. Breathing can be very slow and shallow but may be detectible in the absence of palpable pulses.[22] If cardiac monitoring is not available, the diagnosis of cardiac arrest can be difficult.

Recommendation. Rescuers should make every effort to move the patient to a warm setting, such as a ground or air ambulance or a medical facility where cardiac monitoring is available to guide resuscitation and to start rewarming (**Evidence grade:** 1C). Prior to starting CPR, feel for a carotid pulse for 1 min. If a pulse is not palpated after 1 min, start CPR, including rescue breathing (**Evidence grade:** 1C).

No cut-off temperature for resuscitation

The lowest known core temperature from which a patient with accidental hypothermia has been successfully resuscitated is 13.7°C.[80] The lowest core temperature ever induced therapeutically is 9°C.[81] Both patients survived neurologically intact. Induced hypothermia for cardiac or vascular surgery is usually to 18°C and—unlike accidental hypothermia—a very controlled situation. The lowest temperature from which humans with accidental hypothermia can be successfully resuscitated is not known, and reports of recovery from extremely low core temperatures make establishing a temperature cut-off for resuscitation challenging.

Recommendation. Resuscitation attempts should be continued regardless of the measured core temperature (**Evidence grade:** 2C).

Electrocardiographic monitoring

Electrocardiographic monitoring is the best way to diagnose cardiac arrest in the field. An organized rhythm without detectible pulses may be pulseless electrical activity or may be a perfusing rhythm with very weak pulses. In hypothermic patients, the amplitude of the QRS complexes may be decreased.[10]

Starting CPR in a hypothermic patient with an organized cardiac rhythm carries a risk of causing VF that would convert a perfusing rhythm to a nonperfusing rhythm. If end-tidal CO_2 ($ETCO_2$) monitoring is available, lack of waveform indicates lack of circulation or absence of metabolism.[13] If ultrasound is available, echocardiography can be used to determine if cardiac contractions correspond to electrical activity.[13]

Recommendation. CPR should be started if a nonperfusing rhythm, including ventricular tachycardia, VF, or asystole, is detected. If there is a cardiac rhythm with organized QRS complexes, CPR should not be performed (**Evidence**

grade: 1C) unless $ETCO_2$ monitoring confirms lack of perfusion or echocardiography shows that there are no cardiac contractions corresponding to electrical activity (**Evidence grade:** 1B). Use maximal amplification on the monitor to search for QRS complexes (**Evidence grade:** 1C).

Delaying CPR, intermittent CPR, and prolonged CPR

Cooling reduces resting oxygen consumption of most human tissue by about 6% per 1°C decrease, with a greater decrease in brain tissue. Hypothermia preferentially protects the brain from hypoxia. At a core temperature of 28°C, whole body oxygen consumption is about 50% of normal,[1] while brain oxygen consumption may be reduced to about 35% of normal.[8] Surgical procedures employing deep hypothermic circulatory arrest (DHCA) have demonstrated a 7% decrease in cerebral oxygen consumption for every 1°C decrease in core temperature. Sixty percent of patients with a core temperature less than 18°C demonstrate an isoelectric electroencephalogram. DHCA is a controlled, rapid, decrease of core temperature from 18 to 20°C. Patients over the age of 60 y undergoing DHCA only tolerated an estimated 25 min of cardiac arrest, based upon incidence of postprocedural cognitive injury. Children tolerate longer periods of time, but there is a dearth of information for young and middle-aged adults.[82,83] There are many documented cases of full neurologic recovery, even after extended periods of cardiac arrest as long as 9 h[84,85] in persons who did not have asphyxia before they became hypothermic. Severely hypothermic patients have been resuscitated with good neurologic status after as long as 6 h 30 min of CPR.[23,86–88] Prolonged cardiac arrest in severely hypothermic patients does not necessarily cause brain injury as it does in normothermic patients.

In cardiac arrest, the classic teaching is that CPR must be started promptly and continued without interruption until return of spontaneous circulation (ROSC) can be established or death is confirmed. This CPR strategy may not be possible or warranted in patients with severe hypothermia. Multiple case reports describe survival with neurologic recovery when initiation of CPR was delayed and performed intermittently.[85,89] In 1 case report, a hypothermic avalanche victim was successfully resuscitated with complete neurologic recovery, although CPR was not started for 15 min after a monitored cardiac arrest.[23] In another case report, an avalanche victim was extricated apneic and pulseless after a 5 h burial in a crevasse. No attempt was made to resuscitate the patient, but the patient was flown to a nearby hospital where ECG showed asystole. CPR was started 70 min after rescue. The patient made a full neurologic recovery.[48] A third case report described successful resuscitation with good neurologic recovery of a hypothermic patient in cardiac arrest who was treated during evacuation with CPR in a stationary litter for 1-min periods alternating with 1-min periods of being carried without CPR.[86]

Continuous compressions are ideal, but intermittent compressions may be necessary to successfully and safely evacuate the patient. With properly performed compressions, it takes an estimated 5 min of cerebral oxygenation to overcome the ischemic threshold.[90]

Recommendation. Immediate, high-quality CPR should be performed for a hypothermic patient in cardiac arrest. If it is impossible or unsafe to perform immediate and continuous CPR, rescuers should perform delayed or intermittent CPR. Ideally, compressions will not be delayed for longer than 10 min, a conservative interval based on the uncontrolled nature of out-of-hospital hypothermic cardiac arrest (**Evidence grade:** 1C). If CPR cannot be performed continuously, compressions should be performed for a minimum of 5 min, with interruptions between periods of compressions that should not exceed 5 min (**Evidence grade:** 1C).

CPR technique in hypothermia

A hypothermic patient will have a stiff chest wall that limits the effectiveness of chest compressions and bag-valve-mask ventilation. Myocardial and pulmonary compliance are also markedly reduced in severe hypothermia. During hypothermic cardiac arrest with CPR[91] in a swine model, cardiac output, cerebral blood flow, and myocardial blood flow averaged 50, 55, and 31%, respectively, of those achieved during normothermic closed-chest compressions. However, metabolic demands are also decreased. Although there are no data to support increased survival when a mechanical compression device is used,[92] mechanical devices reduce the incidence of rescuer fatigue and may permit longer periods of uninterrupted compressions, especially when bridging to ECLS.[86,93]

Recommendation. Patients in cardiac arrest should have chest compressions delivered at the same rate as for normothermic patients (**Evidence grade:** 1C). Using a mechanical compression device may decrease interruptions and reduce rescuer fatigue (**Evidence grade:** 1C).

Automated external defibrillator

If an automated external defibrillator (AED) with a cardiac monitor is available, it can be used for cardiac monitoring. An AED without a cardiac monitor can also be used for diagnosis. The cardiac rhythms that may benefit from cardioversion or defibrillation (shockable rhythms) are VT and VF. VT is rare during moderate or severe hypothermia. The instruction “shock is advised” means that the rhythm is VT or VF. The instruction “no shock advised” on an

AED without monitoring capability can mean that the rhythm is asystole or an organized rhythm, which may be pulseless electrical activity. Current AHA guidelines recommend a single shock.[19]

Recommendation. If shock is advised by the AED, rescuers should attempt defibrillation and start CPR. If no shock is advised on an AED, no carotid pulse is found after palpating for at least 1 min, normal breathing or other signs of life are not observed, and ultrasound is not available to verify cardiac activity or pulse, start CPR (**Evidence grade:** 1C).

Initial defibrillation in hypothermia

Defibrillation is only indicated for a shockable rhythm (pulseless VT or VF). An AED will only advise a shock if the rhythm is VT or VF. Current resuscitation guidelines recommend a single shock at maximum power for a patient whose core temperature is below 30°C.[13,17,94]

Recommendation. If a monitor/defibrillator shows VT or VF in a patient whose core temperature is thought to be below 30°C, a single shock should be given at maximum power (**Evidence grade:** 1C).

Repeat defibrillation attempts in hypothermia

Patients have been successfully defibrillated at core temperatures below 26°C.[95–98] If defibrillation below 30°C is unsuccessful, delay further shocks until the temperature is greater than 30°C; below 30°C, defibrillation is less likely to be successful. Defibrillation in a patient whose core temperature has reached 30°C should follow guidelines for normothermic patients.[13]

Recommendations. Wait until a patient has been rewarmed to 30°C before attempting further shocks (**Evidence grade:** 2C). Once the core temperature reaches 30°C, follow defibrillation guidelines for normothermic patients (**Evidence grade:** 1C).

Airway management in hypothermia

The principles of airway management are the same in a hypothermic patient as in a normothermic patient. In a patient who is not breathing spontaneously or who is breathing spontaneously but not protecting their airway owing to a decreased level of consciousness, advanced airway management with endotracheal intubation or a supraglottic airway device is indicated to provide adequate ventilation and to protect against aspiration.[13,99] Although there are case reports of VF occurring during endotracheal intubation of a hypothermic patient,[21,50,100,101] this is an uncommon complication. In a multicenter study, 117 hypothermic patients were intubated endotracheally after preoxygenation with 100% oxygen with no induced dysrhythmias.[102]

Recommendations. The advantages of advanced airway management outweigh the risk of causing VF (**Evidence grade:** 1C). A nasogastric or orogastric tube should be placed after the airway is secured to decompress the stomach (**Evidence grade:** 1C).

Practical considerations. Rapid-sequence intubation with paralysis may not be effective if the paralytic agent is unable to overcome the trismus produced by profound hypothermia. Fiber optic intubation or cricothyroidotomy may be required to place an endotracheal tube if cold-induced trismus prevents laryngoscopy. A supraglottic device may be preferable to endotracheal intubation in these conditions. Overinflation of an endotracheal tube or supraglottic device cuff with cold air should be avoided because the air inside the cuff will expand as the victim rewarms, potentially kinking the tube or rupturing the cuff.

Ventilation in hypothermia without an advanced airway

Hyperventilation has many potentially adverse effects in hypothermia, including decreased cerebral blood flow. As shown in the swine model, ventilation without an advanced airway is limited by decreased thoracic compliance.[91,103] If available, $ETCO_2$ monitoring can be used to prevent hyperventilation.

Recommendation. In the absence of $ETCO_2$ monitoring, ventilation should be delivered at the same rate recommended for a normothermic patient,[13,19] unless an advanced airway is in place (see below) (**Evidence grade:** 2C).

Ventilation in hypothermia with advanced airway

If the patient is intubated or has a supraglottic device, ventilation is more effective than in a patient without advanced airway management.

Recommendation. In a patient with an advanced airway, if $ETCO_2$ monitoring is not available, ventilation should be delivered at half the rate recommended for a normothermic patient to avoid hyperventilation (**Evidence grade:** 1C).

Management of $ETCO_2$

$ETCO_2$ monitoring can be used to keep $ETCO_2$ in the normal range. This range depends on altitude.

Recommendation. If $ETCO_2$ monitoring is available, $ETCO_2$ should be kept within the normal range. In rescues at altitudes above 1200 m, advanced life support personnel should be aware of the normal range of $ETCO_2$ at a given altitude (**Evidence grade:** 1C).

Anesthetic and neuromuscular blocking agents in hypothermia

At low core temperatures, drug metabolism is decreased; anesthesia and neuromuscular blockade are prolonged.[104–106]

Recommendation. In patients with core temperatures lower than 30°C, dosages of anesthetic and neuromuscular blocking agents should be decreased, and intervals should be extended according to the degree of hypothermia. Current data are insufficient to recommend specific protocols (**Evidence grade:** 1C).

Supplemental oxygen

Oxygen extraction is not a limiting factor in survival in hypothermia at sea level.[107]

Recommendation. A hypothermic patient should receive supplemental oxygen, especially at altitudes over 2500 m, because of potential benefits and no known harm (**Evidence grade:** 1C).

Circulatory access in hypothermia

Obtaining intravenous (IV) access is often difficult in hypothermic patients. Intraosseous (IO) access is fast and reliable. Because the myocardium is irritable in hypothermia, catheters that contact the heart may cause dysrhythmias. Internal jugular or subclavian central lines that extend into the right atrium are contraindicated unless a short catheter is inserted. There is a risk of causing VF if the wire used during placement of a central venous catheter using the Seldinger technique is advanced into the heart. The femoral vein approach allows central venous access without the danger of inducing dysrhythmias, but it may be difficult in the field. Unsuccessful attempts often cause hematomas.

Recommendations. If circulatory access cannot immediately be obtained with a peripheral IV catheter, access should be obtained by the IO method (**Evidence grade:** 1C). Central venous access can be obtained using a femoral line if no other option is available (**Evidence grade:** 1C).

Volume replacement in hypothermia

Circulating blood volume in moderate and severe hypothermia is reduced.[9,107] During rewarming, vasoconstriction that previously limited the vascular space is abolished. Volume should be replaced to avoid severe volume depletion with resultant shock, while avoiding administration of fluid sufficient to cause volume overload. To prevent further core temperature cooling, IV/IO fluid should be warmed to at least 40°C and preferably to 42°C. In the field, IV/IO bags and tubing should be insulated. Fluid warmers, preferably commercial products that have been proven effective, should be used. Because the effective perfused mass (thermal core) is decreased in hypothermia as a result of intense peripheral vasoconstriction,[9] administration of fluid warmed to 40 to 42°C may help increase core temperature. Because metabolism is depressed, glucose-containing fluid is not essential. The fluid of choice for volume replacement is normal saline. Lactated Ringer's solution should not be used in a hypothermic patient because the cold liver cannot metabolize lactate.[1] Some clinicians use a mixture of crystalloid and colloid.[1]

Recommendation. Resuscitate a hypothermic patient with normal saline warmed to 40 to 42°C given IV or IO. Use caution to prevent volume overload (**Evidence grade:** 1B).

Fluid management in hypothermia

Giving fluids in boluses, as rapidly as possible, rather than by continuous infusion will alleviate problems with cooling of fluid or freezing of lines, which can occur even if lines are insulated. The ideal method is to saline lock the line when there will be a long pause after a bolus. Boluses of 500 mL can be titrated to maintain adequate systolic blood pressure, depending on the degree of hypothermia. There is no available evidence to quantify a target systolic blood pressure.

Recommendations. When practical, fluids should be given as boluses rather than by continuous infusion (**Evidence grade:** 1C). The goal of fluid administration should be to maintain systolic blood pressure at a level that provides adequate perfusion, depending on the degree of hypothermia (**Evidence grade:** 1C).

Use of exogenous glucose and insulin in hypothermia

Hypo- and hyperglycemia have been reported in hypothermia.[96,108] Point-of-care glucose testing is routine in patients with an altered level of consciousness but may not be available in an out-of-hospital setting. Hyperglycemia has not been shown to be deleterious in hypothermic patients.[96]

Recommendation. Glucose should be administered to the hypothermic patient who is hypoglycemic (**Evidence grade:** 1A). Insulin is not initially indicated for hyperglycemia (**Evidence grade:** 1B). If glucose testing is not available, IV glucose can be administered empirically to the hypothermic patient with altered mental status (**Evidence grade:** 1C).

Effects of vasoactive and antidysrhythmic drugs in hypothermia

There is limited evidence regarding drug effects in hypothermic cardiac arrest in humans. Most of the evidence comes from animal studies.[109] The cold heart has long been considered to be unresponsive to vasopressor or antiarrhythmic medications, although some animal studies have suggested otherwise. In a study of hypothermic dogs, epinephrine increased coronary perfusion pressure and ROSC after defibrillation.[110] In a hypothermic pig study, vasopressin increased coronary perfusion pressure with active compression-decompression CPR using an impedance threshold valve, but not with standard CPR.[111] Vasopressin improved ROSC and 1-h survival after defibrillation in a study of hypothermic pigs.[112] There is a case report of ROSC with vasopressin following unsuccessful use of epinephrine (2 mg) in a hypothermic patient, but the patient subsequently died OF multisystem failure.[113]

The ideal pharmacologic approach to ventricular dysrhythmias remains unresolved. Class III agents, such as bretylium and amiodarone, are theoretically ideal because they act directly against fibrillation. Amiodarone is less effective in hypothermia than in normothermia and carries a risk of inducing torsades des pointes.[114] The safety of amiodarone in hypothermia is not known. In a study of hypothermic dogs, the combination of epinephrine and amiodarone increased ROSC after defibrillation following administration of epinephrine alone.[110] Bretylium failed to increase the incidence of ROSC in a study of hypothermic dogs.[115] In another dog study, neither amiodarone nor bretylium improved ROSC.[116] There are 2 clinical reports of resolution of VF following infusion of bretylium.[117,118]

Recommendation. The panel concurs that no recommendation can be made at this time owing to the limited evidence available.

Dosing of drugs in hypothermia

In hypothermia, drug metabolism is decreased and protein binding is increased.[11] Drugs given have little activity while the patient is hypothermic but may reach toxic levels with rewarming.

Recommendations. Do not administer vasoactive drugs until the patient has been rewarmed to 30°C (**Evidence grade:** 1C). To minimize the potential for toxic accumulation of medications, the usual dose can be given, but dosing intervals should be twice as long as usual when the core temperature is 30 to 35°C (**Evidence grade:** 2C).

Transcutaneous cardiac pacing in hypothermia

Two case reports suggest that transcutaneous pacing may be beneficial in the hypothermic patient.[119] In both cases, transcutaneous pacing was instituted to increase blood pressure to facilitate arteriovenous rewarming rather than to control heart rate.

Recommendation. It is the consensus of the panel that transcutaneous pacing may be beneficial in hypothermia in the setting of bradycardia with hypotension disproportionate to the core temperature (**Evidence grade:** 2C).

Management of atrial dysrhythmias during rewarming of a hypothermic patient

Atrial dysrhythmias in hypothermic patients during rewarming are common and resolve spontaneously once the patient has been sufficiently rewarmed.[120]

Recommendation. No treatment is indicated for atrial dysrhythmias in a hemodynamically stable patient during rewarming (**Evidence grade:** IB).

TRANSPORT/TRIAGE

Severe trauma

Core temperatures <35°C are associated with decreased survival in patients with severe trauma.[121,122] Severe trauma can cause acidosis and coagulopathy. In trauma patients with hemorrhagic shock, the "lethal triad" of acidosis, coagulopathy, and hypothermia is associated with multiorgan system dysfunction[123] and extremely high mortality.[124]

Recommendation. To prevent hypothermia, the severely injured patient should be treated early and aggressively with active rewarming during all phases of out-of-hospital care (**Evidence grade:** 1B).

Stabilizing injuries for transport

Stabilization of injuries for transport is the same in a hypothermic patient as in a normothermic patient.

Recommendations. When preparing a patient for transport, potential spinal injuries should be stabilized[125] (**Evidence grade:** 1C). Fractures and dislocations should be reduced as much as possible to normal anatomic configuration (**Evidence grade:** 1C). Open wounds should be covered (**Evidence grade:** 1C).

Patients with mild hypothermia who are alert

Alert patients with mild hypothermia can be treated in the field.

Recommendation. An uninjured patient who is completely alert and shivering may be treated without being transported to a hospital (**Evidence grade:** 1B).

Choice of destination hospital for hypothermic patients

Profoundly hypothermic patients (<28°C) and those with hemodynamic instability and witnessed out-of-hospital cardiac arrest may benefit from transport to centers capable of ECLS. ECLS includes the techniques of extracorporeal circulation, extracorporeal membrane oxygenation (ECMO), and coronary bypass. ECLS provides both oxygenation and hemodynamic support for unstable patients while allowing for controlled rewarming.

Patients who are not profoundly hypothermic or hemodynamically unstable should be transported to the nearest facility.[87,126–131]

Hypothermic patients with hemodynamic instability

Hemodynamically unstable patients require critical care and may benefit from ECLS with ECMO or CPB. ECMO is preferred over CPB,[127] but both have been used successfully to rewarm severely hypothermic patients. Profoundly hypothermic patients with witnessed cardiac arrest, regardless of return to spontaneous circulation in the field, have a greater chance of survival if transferred to a center where ECLS can be initiated.[87,126–131]

Many geographic areas do not have a hospital capable of ECLS. Bad weather or other factors may prevent transfer of a patient to a hospital with ECLS. Hemodynamically unstable hypothermic patients, including hypothermic patients in cardiac arrest, have been successfully resuscitated with complete neurologic recovery without using ECLS.[88,132–134]

Recommendations. A patient with moderate to severe hypothermia who is hemodynamically stable can be transferred to the closest hospital or other appropriate medical facility, such as a rural clinic (**Evidence grade:** 1C). A patient who is hemodynamically unstable or with a core temperature <28°C should be transferred to a hospital capable of providing critical care and ECLS. If this will require significant additional time—generally more than an additional hour—of noncritical care transport, the patient should first be stabilized at a closer facility (**Evidence grade:** 1C). A patient in cardiac arrest should be transferred to a hospital capable of providing ECLS if possible. If all other factors are equal, ECMO is preferable over CPB (**Evidence grade:** 1B).

In geographic regions where there is no hospital capable of providing ECLS or when a hospital capable of providing ECLS is not accessible, transport a patient in cardiac arrest to the closest hospital where serum potassium can be measured and resuscitation methods not involving ECLS can be attempted for a patient whose serum potassium is $<12\ \text{mmol}\cdot\text{L}^{-1}$ (**Evidence grade:** 1C). (Please see section for use of biochemical markers.)

Hypothermic patients who are alert but have comorbidities, including trauma or asphyxia

Hypothermic patients with injuries or other medical comorbidities should be transferred to a facility able to appropriately manage the patient. Comorbidities can alter the clinical presentation of hypothermia and could potentially delay recognition of severe hypothermia.[135] Asphyxiated patients (from avalanche or drowning) may appear stable but are at risk for delayed complications and are likely to require a higher level of care.[127]

Recommendations. A patient with injuries meeting trauma criteria should be transported to a trauma center (**Evidence grade:** 1B). The asphyxiated patient should be transported to a hospital for observation (**Evidence grade:** 1B).

Use of biochemical markers to determine if resuscitation should be continued in a hypothermic patient without vital signs. Increased serum potassium in a hypothermic patient usually indicates that hypothermia was preceded by hypoxia. As such, it is a marker of cell lysis and death. The highest potassium in a patient resuscitated from hypothermia was $11.8\ \text{mmol}\cdot\text{L}^{-1}$ in a 31-mo-old child. This level is questionable because the repeat potassium 25 min later was $4.8\ \text{mmol}\cdot\text{L}^{-1}$ without mention of therapeutic intervention.[136] The highest levels recorded in patients who were resuscitated were $9.5\ \text{mmol}\cdot\text{L}^{-1}$ in a 13-y-old[137] and $7.9\ \text{mmol}\cdot\text{L}^{-1}$ in a 34-y-old.[138]

Recommendation. If an adult hypothermic patient has a potassium $>12\ \text{mmol}\cdot\text{L}^{-1}$, CPR should be terminated (**Evidence grade:** 1B).

Conclusions

To assist medical providers caring for patients with accidental hypothermia in the out-of-hospital setting, we have provided evidence-based recommendations for evaluation and treatment. There are several important areas of uncertainty that warrant future research. These areas include optimal methods for evaluating patients with accidental hypothermia, best treatments for patients with mild to moderate hypothermia, and optimal methods of resuscitating hypothermic patients in cardiac arrest.

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Supplementary materials

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