HYPOTHERMIA: PART II

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ABSTRACT

When the human body becomes too cold to spontaneously re-warm itself through normal metabolic procedures, hypothermia occurs. Hypothermia can range from mild to severe and its symptoms include mental confusion, slow heart rate, and even death. Since an extreme low core body temperature can suppress heart and brain function, hypothermia treatment protocols vary from the treatment of other heart- and brain-related incidents. This Part II course provides a detailed explanation of hypothermia and explains field treatment protocol, as well as transportation, and in-hospital interventions, including recommended pharmacological treatments specific to types of accidental injuries.
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Accreditation Statement
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Credit Designation
This educational activity is credited for 7 hours. Pharmacology content includes 1.5 hour. Nurses may only claim credit commensurate with the credit awarded for completion of this course activity.

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Statement of Need
Hypothermia is a leading cause of death in several states. Cases of profound hypothermia and devastating consequences have been well documented in the pre-hospital setting. New criteria to determine exposure, prognosis, even death, and critical treatment modalities is important for nurses to know.

Course Purpose
This course will provide advanced learning for nurses interested in hypothermia and critical interventions to support survival.
Learning Objectives

1. Differentiate between active and passive warming and external and internal warming.
2. Describe the difference in resuscitation time frames for hypothermic patients compared to normothermic patients.
3. Identify clinical signs of life in a hypothermic patient.
4. Explain the appropriate use of defibrillation in a hypothermic patient.
5. Identify and characterize the pharmacological treatments for hypothermia and related disorders.

Target Audience
Advanced Practice Registered Nurses, Registered Nurses, Licensed Practical Nurses, and Associates

Course Author & Director Disclosures
Jassin M. Jouria, MD, William S. Cook, PhD, Douglas Lawrence, MS
Susan DePasquale, CGRN, MSN, FPMHNP-BC - all have no disclosures

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Please take time to complete the self-assessment Knowledge Questions before reading the article. Opportunity to complete a self-assessment of knowledge learned will be provided at the end of the course.
1) Which of the following drugs is used in the emergency treatment of chilblains?
   a) Dexamethasone
   b) Nifedipine
   c) Betamethasone
   d) Procainamide

2) Which of the following electrolytes are affected significantly during re-warming efforts on a hypothermic patient?
   a) Sodium
   b) Potassium
   c) Magnesium
   d) Chloride

3) Which of the following are characteristics of third degree frostbites?
   a) Blood-filled blisters
   b) Milky blisters
   c) Mottled skin
   d) Rubbery skin texture

4) Which of the following drugs may be useful in preventing or treating arrhythmias in hypothermic patients?
   a) Lidocaine
   b) Atropine
   c) Bretylium
   d) Nifedipine

5) All of the following patient factors must be present prior to the initiation of passive re-warming methods except:
   a) Intact thermoregulatory mechanisms
   b) Normally functioning endocrine system
   c) Sufficient glycogen stores to create endogenous heat
   d) Loss of consciousness
6) Which of the following is an example of active internal re-warming measure?
   a) Use of devices that expel warm air placed over the patient’s trunk 
   b) Inhalation therapy 
   c) Use of warm blankets 
   d) Warm water immersion

7) Which of the following is the most effective active internal re-warming method?
   a) Extracorporeal re-warming 
   b) Inhalation therapy 
   c) Administration of warm intravenous fluids 
   d) Body cavity lavage

8) Which of the following re-warming methods do not present a risk of core temperature after-drop?
   a) Use of blankets 
   b) Use of heating pads 
   c) Inhalation therapy 
   d) Warm water immersion

9) Which of the following measures are involved in the pre-thaw stage treatment of frostbites?
   a) Rapid re-warming 
   b) Administration prophylactic antibacterials 
   c) Removal of wet clothing 
   d) Psychological support

10) Eschars treated with surgical amputation.
    a) True 
    b) False
11) Which type of frostbite refers to an injury characterized by frozen tissue, hypoxia and general body dehydration?

   a) Frost nip
   b) 3rd degree frostbite
   c) Mountain frostbite
   d) 1st degree frostbite

12) Which drug emulates the actions of endogenous human antidiuretic hormone?

   a) Vasopressin
   b) Desmopressin
   c) Calcium chloride
   d) Nifedipine

13) Which drug is used as a prophylactic measure against digital amputations in severe frostbite injuries?

   a) Reserpine
   b) Bretylium
   c) Tetanus toxoid
   d) Alteplase

14) Hypothermic patients with stable hemodynamic need active external and minimally invasive re-warming which may include all of the following except:

   a) Placement in a warm environment
   b) Application of chemical, electrical, forced-air heating packs/blankets
   c) Initiation of CPB
   d) Administration of warm parenteral fluids.
INTRODUCTION

This Hypothermia Part II course briefly reviews and builds upon some of the key discussions in Part I on pre-hospital care, and more specifically covers the rapid response and interventions required of properly trained personnel in the field, during transport and in hospital. Aggressive management of hypothermia can lead to successful outcomes in many circumstances. Cardiopulmonary resuscitation should be initiated if a victim is found not breathing or has no pulse. Core heat loss prevention involves the immediate removal of wet garments and insulation of the victim, and the use of aggressive, continued warming measures once the patient arrives to the hospital, such as warmed centrally administered intravenous solutions, humidified air/oxygen, to help stabilize core temperature. Ongoing monitoring of the core temperature and cardiac rhythm following post-resuscitation and re-warming techniques is needed to address potential complications resulting from the physiological stress of hypothermia and re-warming. The decision to initiate pharmacologic therapy and treat complications arising during resuscitation efforts of a hypothermic individual requires a skilled physician and treatment team.

TREATMENT OF HYPOTHERMIA

Previously, it was explained how mild, moderate to severe hypothermia conditions lead to critical reduction of blood flow to the brain and other vital organs, which cause a person to appear lifeless. Although victims of hypothermia may appear dead, well-trained rescue teams in hypothermia accidents will begin full resuscitation in the pre-hospital setting that continues during transportation and in-hospital.

There are various causes of clinical hypothermia that must be considered; environmental exposure to cold or submersion in cold water as well as individual predisposition to low core body temperature, such as, due to age,
illness, and socio-economic status. Homelessness and drug/alcohol addiction are common causes of hypothermia in urban centers. Whatever the underlying cause of hypothermia, it’s important that lifesaving measures not be thwarted based on a victim’s clinical presentation; and, rather, medication interventions (discussed later in this study) based on resuscitation guidelines for hypothermia should ensue.

**Modified life support**

Some background to the development of modified life support is helpful to understand. Animal studies on the use of vasopressors in hypothermic cardiac arrest resulted in mixed findings. The European Resuscitation Council Guidelines advise a modified approach to advanced life support, which includes three defibrillations without epinephrine until the core temperature is greater than 30°C and with double intervals between doses until the core temperature is greater than 35°C.

Those recommendations do not coincide nor agree with the American Heart Association (AHA) guidelines, which state:

> “It may be reasonable to consider administration of a vasopressor during cardiac arrest according to the standard ALS (advanced life support) algorithm concurrently with re-warming strategies (4).”

As such, the use of up to three doses of vasopressors in hypothermic cardiac arrest and defibrillation is a rational move, with additional dosing dictated by the clinical response.

**Re-warming techniques**

There are four major types of re-warming techniques. Each one is outlined in the table below and discussed in detail in the succeeding pages.
<table>
<thead>
<tr>
<th>Re-warming technique</th>
<th>Methods</th>
<th>Re-warming rate</th>
<th>Advantages and limitations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Passive external</td>
<td>Blankets</td>
<td>0.5°C/h</td>
<td>Insulation. Effective only in mild hypothermia.</td>
</tr>
<tr>
<td></td>
<td>Spaced blankets</td>
<td>0.5°C/h</td>
<td>Only effective in mild hypothermia; half as effective as heating pads</td>
</tr>
<tr>
<td>Active external</td>
<td>Radiant heat</td>
<td>Variable</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Forced air re-warming device</td>
<td>1-2.5°C/h</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Warm blankets, heating pads</td>
<td>Variable</td>
<td>Risk of burns, temperature after-drop, and re-warming hypotension</td>
</tr>
<tr>
<td></td>
<td>Negative-pressure re-warming</td>
<td>Variable</td>
<td>Not readily available</td>
</tr>
<tr>
<td></td>
<td>Hands and feet in warm water</td>
<td>Variable</td>
<td>Easy to do, inadequate studies on effectiveness</td>
</tr>
<tr>
<td></td>
<td>Hot water bottles</td>
<td>Variable</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Warm water Immersion</td>
<td>2-4°C/h</td>
<td>Difficult to monitor patient; risk of temperature after-drop, and re-warming hypotension</td>
</tr>
<tr>
<td>Active internal</td>
<td>Warm/humidified air</td>
<td>0.5-1.2°C/h</td>
<td>Low heat transport capacity, reduced temperature after-drop risk when used with active external methods</td>
</tr>
<tr>
<td></td>
<td>Warm intravenous Fluids</td>
<td>Variable</td>
<td>More effective in large volumes, risk of fluid overload</td>
</tr>
<tr>
<td></td>
<td>Mediastinal, gastric, colonic, thoracic, peritoneal, bladder lavage</td>
<td>Variable</td>
<td>Limited studies, risk of mucosal injury, and aspiration with gastric lavage</td>
</tr>
<tr>
<td></td>
<td>Peritoneal dialysis</td>
<td>1-3°C/h</td>
<td>Use with heated oxygen</td>
</tr>
<tr>
<td></td>
<td>Open thoracotomy</td>
<td>Up to 8°C/h</td>
<td>Highly invasive</td>
</tr>
<tr>
<td>Extracorporeal</td>
<td>Hemodialysis</td>
<td>2-3°C/h</td>
<td>Widely available, requires trained dialysis nurse</td>
</tr>
<tr>
<td></td>
<td>Hemofiltration</td>
<td>2-3°C/h</td>
<td>Requires adequate blood pressure</td>
</tr>
<tr>
<td>Continuous arteriovenous re-warming (CAVR)</td>
<td>3-4°C/h</td>
<td>Rapid initiation, not readily available</td>
<td></td>
</tr>
<tr>
<td>------------------------------------------</td>
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<td>--------------------------------------</td>
<td></td>
</tr>
<tr>
<td>Cardiopulmonary bypass</td>
<td>7-10°C/h</td>
<td>Provide full circulatory support; requires trained perfusionist, less widely available, delays in initiation</td>
<td></td>
</tr>
</tbody>
</table>

**Passive re-warming**

Patients with mild hypothermia and presenting with core temperatures more than 32°C are recommended to be started on passive re-warming techniques. The end goal of passive re-warming is reduction of heat loss through convection, conduction, and radiation. Complication may arise during re-warming efforts, which is why certain patient factors must be considered prior to its initiation. These factors are (92):

- Patients must have intact thermoregulatory mechanisms,
- Patients must have normal endocrine function, and
- Patients must have sufficient glycogen stores to create endogenous heat.

Passive re-warming proceeds with the following steps:

1. Removal of wet clothing,
2. Patient insulation, and
3. Protection from the cold environment.

If possible, mildly hypothermic patients should be placed in an environment that is at least 21°C to avoid further heat loss. Since respiration naturally leads to heat loss, patients should be breathing in warmed and humidified air to prevent it. They should also be insulated using blankets, foil insulators or space blankets, or other types of insulation material available. Mildly
hypothermic patients have intact shivering mechanisms which allow these measures to warm the core body temperature 0.5°C-2°C/h. If patients are not shivering, they need to be actively re-warmed (93, 94).

*Active external re-warming*

Active external re-warming techniques are indicated for mildly hypothermic patients who fail to respond to passive re-warming, or for those who are moderately hypothermic. It involves the direct skin application of heat, which means the skin is in direct contact with the source of heat. This method is only effective given that blood circulation is intact to bring back warmed blood to the core.

A crossover study involving eight healthy patients found that active external re-warming is twice more rapid compared to passive re-warming (95). Devices that expel warm air are very useful in active external re-warming and permit continuous monitoring of the patient. These devices are ideally placed over the trunk (core) of the patients to warm them at a rate of 1°C-2.5°C/h. These devices do not pose a significant risk of core temperature *after-drop*, which is a continuous core temperature decline despite re-warming efforts (93, 94).

A prospective, randomized trial compared sixteen patients re-warmed from temperatures lower than 30°C with cotton blankets and forced air re-warming devices. The results showed that patients re-warmed using forced air re-warming devices were re-warmed at a rate of 1°C/h faster than patients warmed with cotton blankets alone (93). A separate but similar study drew comparisons between eight patients who were re-warmed with forced air devices and those with inhalation re-warming. The patients were cooled three times separately and administered with meperidine to inhibit shivering. Patients who were re-warmed with forced air devices did so at a rate of 2°C/h
faster compared to those who were warmed using the inhalation re-warming method (94).

The American Society of Anesthesiologists (ASA) recommends forced air re-warming devices in the treatment of hypothermia and maintenance of normothermia in post-operative patients during emergence from general anesthesia and during the recovery phase (96). A prospective study by anesthesiologists found that forced air re-warming was more effective in maintaining normothermia intra-operatively than no intervention at all (97). Another meta-analysis found intra-operative normothermia is best maintained using forced air-warming methods (98).

Other methods of active external re-warming include the use of the following:

- water blankets
- warm blankets
- warm water bottles
- heating pads, and
- warm water immersion

Rescuer and emergency responders must be careful when using these techniques on hypothermic patients, since they can injure the dermis layer of the skin. Ideally, these devices should warm patients at temperatures ranging from 40°C to 45°C (99). Additionally, they should also warm the core (trunk) and extremities of the patients to avoid temperature after-drop and the onset of re-warming acidosis. Rewarming acidosis, explained in Part I, is an outcome of re-warming efforts as the products of anaerobic metabolism are brought back into the blood, which can compound the risk of arrhythmias. These two adverse effects, temperature after-drop and re-warming acidosis, have been associated with poor outcomes (68, 101). These methods should be used in conjunction with internal re-warming methods such as the administration of warmed intravenous fluids and warm humidified air to reduce the incidence of re-warming complications.
Ultimately, these patients should receive sufficient volume resuscitation (100). There is one exception to the core re-warming first rule, as in the case of arteriovenous anastamosis (99).

**Active internal re-warming**

Active internal re-warming techniques are indicated in patients with severe hypothermia or compromised cardiovascular function. These techniques include:

- Use of warm humidified inhaled air (inhalation therapy),
- Use of warm fluid lavage of body cavities, and
- Administration of warm intravenous fluids.

The most effective active internal re-warming technique is called *extracorporeal warming* and is discussed later in detail in a separate section.

To date, there are no comparative studies done on the different active internal re-warming methods. However, medical consensus recommends the use of warm humidified air (inhalation therapy) and warm IV fluids on all hypothermic patients whenever available. These two methods are associated with the least side effects. Humidified oxygen warmed to a temperature of 42°C can increase the core body temperature at a rate of 0.5-1.2°C/h. It can also decrease heat loss caused by evaporation from the skin (25). Other benefits of inhaling warm and humidified oxygen include:

- Rehydration
- Stimulation of mucociliary activity in the respiratory tract, and
- Direct heat transfer from the upper airways to the hypothalamus, brain stem, and other brain structures

When the respiratory and cardiovascular centers are sufficiently warmed with warm and humidified oxygen, the result is a more stable cardio-respiratory system, even in the face of consistently decreased total body heat content. In fact, some anecdotal reports found that the use of warmed and humidified
oxygen in hypothermic patients in the field significantly enhanced the pulse rate and mental state within 20 to 40 minutes of administration. These results are consistent with this therapy of effectively warming the brain stem and other brain structures in the absence of significant elevation of core body heat content. However, the clinical benefit may have also been due to enhanced oxygenation. In light of all these, inhalation therapy should be administered as soon as possible, either singly or in combination with other invasive or noninvasive measures.

Resuscitation intravenous fluids warmed to approximately 40°C can warm hypothermic patients with very little complications. The rate of warming is based on the rate of infusion. Certain animal studies found intravenous fluids warmed up to 60°C and administered centrally to be effective in warming hypothermic patients. However, no similar studies are done on humans (102).

Admittedly, the temperature of intravenous fluids warmed as high as 40°C may cause endovascular injury due to protein denaturation. In the peripheral tissues, the temperature of body fluids should not be greater than 40°C. Intravenous fluids are ideally warmed using a blood warmer as opposed to using a microwave since the latter can generate fatal temperature differentials within the fluid bag (103). After administration, rescuers and emergency responders must monitor the patient for signs of fluid overload such as pulmonary edema. If extracorporeal re-warming cannot be administered, active internal re-warming may be performed through placement of warmed fluids into various body cavities (lavage) such as:

- Mediastinal
- Gastric
- Colonic
- Thoracic
- Peritoneal, and
- Bladder lavage
Multiple case reports of re-warming rates via mediastinal lavage suggest its rate to be about 8ºC/h. One primary drawback of this method is its high degree of invasiveness and potential to cause vascular injury and infections. On the other hand, many studies have demonstrated its significantly low rate of infection with emergency thoracotomy.

Gastrointestinal lavage involves the infusion of warmed fluids through a tube positioned in either the colon or stomach. The majority of published report is centered on gastric lavage. Usual methods involve the delivery of fluids heated to 40ºC into the stomach in aliquots of 200-300 mL. After 15 minutes, the fluid is suctioned out or drained via the actions of gravity. This procedure is repeated until the patient has been warmed to sufficient temperature.

Proponents of gastric lavage point out its advantages, which are listed below:

- Easy and rapid set-up
- Preferential warming of the liver
- Speed up metabolism of drugs and lactate, and
- Selective warming of the heart due to its close proximity to the organ

Conversely, some medical experts have also pointed out its drawbacks, such as:

- Greater risk of aspiration due to the tracheal intubation required before fluid irrigation into the stomach;
- Fluctuating serum electrolyte concentrations caused by high volume irrigation;
- Required cessation of the procedure during the administration of CPR
- Potential risk of ventricular fibrillation during placement of the gastric tube, and;
- Unlikely provision of adequate heat transfer owing to the relatively small gastric surface area.
Animal studies have shown re-warming rates using gastric lavage to be at 3ºC/h. These studies also demonstrate lack of morbidity.

A closed thoracic lavage requires the placement of two thoracostomy tubes; the first tube in the midaxillary line at the 2nd to 3rd intracostal space for warm saline infusion and the second tube in the lower mid clavicular line for continuous outflow. An open thoracic lavage is another option. Experts advocate its use in severely hypothermic patients with cardiac arrest since the procedure permits cardiac massage. Studies have found it to be capable of elevating the core body temperature as high as 8ºC/h.

A retrospective review found hypothermic patients in cardiac arrest that had an open thoracic lavage to have better survival rates than those who only underwent cardiopulmonary bypass (CPB). However, it should be noted that these findings do not automatically mean that open thoracotomy is more effective than cardiopulmonary bypass since the review was non-matched and non-randomized. The results put forward the strong potential efficacy of open thoracotomy lavage. Like cardiopulmonary bypass, the procedure is highly invasive, associated with high risk for morbidity or mortality.

Peritoneal lavage involves irrigation of the relatively expansive surface area of the peritoneal cavity and the stomach to achieve heat transfer from warmed fluids. This procedure usually involves the use of normal saline (NS) or lactated ringer’s (LR) solution, which are heated to temperatures ranging between 40-45ºC and then infused via a peritoneal catheter. The fluid is usually maintained in the cavity for a period of 20 minutes to half an hour, until it is removed through aspiration. The catheter is placed using either an
open or Seldinger technique. Before its insertion, the bladder and stomach need to be emptied. To facilitate rapid re-warming, a second catheter may be placed for fluid drainage. Some clinicians advise inserting four catheters, with each one placed in each abdominal quadrant, and employing two for infusion of fluids and the other two for drainage.

Proponents of peritoneal lavage point out its advantages, such as:

- Preferential re-warming of the liver;
- Dual administration with CPR, and
- Potential to filter off drugs and toxins.

On the other hand, its drawbacks include the following:

- Relatively invasive nature of the procedure, and;
- Requirement of expert placement of the peritoneal catheter to avoid internal injuries to the abdominal area.

Animal studies suggest re-warming rates with peritoneal lavage to be between 3-6°C/h. Human data suggest re-warming rates to be between 1-2°C/h.

*Extracorporeal re-warming*

Extracorporeal re-warming is the most effective active internal re-warming method for hypothermic patients. In addition, it is also the most rapid method of re-warming such patients. Examples of extracorporeal re-warming include:

- Hemodialysis
- Hemofiltration
- Continuous arteriovenous re-warming (CAVR)
- Continuous venovenous re-warming (CVVR), and
- Cardiopulmonary bypass (CPB)

Among the four methods, perhaps the most widely available is hemodialysis. It is capable of elevating the core temperature at a rate of 2-3°C/h (104, 105, 106, 107). Ideal candidates for this method include those with sufficient blood
pressure. Continuous arteriovenous re-warming (CAVR) is a straightforward method that does not need a lot of equipment and set-up. It warms the blood by using blood pressure to drive it through a small counter current heat-exchanging device (108). It can warm the core temperature at a rate of 3-4°C/h (58). This method is discussed later under the topic, *Controversial modalities and techniques*.

On the other hand, continuous venovenous re-warming (CVVR) is also easy to set up and less invasive than CAVR (104, 107). An animal study found CAVR to provide a faster rate of re-warming compared to CVVR, although both methods are effective in re-warming hypothermic patients (109).

Another method of extracorporeal re-warming is cardiopulmonary bypass (CPB). This method can elevate the core body temperature at a rate of 7-10°C/h. It also supports the circulation, and prevents cardiac trauma through cardiopulmonary resuscitation or open thoracotomy massage (110, 111). To date, there are no ongoing controlled trials investigating the efficacy of cardiopulmonary bypass against other extracorporeal re-warming methods; however, some published case reports exhibit a positive prognosis following cardiac arrest.

A study conducted in Finland found a 61% survival rate in 23 patients following an average cardiac arrest time of 70 minutes using cardiopulmonary bypass. These patients underwent complete cardiac arrest and required cardiovascular support and re-warming (112). A similar study found a survival rate of 47% in hypothermic patients with an average temperature of 21.8°C and a mean down time before cardiopulmonary bypass was initiated of 2.5 hours. A follow up of these patients during a 7-year period found no
significant sequelae (113). A similar study involving Mount Hood (Oregon) hypothermia survivors found a similar prognosis with cardiopulmonary bypass (114). Patients of hypothermia-induced cardiac arrest can benefit the most from cardiopulmonary bypass since it effectively re-establishes the circulation and re-warms the blood.

There are several case reports demonstrating the efficacy of cardiopulmonary bypass (115). For example, a case report published in 2007 showed complete recovery of an asystolic hypothermic (to 23.8°C) 2-year-old toddler following cardiopulmonary bypass (116). Compared to other re-warming methods, cardiopulmonary bypass re-warms the blood the fastest while maintaining oxygen supply and blood flow for hypothermic patients under cardiac arrest (117). This is why this is the preferred method of resuscitating such patients. Conversely, pleural lavage can also be effective in similar cases. However, there are currently no studies directly comparing these two extracorporeal re-warming methods.

In addition, some evidence has pointed to the unnecessary use of cardiopulmonary bypass in patients with a pulse. For example, a study in Vienna published in 2002 showed a successful conservative treatment of deep hypothermia with or without constant hemodynamics. The study focused on 36 re-warmed patients with a median temperature of 25.6°C, employing warmed infusions, inhalation re-warming, and forced air re-warming modalities. The results showed that a 92 percent success rate (re-warmed to normothermia), and an in-hospital mortality of 42 percent which was primarily attributed to comorbidities. These results suggest adequate re-warming using conservative methods in such patient groups. However, these results failed to show a clear correlation of this particular re-warming technique on late in-hospital mortality (118).
Other treatment considerations

Healthy patients without complications and comorbid factors should be re-warmed rapidly. Conversely, those with poisoning complications or comorbid infection generally re-warm at a slower rate, usually <1°C/hour, because of reduced inherent capacity for thermogenesis. Achieving a normal body temperature in these patients does not essentially prevent or reduce mortality. This is why re-warming patients is not a sufficient treatment modality, and other general considerations need to be taken such as the detection and treatment of underlying illness or precipitating factors (119).

One good example of underlying illness is hypoglycemia. It should be monitored using a bedside glucometer, if available, or the patients given dextrose because it is most likely that their glycogen stores are exhausted.

Detecting hypoglycemia can be challenging since hypothermia can conceal its signs and symptoms.

Vitamin B1 may also be given empirically since another precipitating factor to hypothermia, although less often, is alcohol or drug intoxication (104, 120).

As mentioned previously, high blood alcohol levels in an altered hypothermic patient are at greater risk of aspiration. If supplementary history is unavailable, clinicians and emergency responders should be alert for the signs and symptoms of alcohol withdrawal.

The majority of patients presenting with hypothermia may be suffering from severe dehydration resulting from cold diuresis and exhibit high levels of serum sodium and osmolality. Patients with hypothermia lasting more than 45 minutes generally need fluid resuscitation due to the expansion of the vascular space caused by vasodilatation (92). In cases where there is a history of adrenal insufficiency or failure to re-warm sufficiently despite non-
conservative re-warming techniques, steroids may be administered empirically.

Patients who are most susceptible to hypothermia complications, such as the homeless, neonates, and the elderly, need empiric broad-spectrum antibiotic treatment. A study involving 96 hypothermic patients found that the re-warming rates were a reflection of the patient’s inherent capacity for thermogenesis. Those who had comorbid infectious diseases responded poorly to re-warming (119). Another study involving 59 adults confined to Bellevue Hospital, New York, between 1968 and 1979, due to hypothermia, found that 24 of them had serious infections. Nine of these infections were not known at the time of admission and contributed to the rise in morbidity and mortality (121). Thus, it is important for peripheral blood cultures to be drawn before starting empiric antibiotic therapy.

During the course of re-warming therapy, patients should be observed carefully for their response to it. Regardless of the elected re-warming method, patients must be kept under surveillance during and after re-warming for possible complications. A study involving 20 patients showed that the administration of the drug, desmopressin, resulted in the partial reversal of hypothermia-induced dysfunction of primary hemostasis in vitro. The study suggested its potential use in stabilizing hemodynamics in hypothermic patients with hemorrhage where instant re-warming is hard to achieve or unwanted.

In the study mentioned above, all patients had their whole blood cooled to 32°C, followed by the measurement of their coagulation time. This data was then compared to the same blood at 37°C. Coagulation time was then measured following administration of different doses of desmopressin compared to saline placebo. The results showed that desmopressin improved coagulation time, which is promising. Although the study needs to be performed in vivo, the results offer a possible life-saving therapy in
hemorrhaging, hypothermic patients who do not require rapid re-warming techniques (122).

**Anoxic injuries**
Past studies have demonstrated patients who suffered from asphyxia before the onset of hypothermia (e.g., burial avalanches or cold water immersion) have poorer treatment outcomes. A study published in 2001 reported the observation of 26 accidental hypothermic patients who also sustained circulatory arrest or major circulatory failure and re-warmed to normal body temperature through extracorporeal circulation. Fifteen of these patients were reported to have asphyxia before the onset of hypothermia. Out of this number, only one patient survived to discharge, and had severe neurologic dysfunction. Out of the eleven patients with no asphyxia, only 7 survived without significant impairment (84).

Generally speaking, hypothermic patients with no asphyxia have better treatment outcomes than those with asphyxia. A popular theory behind this difference in prognosis is the development of hyperkalemia in those patients who sustained an anoxic episode (123, 124).

The Alaska guidelines recommend foregoing resuscitation efforts in those submerged for more than one hour (125). This recommendation is particularly important for pediatric patients since they are especially prone to drowning accidents. A study of 12 pediatric patients who sustained cold-water immersion and hypothermia with cardiac arrest found them to have better prognosis than those with lower core temperatures at the start of extracorporeal circulation. Of the twelve patients, nine survived with the lowest temperature recorded at 16°C and time in the water unknown.

Pediatric patients, even those who sustain immersion injuries, must receive continuous resuscitation until they are sufficiently re-warmed. As mentioned previously, cardiopulmonary bypass is the best resuscitation modality, where
available (126). Conversely, there is insufficient data to establish treatment recommendations for adult hypothermic patients who sustained asphyxiation episodes.

**Trauma**

Hypothermia provides protective benefits for patients who sustained head injuries, cardiac arrests, and shock (56). However, there is also evidence that suggests a strong correlation between hypothermia and poor prognosis in trauma patients with bleeding. Hypothermia occurs as a form of secondary, unintentional hypothermia in trauma patients. Its presence is both a marker of, and a contributor to, poor prognosis. Patients with trauma and core temperatures less than 32°C have a 39 percent risk of mortality based on a retrospective analysis of the 2004 national trauma data bank (127).

It is important to note that hypothermia can set in, not just from external cold stressors, due to:

- The cold environment of the emergency rooms
- Use of cold fluid for resuscitation
- Open body cavities, and
- Dysfunctional thermogenesis brought on by lack of oxygen delivery to the tissues

As mentioned previously, greater morbidity and mortality rates in hypothermic patients are due to comorbid conditions, such as:

- Platelet dysfunction
- Induction of coagulopathy, and
- Aggravated acidosis
Consequently, core temperature after-drop should be minimized and re-warming efforts initiated in hemorrhaging trauma patients in the emergency room.

On the other hand, there is a new field of trauma resuscitation research that is focused on *inducing* severe hypothermia in trauma patients. It involves placing critically injured and under cardiac arrest trauma patients on cardiopulmonary bypass upon their arrival in the emergency room and cooled down to severely hypothermic temperatures (128).

**Controversial modalities and techniques**

*CPR in hypothermic patients*

The benefit of cardiopulmonary resuscitation (CPR) in hypothermic patients is undergoing controversy. The American Heart Association (AHA) in 2005 recommended the initiation of chest compressions in cases where the presence of a pulse is in doubt (129). However, there is a consensus of medical opinion regarding the challenge of palpating a pulse in the cold, stiff hypothermic patient. Additionally, considering that the metabolic requirements of hypothermic patients are extremely low, there is mounting evidence suggesting a strong possibility of an organized rhythm being an actual perfusing rhythm, a sign of life. In fact, it is very possible that the organized pulseless electrical activity (PEA) afford sufficient cardiac squeeze to perfuse the hypothermic body.

Currently, there are conflicting opinions on the type and degree of movement such as CPR administered to hypothermic patients, which can precipitate ventricular fibrillation. Nevertheless, there is strong evidence that ventricular fibrillation in hypothermic patients can be unmanageable despite defibrillation attempts (58). It is important to note that the hearts of hypothermic patients generally fail to respond to cardioactive drugs. Moreover, metabolic activity is decreased in such patients necessitating the withholding of their
administration to circumvent toxicity reactions. In fact, the American Heart Association (AHA) advises clinicians to withhold the administration of cardiac drugs until the core body temperature is at least 30°C. It also advises clinicians to administer such drugs with longer intervals (129). As mentioned previously, bretylium tosylate 5 mg/kg has exhibited anecdotal benefit in the treatment of hypothermia-induced ventricular fibrillation, although this finding was never validated (134).

**Core temperature after-drop**

Core temperature after-drop refers to the phenomenon of systemic vascular collapse characterized by continuous hypothermic condition despite aggressive re-warming efforts. This is also a possible complication stemming from the use of active external re-warming methods. Currently, there are two proposed explanations for the phenomenon of core temperature after-drop:

1. Certain medical experts agree that re-warming of the peripheral extremities using active external methods causes cold acidic blood to return to the core (trunk) leading to the additional decline in core temperature and deteriorating acidosis state. Additionally, the peripheral vasodilatation can cause circulatory collapse (101), which in turn, can add to the risk of hypothermic patients developing potentially life-threatening ventricular arrhythmias (130).

2. The second explanation blames insufficient fluid resuscitation combined with volume contraction, which leads to circulatory collapse. Exposure to cold temperatures triggers vasoconstriction, cold diuresis, and cellular swelling, all of which may lead to volume reduction which can ultimately cause severe hypotension and shock. Experts who put forward this
explanation rely on the animal studies, which found a strong correlation between core after-drop and circulatory collapse, regardless of the return of cold, acidic blood (100).

**Microwave-warmed fluids**

The use of microwaves to warm resuscitation is not typical; however, certain medical facilities are not fully, if at all, equipped with IV fluid warmers. In cases like these warming fluids using a conventional microwave oven becomes an inexpensive option. In fact, there have been many studies that showed the efficacy of such method of warming intravenous resuscitation fluids prior to their administration to hypothermic patients (103, 131, 132). One study advised using caution when it comes to using a microwave that is not sufficiently calibrated (133).

Ideally, intravenous fluids should not be warmed more than 40°C due to the risk of endovascular damage (131). Leaman, et al. studied the use of a microwave in warming packed red blood cells (PRBC) and their findings strongly suggested that it caused hemolysis (103). Additionally, microwave ovens do not offer uniform heating, necessitating the need for shaking the fluids in their containers and their subsequent temperatures measured prior to administration through infusion. Ultimately, this method of warming intravenous fluids may come useful in ill-equipped facilities, though it should be used carefully.

**Arteriovenous anastomoses re-warming**

A novel method of administering active external re-warming is through the use of the arteriovenous anastomoses by immersing the peripheral extremities in water warmed to 45°C. It permits the return of warmed venous blood to the core (trunk) (134). One study compared the outcomes of patients whose hands and feet were immersed in water and re-warmed from 34.3°C to 42°C or 45°C water. Patients who were re-warmed in the 45°C did so at a rate of 9.9°C/h compared to 6.1°C/h in those re-warmed in 42°C water.
Conversely, the rectal temperature showed significant delays in the temperature readings compared to the esophageal and aural canal readings. This means that wide temperature gradients may exist (99).

On another note, a warmed negative pressure device that is applied to the forearm is available and under investigation to make the same measurements (134). However, this method can also add to the incidence of core after-drop, although this may be prevented using adequate fluid resuscitation instead of initial core re-warming, as discussed previously.

An endovascular device, another novel re-warming method, was apparently used for the first time in a case report to warm a patient with severe hypothermia. The temperature control system is the same system employed in the induction of resuscitative hypothermia for surviving trauma patients or those under cardiac arrest. The system was able to re-warm the patient at a rate of 2.8°C/h, which was stopped following successfully bringing the patient’s temperature to 37°C. The report stated a positive hemodynamic recovery by the patient, which then necessitated its withdrawal due to poor neurologic prognosis.

Currently, there are many emergency rooms across the country that have endovascular re-warming devices installed to provide cooling treatments and provide a less invasive, but more effective, alternative to pleural lavage in facilities which not possess extracorporeal re-warming equipment. Since these devices are rapidly being installed and used in many facilities, their widespread use in providing therapeutic cooling will become generally accepted, especially since they do not require a special team to operate them. As of the moment, the only apparent disadvantage with these devices when compared with cardiopulmonary bypass is their requirement for patients to have pulses (135).
Disposition

Because hypothermia is a grave condition accompanied by several possible complications due to the number of physiologic dysfunctions that happen, many of its victims need hospital confinement, usually to the intensive care unit (ICU). A retrospective study of 47 patients admitted to the ICU diagnosed with accidental hypothermia found that the sole variable associated with a rise in mortality rate was the administration of vasopressors during patient resuscitation. In fact, it also recognized many prognostic factors for the 18 patients who died versus the survivors, such as:

- Age
- Systolic blood pressure
- Blood bicarbonate level
- SAPS II score
- Employment of mechanical ventilation
- Administration of vasopressor drugs
- Re-warming time
- Time of discovery of the patient, and
- The initial temperature

The initial temperature did not have any bearing on the overall outcome. However, the administration of vasoactive medications was identified as a prognostic factor in the multivariate analysis. This means that the finding of shock, which requires the administration of vasoactive drugs, is an independent factor for mortality, while initial temperature, on the other hand, is not (136).

Only those patients with mild hypothermia, with initial core temperatures more than 32°C, were discharged after successful re-warming efforts. On another note, these patients must not be discharged if they exhibit any resistance to passive external re-warming methods, have unclear etiology for their hypothermia, or signs of underlying complications such as infections or
thyroid dysfunction. Conversely, patients with moderate to severe hypothermia require immediate hospital confinement, typically into the intensive care unit (ICU) to accommodate their requirement of constant medical surveillance.

Re-warming is usually carried out over a protracted period, often initiated prior to hospital arrival and remaining incomplete even before the relocation from the emergency room. In fact, even the fastest re-warming methods such as cardiopulmonary bypass only re-warms at a rate of 4-7°C/hr (58). Additionally, hypothermic patients require round the clock surveillance for the onset of a variety of possible complications during or after re-warming. Examples include:

- Delayed hypotension
- Arrhythmias
- Hypoglycemia
- Hyperkalemia
- Bleeding diathesis
- Rhabdomyolysis
- Extremity injuries, and
- Infection

Patients who exhibit delayed response to re-warming techniques must be investigated further and treated empirically for possible underlying etiologies for their hypothermia. Some of the frequently cited underlying etiologies include:

- Myxedema coma
- Adrenal insufficiency, and
- Infection

Usually, the greatest challenge regarding the disposition of hypothermic patients is the duration of resuscitation. Owing to the unique pathophysiology
of the condition, the resuscitation of such patients that exhibit an absent pulse and reduced cardiac activity can be successful. Because of this, all hypothermic patients must be completely resuscitated regardless of the absence of signs of life until their core temperature has risen to above 30°C (92, 137). However, as mentioned previously, there are exemptions to this, including (68):

- Apparent fatal injuries
- A signed do not resuscitate order (DNR) or
- A severely frozen patient for which resuscitation is impossible

**Treatment of frostbites**

In any case, the treatment of hypothermia precedes that of frostbites and trench foot (5). Treatment of frostbites is focused on salvaging healthy tissues through the reversal of the damaging effects of severe cold on tissues and subsequent inflammatory responses. It proceeds in three stages (5):

1. Pre-thaw stage
2. Hospital care stage
3. Post-thaw stage

**Pre-thaw stage**

The focus of the initial stage of frostbite treatment is prevention of thawing and re-freezing, a recurring process that amplifies tissue damage. To prevent this, the injured area should not be exposed to external dry heat sources as it can further dehydrate and partially thaw the frostbite (5).
It is during the pre-thaw stage that wet clothing is removed from the site of injury. If frostbites occur within a city where hospitals are easily reached, thawing attempts in the field must be avoided. The site of injury needs to be covered loosely with cloth and splinted to avoid further tissue damage. Once this is done, the site of injury must be kept immobilized as much as possible; it must not be massaged with snow or warm hands to prevent further mechanical trauma. Additionally, when attempting to re-warm the patient, heating pads or heat lamps must be avoided since the site of injury is desensitized and cutaneous burns can happen (5).

Many patients with frostbite may also be dehydrated. This is why it is important to administer oral or intravenous fluids to enhance the blood flow. As mentioned previously, the re-warming procedure can be very painful, necessitating the use of parenteral analgesics (5).

**Hospital care stage**

Once patients arrive at the hospital, the clinicians must shift the treatment focus towards rapid re-warming. The injured area needs to be sufficiently warmed to temperatures ranging between 40-42°C. Next, as a prophylactic measure to infections, mild anti-bacterials such as hexachlorophene or povidone-iodine may be considered (5).

Frostbites are painful, making the re-warming procedure sometimes intolerable without the use of pain medications such as narcotics. Re-warming should be stopped once the skin attains a pliable texture and reddish-purple hue (5). Ideally, the successful completion of re-warming must be followed by sustained immediate treatment of frostbite injuries to prevent further tissue damage. However, this does not always happen, especially with homeless patients.
To date, there are no existing clear guidelines for the immediate treatment of frostbite following rapid re-warming. However, many clinicians have commonly used the McCauley’s protocol for several years. It proceeds as follows (5):

- Debridement of white blisters
- Application of topical aloe vera every 6 hours to avoid thromboxane production
- Keeping bloody or hemorrhagic blisters intact and undisturbed
- Splinting and elevation of the frostbitten area
- Prophylactic administration of tetanus vaccine
- Administration of intravenous narcotics (whenever required)
- Administration of oral ibuprofen 400 mg every 12 hours
- Prophylactic administration of intravenous Pen G 500,000 units every 6 hours for 48-72 hours to prevent streptococcal infection during the edema phase
- Daily hydrotherapy for 30-45 minutes at 40-42°C; and
- Smoking cessation

Patients should stop smoking since nicotine causes vasoconstriction and can worsen the tissue injury. Surgery is usually not necessary in treating frostbites unless it is accompanied by compartment syndrome (5).
Aloe vera enhances tissue salvage because of its multiple actions on the frostbite injury, leading to better outcomes. It exerts antioxidant, anti-thromboxane, and antibacterial effects. Its anti-thromboxane effects are critical to the healing of the wound since thromboxane aggravates inflammation (5).

**Post-thaw care stage**

The post-thaw care stage is focused on two primary issues (5):

1. Prevention of secondary infection, and
2. Psychological support particularly for those with severe frostbite awaiting auto-amputation of digits or fingers.

Eschar formation occurs in severe frostbites, approximately 9-15 days after incurring a cold injury. A hard, black, and leathery tissue characterizes it. Approximately 3-6 weeks after the injury, a demarcation of the gangrenous tissue occurs, making way for the separation of the viable from the non-viable eschar. During this period, patients must be carefully inspected for the appearance of pus discharge, an indication of cellulitis or a deeper infection of the bone such as osteomyelitis (5). Eschars are usually treated surgically. An incision or excision is usually sufficient (5).

Mild wounds such as shallow ulcers formed by blisters require daily treatment. It can include the application of thin coats of topical silver sulfadiazine followed by clean dressing changed two times a day. This routine protects the ulcer and rapidly dries it (5). Conversely, severe frostbites are known to cause exceptionally painful peripheral neuropathy. In cases like these, narcotics are usually needed to manage the nerve pain. As the wound heals, the dose of the narcotic used is usually tapered.

On another note, a non-narcotic neuropathic pain medication that can be used off-label is gabapentin. A potential novel treatment method involves the
administration of tissue plasminogen activator (TPA) to improve perfusion and reduce the incidence of amputation (5).

**Amputation**

The old adage, *frozen in January, amputate in July* holds true. Even when amputation is indicated, clinicians must only amputate those tissues that are clearly non-viable. Above knee or below knee amputation is generally required for one or more gangrenous toes. This is because the peripheral circulation is severely compromised which in turn will not be able to support the healing of distal amputation wounds. Severe frostbites can cause more than just neuropathic pain; it can cause auto-amputation In fact, the majority of fingers and toes that sustained severe frostbites are known to mummify and auto-amputate in 21-42 days following initial injury.

There have also been reports of this occurring far later during the recovery process. To prevent the delayed agony of waiting for this critical period to pass, some imaging modalities have emerged as useful in accurately measuring the severity of tissue damage within the 7-14 days of injury. For example, technetium scintigraphy and magnetic resonance imaging have become potential approaches to guide early clinical decisions, including the use of surgical intervention (5).

Other common complications of frostbite are (5):

- Residual pain
- Cold and heat intolerance
- Hyperhidrosis
- Atrophy of the skin, and
- Skin pigment alterations
Other less common complications include phantom pain, which can occur many months after auto-amputation of toes or fingers. This is due to the severed nerves caused by auto-amputation. Patients with such complaints may be sent in for further medical evaluation, and if qualified, can undergo spinal cord stimulation. The procedure involves the direct placement of a tunneled wire in the spine, under the skin to a transducer. The presence of this embedded device allows patients to autonomously treat the pain by stimulating their spine whenever the pain occurs (5).

**Treatment of trench foot**

Treatment of trench foot requires keeping the affected foot warm, clean, and dry. Once that’s been achieved, the affected foot must be elevated.

The injured tissues of the foot usually die and shed off. Severe cases of trench foot can result in painful blisters and gangrene, although massive tissue loss is unusual and usually only happens when the duration of cold exposure was exceptionally long before rescue (138).

**Treatment of chilblains**

Treatment of chilblains is supportive. They usually heal on their own once cold exposure is terminated. They do not cause any permanent damage. Preventive measures include wearing appropriate warm gloves and socks, and staying out of the cold. European emergency rooms have used calcium-channel blockers such as nifedipine. Nifedipine causes vasodilation of the small blood vessels that have constricted in response to cold stimuli. The same drug can be used to prevent the recurrence of chilblains. Topical steroid formulations are usually not recommended anymore.
Treatment of frostnip
Frostnip is mild frostbite. It is a sign of impending frostbite. It can be easily treated in the field, prior to hospital arrival. Blowing into hands cupped around it may warm an affected nose. Affected hands may be tucked in the armpits (139).

Treatment of burial avalanche
Pre-hospital care of victims of burial avalanche starts with gentle extrication, followed by constant core temperature and electrocardiogram monitoring. Victims with no apparent pulse, a patent airway and a core temperature more than 32°C should receive continuous cardiopulmonary resuscitation (CPR) and be transported to the nearest hospital with extracorporeal re-warming facilities.

Treatment of cold water submersion
The treatment of cold-water immersion is similar to other cases of hypothermia. The number one cause of mortality in cold-water immersion is the first shock of cold water on the body. To increase the chances of survival, victims are advised to:

- Avoid inhaling water
- Stay afloat
- Keep head above water, and
- Wear a life jacket at all times, if available.

TRANSPORT TO HOSPITAL
This section highlights the importance of an efficient rescue and transport system to transfer exposed hypothermic victims to a nearby hospital appropriately equipped to treat frostbite and other exposure injuries.
**Frostbite injuries**

Patients with severe frostbite injuries must be transferred to another facility if treating personnel in the current facility are not familiar with the management of such cold injuries and their sequelae.

In some hospital settings, burn units possess management expertise required in addressing severe frostbite injuries. A study reported 29% of homeless patients who were admitted to a burn unit were in fact admitted for frostbite injuries. As such, the decision to transfer to a facility with a burn unit may prove to be helpful for patients with severe frostbite injuries.

Patients who are on Swiss staging system HT I stage of hypothermia may be treated in the field in the absence of significant injury or brought to the nearest hospital if re-warming is not a feasible option in the field. Conversely, those with impaired consciousness, such as those on stages HT II, HT III or HT IV, require hemodynamic stability assessment. As mentioned previously, hypothermic patients that are stable hemodynamically need active external and minimally invasive re-warming. Some examples include:

- Placement in a warm environment
- Application of chemical, electrical, or forced-air heating packs or blankets, and
- Administration of warm parenteral fluids

Hypothermic patients who exhibit unstable hemodynamics prior to hospital arrival require immediate transportation to a medical facility with extracorporeal membrane oxygenation (ECMO) or cardiopulmonary bypass (CPB) capabilities, unless comorbid conditions such as trauma mandate rapid transportation to the closest hospital. A systolic blood pressure below 90 mmHg is a sensible pre-hospital approximate of cardiac instability.

Hypothermic patients with cardiac arrest in a remote area may require extracorporeal oxygenation or cardiopulmonary bypass. To guide this
decision, the serum potassium concentration of patients may need to be measured, ideally at an intermediate hospital. If rescuers decide to stop at an intermediate facility so serum potassium level can be measured, the one that is en route to the hospital that can provide extracorporeal membrane oxygenation or cardiopulmonary bypass must be chosen. A serum potassium concentration greater than 12 mmol per liter may require rescuers to consider cessation of cardiopulmonary resuscitation efforts. On the other hand, if transport time is inevitably long, rescuers should consider employing mechanical chest-compression devices because it helps in conserving their energy, promotes safety, and can enhance overall patient outcomes. Additionally, the destination hospital needs to be informed in advance to make sure that extracorporeal membrane oxygenation or cardiopulmonary bypass is available. In remote regions, the transport adviser needs to carefully weigh the risks against the benefits associated with longer transport time.

**PROGNOSIS**

The rate at which a body cools differs widely between individuals and depends on many factors. These are identified below:

- Body size
- Age
- Gender
- Water and air temperature
- Waves
- Wind
- Water currents, and
- Other factors

The survival chances (measured in time) of an average sized adult that is lightly clothed, in most situations, is demonstrated in the table below:
<table>
<thead>
<tr>
<th>Situation and equipment</th>
<th>Survival time in the cold water</th>
</tr>
</thead>
<tbody>
<tr>
<td>Drown-proofing without life jacket</td>
<td>1.5 hours</td>
</tr>
<tr>
<td>Treading water without life jacket</td>
<td>2 hours</td>
</tr>
<tr>
<td>Swimming with life jacket</td>
<td>2 hours</td>
</tr>
<tr>
<td>Holding still with life jacket</td>
<td>2.7 hours</td>
</tr>
<tr>
<td>H.E.L.P. position with life jacket</td>
<td>4 hours</td>
</tr>
<tr>
<td>Huddling with others with life jacket</td>
<td>4 hours</td>
</tr>
<tr>
<td>Wearing insulated flotation jacket</td>
<td>3-9 hours</td>
</tr>
</tbody>
</table>

To increase the chances of survival in cold water, victims are advised to:

- Wear a personal flotation device (PFD)
- Adopt a survival position
- Keep clothing on
- Remain still and in place unless a floating object, another person, or the shore is nearby, and
- Keep a positive mental outlook

As mentioned previously, victims are better off remaining still than attempting to swim through unknown waters. Remaining still conserves energy and thus, body heat. Wearing a personal flotation device such as a life jacket when out in a boat in the open seas or waters is essential in case accidents happen. On the other hand, if no life jacket is worn, the best thing to do is tread water and avoid the conventional drown-proofing by repeatedly lowering the head into the water and floating since this causes rapid heat loss.

The Heat Escape Lessening Posture (H.E.L.P.) is only useful if the victim is wearing a personal flotation device such as a life jacket. This position can be adopted by following these:
1. Hold arms tightly against sides and across the chest, and
2. Pull legs together and up toward the chest.

It must be noted that the H.E.L.P. position may be difficult to keep because of waves and water conditions, life-jacket design, and body size. Ideally, huddling together in groups is the best strategy to conserve body heat. The presence of other victims can offer moral support as well as offer greater visibility chances for rescuers.

**Hypothermia**
There have been reports of patients who experienced accidental drops in core body temperatures as low as or lower than 14°C who made full neurologic recovery. On the other hand, there are patients who have undergone therapeutic hypothermia with core temperature as low as 9°C and fully recovered.

A study of patients with Swiss stage system IV hypothermia at a facility exhibited organ failure to be quite common 24 hours following hospital admission. Of these cases, the most frequently cited cause of mortality was pulmonary edema.

Patients with uncomplicated hypothermia and stable hemodynamics who have been treated with active external re-warming and minimal invasive re-warming methods generally have a very good prognosis; an intact neurological survival of about 100 percent. Conversely, hypothermic cardiac patients treated with extracorporeal re-warming only have a survival rate with intact neurological function of about 50 percent (83, 84, 140, 141). As mentioned previously, full recovery in hypothermic cardiac patients is more likely if hypoxia preceded the onset of hypothermia, there are no serious underlying disorders or trauma, and extracorporeal re-warming was used (140, 141).
**Frostbite**

The severity of frostbite injuries is difficult to measure and establish during its early stages. In fact, the majority of clinicians who have handled frostbite injuries are themselves surprised at the extent or lack of it, after the tissue has unfrozen. Sometimes, even after thawing, the extent of the injury cannot be completely determined with accuracy. Usually the appearance of purple discoloration is a sign of marked severe damage.

As mentioned previously, moderate frostbites are characterized by the appearance of blisters filled with clear fluid. These characteristics are a good indication of tissue recovery. On the other hand, severe frostbites are characterized by either the appearance of blood-filled blisters or lack of it. Either way, it indicates tissue damage beyond repair. These blisters turn into gangrenous tissues, eschars, and finally break off spontaneously without surgery months after the initial injury.

**Trench foot**

The majority of patients who suffered from trench foot do not recover fully from their injuries. They usually have permanent decreased intolerance to cold. For example, British soldiers stationed at the Falklands seemed to have recovered from trench foot by the time their transport ship arrived in Britain. However, random check ups from this group of soldiers found them to have damaged nerves such as demyelinated medial or lateral plantar nerves. In addition, many of them experienced residual cold sensitivity. They experienced apparent vasoconstriction when exposed to mild cold stimuli, which persisted despite re-warming.

Patients with severe trench foot requiring surgery are often too disabled to continue military duty. In fact, some of them have turned to surgery to treat intractable pain caused by nerve damage months or even years after the initial injury.
Chilblains
Generally, chilblains last for a week and eventually resolve within another week or so. Some individuals get recurring bouts of chilblains each winter.

Frostnip
In more minor injuries, such as frostnip, the affected tissues such as the ears, nose and fingertips usually turn red for a few days. Sometimes, crust forms over the injured tissue accompanied by the loss of the superficial layer of the skin.

Early identification of the type of injury and prognosis is critical for improved treatment outcomes in a case of accidental hypothermia. The section below discusses preventive measures to avoid hypothermia through proper precautions.

Preventive measures
Accidental hypothermia is avoidable. It’s crucial that individuals show vigilance and appropriate preparation for cold conditions, which consists of the following steps:

- Appropriate cold weather clothing and survival bags if walking or climbing in a cold climate;
- Avoidance of alcohol consumption if expecting cold exposure since alcohol can disrupt temperature homeostasis via its vasodilation effects;
- Proceed with caution and be on the alert for early symptoms of hypothermia;
- Maintain sufficient heat in the home;
- Refer homeless patients to a social service agency for help with adequate housing, heat, and/or clothing.
COMPLICATIONS AND RELATED DYSFUNCTIONS

A certain type of extreme frostbite injury called *mountain frostbite* is frequently seen among mountain climbers and others exposed to severely cold temperatures and strong winds at high altitude. This type of injury is a combination of tissue freezing with hypoxia and general body dehydration.

Other risk factors for frostbite injuries and resulting complications include:

- Chronic medical conditions (*i.e.*, cardiovascular disease, peripheral vascular disease, Raynaud phenomena)
- African American race
- Vibration-induced white finger (VIWF)
- Previous history of frostbite, and
- Use of certain medications (*i.e.*, beta-blockers, sedatives)

Sequelae to frostbites include the following:

1. Excessive sweating
2. Cool extremities
3. Numbness
4. Abnormal color
5. Nail Disorder
6. Skin Pigment Changes

**Burial avalanche**

There are an increasing number of avalanche-related deaths in North America due to greater interest and participation in winter recreational activities, such as those listed below:

- Backcountry skiing and snowboarding
- Helicopter and snowcat skiing
- Snowmobiling
- Out-of-bounds skiing
- Ice climbing
- Mountaineering
- Snowshoeing

The frequently cited causes of avalanche-related death include:

- Asphyxia
- Trauma
- Hypothermia
- A combination of asphyxia, trauma and hypothermia

Rescue and resuscitation modalities are primarily targeted towards the management of asphyxia and hypothermia.

**Cold water submersion and drowning**

Cold-water submersion injuries include drowning and hypothermia. Approximately 500,000 deaths are attributed to drowning every year in the world. However, it is a preventable cause of morbidity and mortality.

Cold-water submersion involves the immersion of both the head and body in a body of water of very low temperature.

**Potential other injuries**

A decline in mental status is usually observed in patients with a core temperature below 31.7°C. On the other hand, if the patient has a core temperature above 31.7°C and exhibits declining mental status, the rescuer or clinician should consider other injuries and comorbidities that could occur in complicated or extreme scenarios, such as:

- Head injury
- Infection
- Toxins
- Metabolic abnormalities
TREATMENT

Treatment interventions are discussed in this section. In particular, treatment involves the fundamental steps of:

- Extricating the patient from the cold environment
- Providing modified BLS or ACLS
- Transporting the patient immediately to the nearest capable hospital

At the outset, it's important to note that, in general, empiric steroid treatment should not be given to all patients. It should be limited to those with a documented history of adrenal insufficiency and those whose body temperature do not respond to the administration of proper re-warming techniques.

Modified Basic Life Support (BLS)

Out in the field, emergency responders should first assess the patient’s breathing, and then later on, the pulse, for about 30-45 seconds to verify respiratory arrest, pulseless cardiac arrest, or severe bradycardia which may require the administration of CPR. It is important to keep in mind that hypothermic patients will most likely exhibit the following signs during this period of initial assessment:

- Slow pulse and respiratory rates
- Shallow breathing
- Hard-to-feel peripheral vasoconstriction

If the patient does not show signs of breathing, rescue breathing must be initiated immediately. Whenever possible, the administration of humidified oxygen warmed to about 42-46°C should be done during bag-mask ventilation. On the other hand, if the patient exhibits no detectable signs of circulation (pulseless), chest compressions must be started immediately. The
bottom line is that BLS should not be withheld until the patient has been sufficiently re-warmed.

As mentioned previously, wet clothing must be removed and further heat loss prevented. Additionally, rough movements must be avoided and so is the application of external re-warming devices in the field. More importantly, the patient should be prepared for transport to a nearby hospital as soon as possible. At this point, other field interventions need Advanced Cardiovascular Life Support (ACLS) capacity.

To date, attempting to treat patients with severe hypothermia in the field is not warranted. This is mostly because first aid responders or rescuers often do not have the equipment nor the time to accurately evaluate the core body temperature or to administer re-warming with warm, humidified oxygen or resuscitation fluids, although these modalities must be started whenever available to avoid further core temperature decline and after-drop. Some emergency responders may be equipped with aural or rectal probes to assess core temperatures in the field. They should be used but their use should not holdup transfer to the nearest hospital. Ideally, hypothermic patients should be handled carefully and gently, and transported in a horizontal position to prevent exacerbation of hypotension.

If the hypothermic patient is in cardiac arrest, the universal approach to Basic Life Support management remains focused on the usual airway, breathing, and circulation, although some modifications are needed. In the presence of ventricular fibrillation, defibrillation attempts must be started. Ideally, automated external defibrillators must be made available on all BLS rescue units.

As mentioned previously, if ventricular fibrillation is detected, emergency responders must be able to deliver up to 3 shocks to establish fibrillation responsiveness. If ventricular fibrillation continues following the administration of these 3 shocks, emergency responders should postpone
Further attempts in favor of immediate initiation of CPR and re-warming, and preparation and stabilization of the patient for transportation. If core temperature is less than 30°C, successful switch to normal sinus rhythm may only be after sufficient re-warming has been achieved.

Many clinicians believe in the old adage, *not dead until warm and dead*. This means that patients who look dead following extended exposure to cold temperatures must not be declared dead until they have been warmed enough close to normal core temperature and still fail to respond to CPR. Studies have found hypothermia to provide a protective effect on the brain and internal organs if its development was rapid enough in patients who sustained cardiac arrest.

When a hypothermic patient is first discovered, it is almost always impossible to determine the cause of hypothermia. This is particularly true if the patient is discovered in cardiac arrest in a severely cold environment with no witnesses. In this case, emergency responders and hospital personnel will be able to identify whether the arrest was caused by hypothermia or whether hypothermia succeeded the cardiac arrest (such as, an individual experiencing cardiac arrest while shoveling snow will become hypothermic after the arrest). Moreover, the patient may have also suffered internal organ injuries. For example, successful resuscitation can become harder to achieve if drowning occurred before the onset of hypothermia.

When it is clinically not possible to determine which event (hypothermia or cardiac arrest) occurred first, emergency responders should try to stabilize the patient with CPR. If hypothermia is recognized, basic life support should be initiated as well as measures to limit heat loss and re-warming. Ultimately, only clinicians in the hospital should make the decision whether to continue resuscitative and re-warming efforts or stop altogether.
Modified Advanced Cardiovascular Life Support (ACLS)

In cases where the hypothermic patient is not on cardiac arrest, rescue efforts must then focus on the evaluation and support of:

- Oxygen requirements and ventilation
- Circulation
- Re-warming, and
- Prevention of further heat loss

As mentioned many times before, hypothermic patients must be handled gently at all times, not just during transport, to prevent the onset of ventricular fibrillation. This includes during endotracheal or nasogastric intubation, temporary pacing, or insertion of a pulmonary artery catheter. However, these interventions must not be delayed nor postponed when clearly indicated. In fact, a prospective multicenter study involving hypothermia patients showed no onset of ventricular fibrillation following careful endotracheal intubation. In fact, the apprehension of triggering the onset of ventricular fibrillation during endotracheal intubation may be exaggerated, and must not come in the way of careful intubation.

Endotracheal intubation is needed if the hypothermic patient has lost consciousness or if ventilation is insufficient. This procedure is done for two reasons:

1. To enable the steady supply of effective ventilation with warm, humidified oxygen, and;
2. To isolate the airway to decrease the risk of aspiration. Usually, ventilation with 100% oxygen administered through a bag-mask prior to an intubation procedure is sufficient.

On the other hand, patients who are conscious and only signs of mild hypothermia may be re-warmed with external active and passive re-warming techniques (i.e., warm packs, warmed sleeping bags, and warm baths).
The Advanced Cardiovascular Life Support management of patients on cardiac arrest caused by hypothermia is not the same as the management for normothermic patients. The main re-warming modality used in hypothermic patients on cardiac arrest or unconscious with bradycardia is active core re-warming. As mentioned previously, the heart of a hypothermic patient on cardiac arrest may fail to respond to the stimulation effects of drugs, pacemakers, and defibrillation.

Despite findings pointing to the positive effects of epinephrine and vasopressin for hypothermic patients in a state of cardiac arrest, there is growing apprehension that repeated administration of these medications can lead to toxicity reactions due to their accumulation in the peripheral tissues. Other anti-arrhythmic drugs that may also accumulate include lidocaine and procainamide. As such, their IV administration is often suspended if the patient’s core body temperature is less than 30°C. On the other hand, if the patient’s core body temperature is more than 30°C, these drugs may be administered intravenously but with greater intervals between doses.

To date, there are no studies or findings that suggest the optimal range of temperatures at which defibrillation must be initially tried and its frequency in patients with severe hypothermia. Generally, defibrillation must be first performed once ventricular fibrillation is present. If the patient remains unresponsive to the three first defibrillation attempts or antiarrhythmic medication, succeeding defibrillation attempts or further doses of the medication must be suspended until the core temperature is more than 30°C. The slow heart rate may be inherent in severely hypothermic patients. In this case, cardiac pacing is skipped unless the slow heart rate continues after re-warming.

Treatment of severely hypothermic victims on cardiac arrest in the hospital should be directed at rapid core re-warming. Modalities that are best suited
for in-hospital controlled re-warming are discussed in detail in the succeeding pages and include:

- Administration of humidified oxygen warmed to a range of 42°C to 46°C;
- Administration of resuscitation fluids warmed to 43°C and administered via central intravenous line, ideally at rates ranging from 150-200 mL/h;
- Peritoneal lavage of fluid without potassium warmed to about 43°C and administered at a volume of 2000 mL per dosing interval.

**Extracorporeal re-warming**

Extracorporeal re-warming via *partial bypass* is the preferred method of active internal modality since it provides sufficient support of oxygenation and ventilation during gradual core body temperature re-warming. Other methods of rewarming, such as, the use of esophageal re-warming tubes have been utilized widely with great success in Europe; however, there are no reports of its use in the US. There have also been reports of successful treatment with pleural lavage using warm saline administered via a chest tube.

During the re-warming process, patients that have been hypothermic for more than 45-60 minutes may also need to be administered with fluids since there is greater likelihood that their vascular space has expanded as a consequence of vasodilation. In addition, the heart rate and hemodynamics should be monitored carefully during this time. Many facilities administer steroids, barbiturates, and antibiotics, although there is no scientific data that backs up this practice. Their administration does not increase survival nor reduce post-resuscitative injury.

As mentioned previously, severe hyperkalemia is a very dangerous complication that can occur during the re-warming process. In fact, severe hyperkalemia has been documented in patients pulled from under an
avalanche of snow who suffered both physical injuries and hypothermia. In addition, there have also been reports of severe hyperkalemia among hypothermic patients in North America with no physical injuries. As mentioned previously, the severity of hyperkalemia is associated with mortality. Because of the fatal consequences, the management of hyperkalemia needs to be performed using the traditional Advanced Cardiovascular Life Support approach, with the administration of calcium chloride, sodium bicarbonate, glucose with insulin, and Kayexalate enema. Other aggressive treatment to decrease alarmingly elevated levels of serum potassium may comprise dialysis or exchange transfusion.

In cases of cold-water submersion, successful revival is rare if drowning occurred before the onset of hypothermia. Cases of severe and accidental hypothermia are often preceded by other problems such as drug and alcohol toxicity and trauma. This is why medical responders and clinicians need to check for and treat such problems while concurrently treating the hypothermia. If alcohol or drug intoxication is strongly suspected, the intravenous administration of thiamine 100 mg early during the re-warming process is warranted.

**Malnourished children**

Children who are severely malnourished are more likely to suffer from severe hypothermia. In this context, the World Health Organization defines hypothermia as a rectal temperature less than 35.5 °C or an axillary temperature less than 35.0°C. The prevention and treatment of hypothermia is significant move towards the initial stabilization phase of the treatment of severely malnourished children with severe malnutrition (1).

There are several factors that make malnourished children particularly susceptible to hypothermia, namely (2-6):

- Slower metabolic rate resulting in reduced heat production because of decreased energy stores;
• Larger body surface area (BSA) per kilogram;
• Less fat means decreased insulation and greater heat loss, and;
• Infections, which decrease available energy for thermoregulation.

Malnourished children with acute malnutrition, appearance of lesions on large skin surfaces, or severe infections are the most susceptible to develop hypothermia (1, 7). On the other hand, the edema seen in severely protein deficient (Kwashiorkor Syndrome) children serve as an insulator (8).

The World Health Organization (WHO) treatment guidelines for severely malnourished infant and children recommend the initiation of re-warming efforts as soon as the patient is found to be hypothermic. This may be done by any of the following two methods:

1. The kangaroo technique, which involves placing the patient on bare chest or abdomen of the mother to allow bare skin contact and heat transfer. Next, both of them must be covered to reduce heat loss to the environment as much as possible; or
2. Clothing or covering the patient with a warmed blanket and placing an incandescent lamp nearby. When doing so, the lamp must not touch the patient’s body since it can cause skin burns. Additionally, hot water bottles must not be used in such cases (1).

During re-warming efforts, the core temperature of the patient must be monitored closely to prevent the onset of hyperthermia, which puts the patient at risk of dehydration and further energy store depletion. This can be achieved by the following measures (1):

1. Measuring rectal temperature as frequently as every 30 minutes when using a re-warming lamp, until such time that initial phase of the treatment is complete and the patient is declared stable; or
2. Measuring rectal temperature every 2-4 hours when not using a re-warming lamp, until such time that initial phase of the treatment is complete and the patient is declared stable.

However, these recommendations are not feasible in places with low limited resources. As such, a decrease in the frequency of temperature monitoring has been proposed and is backed up by study results exhibiting a decrease in hypothermia prevalence in severe malnutrition and absent link with poor outcome (1). On the other hand, the suggested revision to the WHO recommendations must not be taken as a substitute to the original since there are very few similar studies conducted on it. The bottom line is that the initial guideline of frequent temperature monitoring must still be employed whenever possible.

There are 2 other critical interventions for hypothermic children, namely:

- Treat hypoglycemia, and;
- Treat serious systemic infections.

Hypoglycemia may be managed by feeding severely malnourished patients frequently to provide for a constant supply of energy to support essential metabolic and other physiological functions, such as, heat production that can prevent or treat hypothermia. The use of broad-spectrum antimicrobials eliminates the onset of other fatal comorbidities related to infections and sepsis (3, 4, 7, 8, 9, 10).

Despite the contradicting reports on the prevalence and consequences of hypothermia in severely malnourished children, there have been no reports of detrimental effects of monitored re-warming. In cases where heat lamps are unavailable or electricity supply is unstable, the kangaroo technique should be used with the assistance of well-trained health personnel (11, 12). However, these techniques are also accompanied by some major challenges, such as those listed below (9, 14, 15, 16):
- Scarce availability of blankets
- Irregular change of wet sheets
- Failure to monitor core temperatures
- Separation of the child from the mother, and
- Lack of instructions for the mother to keep her child warm

As such, it is critical for mothers and health personnel to be made aware of the existence of the above challenges and trained to overcome them. Well-aware and trained personnel can help ensure the successful implementation of such simple interventions that prevent and treat hypothermia (17).

**Treatment of frostbites**

*Pre-thaw stage*

Life-threatening conditions such as hypothermia and trauma should always be addressed first. However, if a nearby shelter is present, the patient may walk towards it with frozen feet instead of attempting to re-warm it at the scene. However, walking prior to re-warming may cause fracture and tissue damage.

Lastly, jewelry worn in the affected extremities must be removed carefully. Alcohol and sedatives must not be administered to the patient since it can enhance further heat loss and impair shivering.

*Hospital care stage*

If the vaccination history is unknown, tetanus prophylaxis should be administered to avoid infection.

Frostbites are painful, making the re-warming procedure sometimes intolerable without the use of narcotic analgesics such as morphine sulfate or ordinary pain relievers such as ibuprofen (mild frostbites). An example of a suitable re-warming technique is hot water whirlpool bath warmed to 37-39°C. Temperatures more than the mentioned range can put patients at risk of thermal injury. Mild antibacterial soap can be used.
Thrombolytic therapy with tissue plasminogen activator (TPA) such as streptokinase or alteplase may be useful for deep frostbite within 24 hours of thawing. Angiography can help evaluate the tissue before and after thrombolysis. Angiography or technetium Tc 99 bone scanning can help identify viable tissues from dead tissues, guiding surgical consultants in determining the need for tissue debridement or amputation.

Patients who also sustained musculoskeletal dislocations should undergo reduction immediately after the completion of thawing. These fractures must be managed conservatively until post-thaw edema disappears.

**Burial avalanche conditions**

Avalanches usually happen in remote and often difficult to access by responders to conduct timely rescue operations. Avalanches usually result in several victims awaiting extrication and resuscitation. The initial decision to commence complete rescue efforts is based on factors such as those listed below:

- Number of victims
- Resources available
- Likelihood of survival

As mentioned previously, there is a distinct pattern of survival of avalanche victims. Specifically, past scientific data have shown a progressive nonlinear decrease in survival corresponding to the duration of avalanche burial. The chances of survival is dismal for avalanche victims in the following circumstances:

- Been buried for more than 35 minutes;
- Sustained an obstructed airway and cardiac arrest during rescue;
- Buried for an unknown duration and in cardiac arrest during rescue with an obstructed airway and an initial core temperature of less than 32°C.
As mentioned previously, the exact or even the approximate burial time of avalanche victims is hard to pinpoint. However, the core temperature at the time of rescue can serve as a proxy for duration of burial. Multiple cases of buried avalanche victims exhibited a maximum cooling rate of 8°C/hour, whereas one case report puts it to 9°C/hour. These cooling rates, at best, hints at the possibility of rescuers and responders, at 35 minutes of burial, being able to attain a core temperature as low as 32°C.

If the duration of burial or the patency of the airway on rescue is unknown to the receiving clinician, a serum potassium concentration that is less than 8 mmol/L upon Emergency Department admission may serve to estimate the survival chances of the hypothermic patient. The potassium level is an indicator for Return of Spontaneous Circulation (ROSC) and survival to hospital discharge.

Elevated potassium concentrations are linked with asphyxia. Moreover, an inverse relationship exists between admission potassium concentration and survival to discharge in all hypothermic patients (i.e., not just accidental hypothermia). In fact, multiple studies involving 32 avalanche survivors found the greatest serum potassium concentrations to be 6.4 mmol/L, although one report found a case of a 2-and-a half year old toddler with a potassium concentration of 11.8 mmol/L showing signs of hypothermia from cold exposure but not avalanche burial who survived. This data is an indication that the upper survivable limit of potassium is unavailable in pediatric hypothermic patients and victims of avalanche.

Whenever available, complete rescue measures such as extracorporeal rewarming must be used for all avalanche victims without the findings outlined above that consider them unlikely to survive or with any apparent fatal trauma. In the case of drowning, all patients need resuscitative efforts, which may include rescue breathing singly or in combination with other measures. In addition, they require immediate transport to the hospital for thorough
assessment and monitoring, even if they appear to be conscious and exhibit effective cardio-respiratory function upon extrication and rescue.

**Drowning conditions**

There are several old and outdated terminologies that describe the process of drowning, such as:

- Wet drowning
- Dry drowning
- Active or passive drowning
- Near-drowning
- Secondary drowning, and
- Silent drowning

The current definition of the term drowning is “a process resulting in primary respiratory impairment from submersion in a liquid medium (142).” Inherent in this latest definition is the presence of a liquid-air interface at the entrance to the victim's airway, which hinders breathing and proper oxygenation. Drowning can produce many possible outcomes, such as:

- Delayed morbidity
- Delayed or rapid death, or
- Life without morbidity

As mentioned previously, cold water submersion and the consequent onset of hypothermia prior to drowning increases the chances of survival. In fact, there have been reports of drowning patients who sustained long-drawn-out submersion in cold water and required prolonged resuscitation who successfully recovered with completely intact neurological function.

On-the-scene resuscitation must be started and the patient transported to the nearest hospital unless there is apparent signs of death, such as those listed below:
• Rigor mortis
• Decomposition
• Hemisection
• Decapitation, and
• Lividity

Basic Life Support Modifications

Hypoxia is the most significant and damaging consequence of cold-water submersion; which is why there is an urgent need for restoration and resumption of oxygenation, ventilation, and perfusion once the victim has been found. To achieve this, an immediate bystander cardiopulmonary resuscitation (CPR) plus activation of the emergency medical services (EMS) is needed. It should follow the 2010 AHA Guidelines for CPR and ECC (emergency cardiovascular care), beginning with chest compressions in a C-A-B (chest compression-airway maintenance-breathing) sequence.

Clinicians should note that the guidelines advise doing the sequence based on the alleged cause of the arrest. This type of CPR when used on drowning patients with hypoxia is primarily successful, responding positively to the initial administration of a few artificial breaths.

Extrication from the water

When trying to initially rescue a drowning patient from the water, the rescuer should get to the patient as soon as possible. However, during the process, the rescuer must keep personal safety a top priority.

There is an extremely low incidence rate of cervical spine injury in rescued drowning patients. As such, routine cervical spine immobilization is often not required during field rescue. In fact, it can hinder the patency of the airway and delay delivery of rescue breaths. On the other hand, routine stabilization of the cervical spine may be initiated in the presence of clues that indicate a spinal injury.
**Rescue breathing**

Once the patient has been extricated from the water, the first and most critical intervention needed is the immediate provision of ventilation. The timely start of rescue breathing raises the chance of survival.

Rescue breathing is frequently administered if the patient remains unconscious in shallow water or out of the water. If the rescuer experiences difficulties in pinching the nose, supporting the head, and opening the airway in the water, the alternative to mouth-to-nose ventilation, mouth-to-mouth ventilation, can be performed instead.

Generally, the management of the airway and breathing is analogous to that recommended for any patient on cardiac arrest. Some patients do not breathe in water since they develop laryngospasm or breath holding. Even if water is breathed in, there still is no indication to clear the breathing passages of aspirated water, since in most cases, only an insignificant amount of water is aspirated which is quickly absorbed into the central circulation. As such, no attempt should be made to clear aspirated water from the airway by abdominal thrusts or the Heimlich maneuver. If absolutely necessary, a simple suction is the only safe means to do so.

**Chest compressions**

If there is no breathing, the rescuer should provide two rescue breaths, which should result in the rise of the chest cavity. In cases where the delivery of two rescue breaths is not effective and no pulse is felt, the rescuer must initiate chest compressions and provide cycles of compressions and ventilations according to the BLS guidelines.

The rescuers should connect the patient to an automated external defibrillator (AED) and try defibrillation if a shockable rhythm is recognized. Dry the chest area prior to the application of defibrillator pads and using the AED. If hypothermia is present, the treatment guidelines discussed previously must be followed.
**Vomiting during resuscitation**

During resuscitation, there is a possibility that patients vomit when the rescuer administers chest compressions or rescue breathing. In fact, a decade-long study in Australia found that two thirds of patients who received rescue breathing, and more than three quarters of those who required compressions and ventilations, vomited. In cases like these, rescuers should turn the victim to the side and remove the vomitus using a finger, a cloth, or suction to prevent its airway obstruction.

Patients with suspected spinal cord injury need to be handled carefully, preferably logrolled so that the head, neck, and torso are turned as a unit. This maneuver preserves the fragile integrity of the cervical spine.

**ACLS modifications**

Patients in cardiac arrest may present with asystole or pulseless ventricular fibrillation. These arrhythmias must be treated using the appropriate PALS (pediatric advanced life support) or ACLS guidelines. There have been reports of the administration of surfactants in pediatric patients to induce fresh-water respiratory distress, although this type of intervention requires further studies. There have been reports of the use of extracorporeal membrane oxygenation in severely hypothermic patients after cold-water submersion.

**PREVENTION OF HYPOTHERMIA**

Hypothermia is a life-threatening but avoidable condition. This is why prevention through education and preparation is very important, especially among those who reside in remote northern climates. The Centers for Disease Control and Prevention (CDC) issued the following recommendations:

- Create a winter survival kit for indoor safety, including a stock of canned food supplies, water, blankets, a first aid kit, and medications.
- Use weather stripping and insulated doors in the house, especially for individuals of advanced age.
• If stranded in a car, relocate all items from the trunk compartment into the interior of the vehicle to conserve heat.
• When outdoors, wear several layers of clothing, preferably with the innermost layers fabric made of wool, silk, or polypropylene since they are better insulators compared to cotton. Layering entraps several layers of air, effectively reducing heat loss through convection.
• Wear a hat or headscarf to reduce heat loss by radiation.
• Seek shelter indoors as soon as signs or symptoms of mild hypothermia become apparent to avoid its progression to severe hypothermia.

PHARMACOLOGY: HYPOTHERMIA AND RELATED DISORDERS

The following drugs have been mentioned and some discussed in previous sections of this study. In this section, their complete drug profile is outlined.

Lidocaine

Indication: Ventricular arrhythmias

Mechanism of action:
Lidocaine stabilizes the neuronal membrane by inhibiting the ionic fluxes required for the initiation and conduction of impulses thereby effecting local anesthetic action. Lidocaine alters signal conduction in neurons by blocking the fast voltage gated sodium channels in the neuronal cell membrane that are responsible for signal propagation. With sufficient blockage the membrane of the postsynaptic neuron will not depolarize and will thus fail to transmit an action potential.

Dosing and administration:
• 1-1.5 mg/kg slow IV bolus over 2-3 minutes
• May repeat doses of 0.5-0.75 mg/kg in 5-10 minutes, to 3 mg/kg total
• Continuous infusion: 1-4 mg/min IV
• If IV not feasible may use IO/ET
• Monitor: ECG
*Interactions*: Bupivacaine liposome, dofetilide, lomitapide

*Contraindications*:
- Hypersensitivity to lidocaine or amide-type local anesthetic
- Adams-Stokes syndrome, SA/AV/intraventricular heart block in the absence of artificial pacemaker
- CHF
- Cardiogenic shock
- 2nd and 3rd degree heart block
- Wolff-Parkinson-White Syndrome

*Common adverse effects*:
- Cardiovascular: Hypotension
- Dermatologic: Edema, erythema at injection site, petechiae, skin irritation
- Gastrointestinal: Constipation, Nausea, vomiting
- Neurologic: Confusion, dizziness, headache, paresthesia, somnolence, tremor

*Serious adverse effects*:
- Cardiovascular: Cardiac arrest, cardiac dysrhythmia
- Hematologic: Methemoglobinemia
- Neurologic: Seizure
- Anaphylactoid reactions
- Malignant hyperthermia

**Bretylium**

*Indication*: Hypertension; and ventricular arrhythmias that are refractory to lidocaine
**Mechanism of action:**
Bretylium blocks the release of norepinephrine from the peripheral sympathetic nervous system, and is used in emergency medicine, cardiology, and other specialties for the acute management of ventricular tachycardia and ventricular fibrillation. The primary mode of action for bretylium is thought to be inhibition of voltage-gated potassium channels. Recent evidence has shown that bretylium may also inhibit the sodium potassium-ATPase by binding to the extracellular potassium site.

**Dosing and administration:** 5mg/kg

**Contraindications:** AV heartblock, digoxin toxicity

**Common adverse effects:**
- Vertigo
- Dizziness
- Syncope
- Hypotension
- Bradycardia
- Increase in PVCs
- Angina pectoris

**Epinephrine**

**Indication:** Cardiac arrest, severe anaphylactic reactions

**Mechanism of action:**
Epinephrine exerts strong alpha-adrenergic effects, which cause an increase in cardio output and HR, a decrease in renal perfusion and PVR, and a variable effect on BP, resulting in systemic vasoconstriction and increased vascular permeability. It also exerts strong beta1- and moderate beta2-adrenergic effects, resulting in bronchial smooth muscle relaxation.
**Dosing and administration:**

- 0.5-1 mg IV q3-5min PRN; may administer up to 0.1 mg/kg if no response.
- High dose: 1-5 mg IVP
- ET: 2-2.5 mg q3-5min until IV/IO access established or spontaneous circulation restored
- Intracardiac: 0.1-0.5 mg into left ventricular chamber
- May follow initial dose with 1-4 mcg/min IV infusion (1:10,000 solution)

**Contraindications:**

- Hypersensitivity
- Shock
- Organic brain damage
- Narrow-angle glaucoma
- Co-administration during general anesthesia with halogenated hydrocarbons or cyclopropane
- Labor
- Cardiac dilatation
- Coronary insufficiency

**Use caution:**

- Cerebrovascular insufficiency
- Heart disease, angina, hypertension, diabetes mellitus, thyroid disease, prostatic hypertrophy, geriatric patients, pregnancy, previous hospitalization for asthma
- In conjunction with local anesthetics: Use caution when administering in fingers, toes, ears, nose, or genitalia, due to potential for ischemia due to vasoconstriction
- Concomitant use of digitalis, mercurial diuretics, quinidine, or drugs that may sensitize the heart to arrhythmias
- Concomitant use of MAOIs or tricyclic antidepressants
• Rapid BP increase resulting in cerebral hemorrhage, especially in elderly
• Accidental injection may result in increased HR, local reactions (coldness, injection-site pallor, hypoesthesia), local injury (bruising, bleeding, discoloration, erythema, skeletal injury)

Adverse effects:
• Angina
• Anxiety
• Apprehensiveness
• Cardiac arrhythmias
• Dizziness
• Dyspnea
• Flushing
• Headache
• Hypertension
• Nausea
• Nervousness
• Pallor
• Palpitations
• Respiratory difficulties
• Restlessness
• Sweating
• Tachycardia
• Tremor
• Vasoconstriction
• Vomiting
• Weakness

Vasopressin

Indications: Off-label use for vasodilatory shock
**Mechanism of action:**
Vasopressin acts on three different receptors, vasopressin receptor V1a (which initiates vasoconstriction, liver gluconeogenesis, platelet aggregation and release of factor VIII), vasopressin receptor V1b (which mediates corticotrophin secretion from the pituitary) and vasopressin receptor V2, which controls free water reabsorption in the renal medullar. The binding of vasopressin to the V2 receptor activates adenylate cyclase, which causes the release of aquaporin 2 channels into the cells lining the renal medullar duct. This allows water to be reabsorbed down an osmotic gradient so the urine is more concentrated.

**Dosing and administration:**
- 0.01-0.04 unit/min IV
- Hepatic impairment: Lower doses may be required to achieve response

**Contraindications:** Hypersensitivity

**Warnings:**
- With gastrointestinal bleeding, infusion should be continued for 12-24 hours after bleeding has stopped, and dosage should then be tapered over 24-48 hours
- Continuous infusion should be administered via controlled infusion device
- Use caution in chronic nephritis with nitrogen retention
- Pre- and postoperative patients with polyuria
- Use caution in patients with seizure, migraine, asthma, heart failure, vascular disease, angina pectoris, coronary thrombosis, renal disease
- Use in pregnant women only when clearly needed

**Adverse effects:**
- Abdominal cramps
- Allergic reaction
• Angina
• Bronchial constriction
• Circumoral pallor
• Diarrhea
• Nausea
• Pounding in the head
• Sweating
• Tremor
• Uterine contraction
• Vertigo

**Procainamide**

*Indication:* Life-threatening ventricular arrhythmias, atrial fibrillation (off-label)

*Mechanism of action:*
Procainamide is a sodium channel blocker. It stabilizes the neuronal membrane by inhibiting the ionic fluxes required for the initiation and conduction of impulses.

*Dosing and administration:*
- **IM Administration:** 0.5-1 g IM q4-8hr
- **IV Administration:**
  - Loading dose: 100-200 mg/dose or 15-18 mg/kg; infuse slowly over 25-30 min; may repeat every 5 min as needed but not to exceed 1 g
  - Renal impairment: Reduce loading dose to 12 mg/kg
  - Maintenance: 1-4 mg/min by continuous IV infusion
  - Renal impairment: Reduce infusion to one third in moderate renal or cardiac impairment and two thirds in severe renal or cardiac impairment
• To convert from IV to PO: Total mg/24 hr IV dose divided into 4 daily SR doses, round to dosage form; immediate-release should rarely be used

**Contraindication:**

• Hypersensitivity to procainamide or other ingredients
• Complete heart block, 2°/3° AV block, SLE, torsades de pointes

**Use with caution:**

• Acute ischemic heart disease, blood dyscrasias, cardiomyopathy, CHF, 1° heart block, liver disease, renal impairment, myasthenia gravis, post MI patients
• May produce life-threatening hematologic disorders (leukopenia, agranulocytosis)
• Concomitant use of digoxin, other class IA anti-arrhythmics
• Toxicity if serum level >12 mg/L
• May exacerbate arrhythmias or produce paradoxical ventricular tachycardia in atrial fibrillation patients

**Adverse effects:**

• Increase in antinuclear antibodies
• Hypotension
• Diarrhea

**Thiamine**

**Indication:** Alcohol withdrawal

**Mechanism of action:**

It is thought that the mechanism of action of thiamine on endothelial cells is related to a reduction in intracellular protein glycation by redirecting the glycolytic flux. Thiamine is mainly the transport form of the vitamin, while the
active forms are phosphorylated thiamine derivatives. There are five known natural thiamine phosphate derivatives: thiamine monophosphate, thiamine diphosphate, also sometimes called thiamine pyrophosphate, thiamine triphosphate, and the recently discovered adenosine thiamine triphosphate, and adenosine thiamine diphosphate.

_Dosing and administration:_ 100 mg of thiamine hydrochloride given intramuscularly, or intravenously.

_Contraindication:_ Hypersensitivity

_Use with caution:_

- In pregnancy (doses more than the recommended RDA)
- Acute thiamine deficiency reported with dextrose administration; use caution when thiamine status uncertain
- Hypersensitivity reactions reported following repeated parenteral doses
- Parenteral products may contain aluminum; use caution in patients with impaired renal function

_Adverse effects:_

- Warmth
- Anaphylaxis
- Cyanosis
- Diaphoresis
- Restlessness
- Angioneurotic edema
- Pruritus
- Urticaria
- Pulmonary edema
- Weakness
- Tightness of the throat
- Nausea
**Povidone-iodine**

*Indication*: Topical antisepsis of frostbite wounds

*Mechanism of action*:
It oxidizes cell constituents; iodinates proteins and inactivates them.

*Dosing and administration*: Apply to clean wound as needed

*Contraindication*: Hypersensitivity

*Use with caution*: Pregnancy (Pregnancy category B)

*Adverse effects*:
- Hypothyroidism in neonates (<28 do) after use by mother prior to delivery; use with caution in pregnancy, lactation & children
- Severe pain on application
- Irritation
- Pruritic
- Erythema
- Edematous erythema
- Acneform eruption

**Ibuprofen**

*Indication*: Pain associated with frostbites

*Mechanism of action*:
The exact mechanism of action of ibuprofen is unknown. Ibuprofen is a non-selective inhibitor of cyclooxygenase, an enzyme involved in prostaglandin synthesis via the arachidonic acid pathway. Its pharmacological effects are believed to be due to inhibition cylooxygenase-2 (COX-2) which decreases the synthesis of prostaglandins involved in mediating inflammation, pain, fever and swelling. Antipyretic effects may be due to action on the hypothalamus, resulting in an increased peripheral blood flow, vasodilation, and subsequent
heat dissipation. Inhibition of COX-1 is thought to cause some of the side effects of ibuprofen including GI ulceration.

**Dosing and administration:**
- 200-400 mg per oral every 4-6 hours; not to exceed 1.2 g daily
- Monitoring: Severe renal disease and consider reduced dosage if needed

**Absolute contraindications:**
- Aspirin allergy
- Perioperative pain in setting of coronary artery bypass graft (CABG) surgery
- Preterm infants with untreated proven or suspected infection; bleeding with active intracranial hemorrhage or GI bleed; thrombocytopenia, coagulation defects, proven or necrotizing enterocolitis, significant renal impairment, congenital heart disease where patency or the PDA is necessary for pulmonary or systemic blood flow

**Relative contraindications:**
- Bleeding disorder
- Duodenal/gastric/peptic ulcer
- Stomatitis
- Systemic lupus erythematosus (SLE)
- Ulcerative colitis
- Upper GI disease
- Late pregnancy (may cause premature closure of ductus arteriosus)

**Adverse effects:**
- Dizziness
- Epigastric pain
- Heartburn
- Nausea
- Rash
- Tinnitus
- Edema
- Fluid retention
- Headache
- Vomiting

**Silver sulfadiazine**

*Indication*: Adjunct for the prevention and treatment of wound sepsis in patients with severe frostbite wounds.

*Mechanism of action*:

Studies utilizing radioactive micronized silver sulfadiazine, electron microscopy, and biochemical techniques have revealed that the mechanism of action of silver sulfadiazine on bacteria differs from silver nitrate and sodium sulfadiazine. Silver sulfadiazine acts only on the cell membrane and cell wall to produce its bactericidal effect. A specific mechanism of action has not been determined, but silver sulfadiazine's effectiveness may possibly be from a synergistic interaction, or the action of each component.

Silver is a biocide, which binds to a broad range of targets. Silver ions bind to nucleophilic amino acids, as well as sulphydryl, amino, imidazole, phosphate, and carboxyl groups in proteins, causing protein denaturation and enzyme inhibition. Silver binds to surface membranes and proteins, causing proton leaks in the membrane, leading to cell death. Sulfadiazine is a competitive inhibitor of bacterial para-aminobenzoic acid (PABA), a substrate of the enzyme dihydropteroate synthetase. The inhibited reaction is necessary in these organisms for the synthesis of folic acid.

*Dosing and administration*: 1% cream to be applied daily to frostbite wounds.

**Contraindication**:  
- Sulfonamides may increase possibility of kernicterus, therefore do not use during near term pregnancy, in premature infants or infants <2 mo
- Sulfa allergy, G6PD deficiency, hypersensitivity

**Adverse effects:**
- Pain
- Burning
- Itching
- Rash
- Necrosis of the skin
- Erythema multiforme
- Transient skin discoloration
- Hemolytic anemia
- Agranulocytosis
- Aplastic anemia
- Thrombocytopenia
- Leukopenia
- Dermatologic & hypersensitivity reactions
- Adverse GI effects
- Hepatitis & hepatocellular necrosis
- Adverse nervous system effects
- Toxic nephrosis
- Interstitial nephritis

**Gabapentin**

**Indication:** Neuropathic pain

**Mechanism of action:**
Gabapentin interacts with cortical neurons at auxillary subunits of voltage-sensitive calcium channels. Gabapentin increases the synaptic concentration of GABA, enhances GABA responses at non-synaptic sites in neuronal tissues, and reduces the release of mono-amine neurotransmitters. One of the mechanisms implicated in this effect of gabapentin is the reduction of the axon excitability measured as an amplitude change of the presynaptic fibre.
volley (FV) in the CA1 area of the hippocampus. This is mediated through its binding to presynaptic NMDA receptors. Other studies have shown that the antihyperalgesic and antiallodynic effects of gabapentin are mediated by the descending noradrenergic system, resulting in the activation of spinal alpha2-adrenergic receptors. Gabapentin has also been shown to bind and activate the adenosine A1 receptor.

*Dosing and administration*: 900 mg/day PO initially; may increase gradually every 3 days to 1800-3600 mg/day

Renal impairment (Neurontin)
- CrCl >60 mL/min: 300-1200 mg PO TID
- CrCl 30-60 mL/min: 200-700 mg every 12 hours
- CrCl 15-29 mL/min: 200-700 mg every day
- CrCl <15 mL/min: 100-300 mg every day
- Hemodialysis (CrCl <15 mL/min): Administer supplemental dose (range 125-350 mg) posthemodialysis, after each 4 hr dialysis interval; further dose reduction should be in proportion to CrCl (e.g. CrCl of 7.5 mL/min should receive one-half daily posthemodialysis dose)

Renal impairment (Gralise)
- CrCl ≥60 mL/min: 1800 mg every day with evening meal
- CrCl 30-60 mL/min: 600-1800 mg every day with evening meal
- CrCl <30 mL/min or hemodialysis: Do not administer

*Contraindication*: Hypersensitivity

*Use with caution*:
- Increased blood CPK levels and rhabdomyolysis reported
- Antiepileptic drugs increase risk of suicidal thoughts or behavior in patients taking these drugs for any indication; monitor for emergence or worsening depression, suicidal thoughts or behavior, and/or any unusual changes in mood or behavior
- May cause CNS depression, which may impair physical or mental abilities
- May potentiate effects of other sedatives or ethanol when administered concomitantly
- Do not discontinue abruptly (may increase seizure frequency); gradually taper over a minimum of 1 week
- Ages 3-12 years: Risk of neuropsychiatric adverse events, including emotional lability, hostility, thought disorders, and hyperkinesia
- Drug reaction with eosinophilia and systemic symptoms (DRESS), also known as multiorgan hypersensitivity, reported; some of these events have been fatal or life-threatening; typically presents with fever, rash, and/or lymphadenopathy in association with other organ system involvement (i.e., hepatitis, nephritis, hematologic abnormalities, myocarditis, myositis) and may resemble an acute viral infection

Adverse effects:
- Ataxia
- Dizziness
- Fatigue
- Somnolence
- Diplopia
- Nystagmus
- Tremor
- Amblyopia
- Back pain
- Constipation
- Depression
- Dry mouth
- Dysarthria
- Dyspepsia
- Increased appetite
- Leukopenia
- Myalgia
- Nervousness
- Peripheral edema
- Pharyngitis
- Pruritus
- Rhinitis
- Vasodilation
- Weight gain
- Abnormal vision
- Anorexia
- Arthralgia
- Asthenia
- HTN
- Malaise
- Paresthesia
- Purpura
- Vertigo
- Angioedema
- Blood glucose fluctuation
- Breast enlargement
- Erythema multiforme
- Elevated liver function tests
- Fever
- Hyponatremia
- Jaundice
- Movement disorder
- Stevens-Johnson syndrome
Tissue Plasminogen Activator (Alteplase)

*Indication:* Prophylactic measure against digital amputations in severe frostbite injuries

*Mechanism of action:*
Recombinant human tissue-type plasminogen activator (t-PA), which produces local fibrinolysis; it promotes thrombolysis by converting plasminogen to plasmin, and plasmin degrades fibrin and fibrinogen.

*Dosing and administration:* Initial rate of 0.5-1 mg/hour

*Contraindication:*
- Hypersensitivity
- AMI/PE: Active internal hemorrhage, history of CVA or intracranial hemorrhage, intracranial neoplasm, aneurysm, recent intracranial or intraspinal surgery or trauma, bleeding diathesis, AVM, severe uncontrolled HTN, suspected aortic dissection
- Ischemic stroke: Active/suspected/history of intracranial hemorrhage, suspicion of subarachnoid hemorrhage, hemorrhagic diathesis, recent (within 3 months) intracranial or intraspinal surgery
- Recent previous ischemic stroke (within 3 months), uncontrolled HTN, HTN requiring aggressive treatment, seizure at onset of stroke, active internal hemorrhage, recent (within 3 weeks) GI or urinary tract hemorrhage, intracranial neoplasm, AVM, aneurysm, heparin within 48 hr preceding onset of stroke, patients on warfarin
- Recent GI or GU bleeding
- Hypertension: Systolic BP >175 mm Hg; diastolic BP >110 mm Hg
- High likelihood of left heart thrombus (*i.e.*, mitral stenosis with atrial fibrillation)
- Acute pericarditis
- Subacute bacterial endocarditis
**Use with caution:**

- In recent major surgery, cerebrovascular disease, HTN, acute pericarditis, hemostatic defects, severe thrombophlebitis, severe hepatic/renal dysfunction
- May increase risk of bleeding in patients with diabetic hemorrhagic retinopathy, severe neurological deficit (NIHSS >22), patients with major early infarction signs on CT, recent lumbar puncture, pregnancy, elderly
- Ischemic Stroke: May have no benefit if used after 3 hr of onset
- Current use of warfarin and INR in high range may increase bleeding risk
- Cathflo Activase specific for restoring patency to central venous access devices
- Coronary thrombolysis may result in reperfusion arrhythmias
- Doses ≥150 mg associated with significantly increased risk of intracranial hemorrhage compared to doses ≤100 mg

**Adverse effects:**

- Stroke
- Accelerated idioventricular rhythm
- Pulmonary edema
- Arterial embolism
- Bruising
- Bleeding
- DVT
- Hypotension
- Intracranial hemorrhage
- GI/GU hemorrhage
- Pulmonary embolism
- Fever/chills
- Nausea/vomiting
• Sensitivity reaction
• Sepsis
• Shock

**Nifedipine**

*Indication:* Frostbites, refractory perniosis

*Mechanism of action:*
It promotes relaxation of vascular smooth muscle cells and leads to vasodilatation. Nifedipine reduces the number of and severity of attacks but effects may be short-lived and patients often have adverse effects such as hypotension, flushing, headache and tachycardia

*Dosing and administration:* 20-60 mg daily

*Contraindication:*
• Hypersensitivity to nifedipine or other calcium-channel blockers
• Cardiogenic shock
• Concomitant administration with strong CYP3A4 inducers (*i.e.*, rifampin, rifabutin, phenobarbital, phenytoin, carbamazepine, St John's wort) significantly reduces nifedipine efficacy
• Immediate release preparation (sublingually or orally) for urgent or emergent hypertension

*Use with caution:*
• Use with caution in (≤4 weeks) myocardial infarction (MI), congestive heart failure (CHF), advanced aortic stenosis, peripheral edema, symptomatic hypotension, unstable angina, concurrent use of beta blockers, hepatic or renal impairment, persistent progressive dermatologic reactions, exacerbation of angina (during initiation of treatment, after a dose increase, or after withdrawal of beta blocker)
• Short-acting nifedipine may be less safe than other calcium-channel blockers in management of angina, hypertension, or acute MI
• Use cautiously in combination with quinidine
• Conventional (short-acting) form not indicated for hypertension
• Use extended-release form with caution in severe GI stenosis; rare reports of GI obstructive symptoms in patients with known strictures or without history of GI obstruction in association with ingestion of long-acting nifedipine; bezoars can occur in very rare cases and may necessitate surgical intervention
• Extended-release form contains lactose; thus, patients with rare hereditary problems of galactose intolerance, Lapp lactase deficiency, or glucose-galactose malabsorption should not take this medicine
• Cirrhosis: Clearance reduced and systemic exposure increased
• CYP3A inhibitors (i.e., ketoconazole, fluconazole, itraconazole clarithromycin, erythromycin, grapefruit, nefazodone, saquinavir, indinavir, nelfinavir, ritonavir) may inhibit nifedipine metabolism and result in increased exposure when coadministered
• Strong CYP3A inducers (i.e., rifampin, rifabutin, phenobarbital, phenytoin, carbamazepine, and St John’s wort) may enhance nifedipine metabolism and result in decreased exposure when coadministered

Adverse effects:
• Peripheral edema
• Dizziness
• Flushing
• Headache
• Heartburn
• Nausea
• Muscle cramps
• Mood change
• Nervousness
- Cough
- Dyspnea
- Palpitations
- Wheezing
- Hypotension, transient
- Urticaria
- Pruritus
- Constipation
- Chest pain
- Gingival hyperplasia
- Agranulocytosis
- Erectile dysfunction
- Exfoliative or bullous skin adverse events
- Photosensitivity reactions
- Acute generalized exanthematous pustulosis

**Tetanus toxoid**

*Indication:* Post-exposure prophylactic measure against tetanus infection in frostbite injuries

*Mechanism of action:*
Protection against disease attributable to *Clostridium tetani* is due to the development of neutralizing antibodies to tetanus toxin.

*Dosing and administration:* Each dose of tetanus toxoid-containing vaccine is 0.5 mL.

*Contraindication:* Tetanus toxoid-containing vaccines are contraindicated in persons with a history of anaphylaxis after previous administration of the vaccine and in persons with proven immediate or anaphylactic hypersensitivity to any component of the vaccine or its container.
Use with caution in:
- Persons with moderate or severe acute illness, and
- Persons with minor acute illness.

Adverse effects:
- Erythema, swelling and pain at the injection site
- Nodule may be palpable at the injection site and persist for several weeks
- Abscess at the injection site has been reported
- Tenderness
- Fever
- Irritability
- Limb swelling
- Headache
- Fatigue
- Chills

Reserpine

Indication: Long lasting relief of functional arterial vasospasm.

Mechanism of action:
Reserpine acts by depletion of neuronal norepinephrine, with onset of action in 3 to 24 hours and duration of 14-21 days per injection. Limbs treated using this protocol become red and warm.

Dosing and administration: Intra-arterial injection of 0.5 mg reserpine

Contraindications:
- Hypersensitivity, active peptic ulcer, ulcerative colitis, history of depression, history of gallstones; electroconvulsive treatment within 1 week
- MAOIs: discontinue several days before starting reserpine therapy
Avoid during breast-feeding

Use with caution in:
- Asthma
- History of gall stones, PUD, ulcerative colitis
- Breastfeeding

Adverse effects:
- Angina
- Bradycardia
- Syncope
- Dizziness
- Depression
- Lethargy
- Nightmare
- Tardive dyskinesia
- GI hypersecretion
- Impotence
- Nasal congestion

**Morphine**

*Indication:* Pain reliever for the frostbite wound

*Mechanism of action:*

The precise mechanism of the analgesic action of morphine is unknown. However, specific CNS opiate receptors have been identified and likely play a role in the expression of analgesic effects. Morphine first acts on the mu-opioid receptors. The mechanism of respiratory depression involves a reduction in the responsiveness of the brain stem respiratory centers to increases in carbon dioxide tension and to electrical stimulation. It has been shown that morphine binds to and inhibits GABA inhibitory interneurons.
These interneurons normally inhibit the descending pain inhibition pathway. So, without the inhibitory signals, pain modulation can proceed downstream.

_Dosing and administration:_ Morphine sulfate 2-5 mg given intravenously. The dose may be adjusted according to body weight (0.05 mg/kg)

_Contraindications:_
- Hypersensitivity
- Paralytic ileus
- Toxin-mediated diarrhea
- Respiratory depression, acute or severe bronchial asthma, upper airway obstruction
- Within 2 weeks of monoamine oxidase inhibitor (MAOI) therapy

_Use with caution in:_
- Acute pancreatitis
- Addison disease
- Benign prostatic hyperplasia
- Cardiac arrhythmias
- Central nervous system depression
- Drug abuse or dependence
- Emotional lability
- Gallbladder disease
- Gastrointestinal disorder
- Pseudomembranous colitis
- GI surgery
- Head injury
- Hypothyroidism or untreated myxedema
- Intracranial hypertension
- Brain tumor
- Toxic psychosis
- Urethral stricture
- Urinary tract surgery
- Seizures
- Acute alcoholism
- Delirium tremens
- Shock
- Cor pulmonale
- Chronic pulmonary disease
- Emphysema
- Hypercapnia
- Kyphoscoliosis
- Severe obesity
- Renal or hepatic impairment
- Elderly or debilitated patients
- Neonates
- History of mental illness
- History of drug dependence or addiction
- History of alcohol abuse

**Adverse effects:**

- Pruritus
- Urinary retention (epidural/intrathecal)
- Vomiting
- Constipation
- Headache
- Somnolence
- Abdominal pain
- Asthenia
- Backache
- Depression
- Diarrhea
- Dyspnea
- Fever
- Insomnia
- Loss of appetite
- Nausea
- Paresthesia
- Peripheral edema
- Rash
- Sweating
- Xerostomia
- Respiratory depression (IT)
- Anxiety
- Dizziness
- Abnormal liver function test results
- Amblyopia
- Hiccups
- Orthostatic hypotension
- Syncope
- Urinary retention (PO)
- Respiratory depression (epidural)
- Anaphylaxis (rare)
- Cardiac arrest
- Circulatory depression
- Finding of intracranial pressure
- Ileus
- Lightheadedness
- Malaise
- Miosis
- Myoclonus
- Shock
- Thinking disturbances
- Vertigo
**Hexachlorophene**

*Indication:* Use as a bacteriostatic skin cleanser. It may also be used to control an outbreak of gram-positive infection where other infection control procedures have been unsuccessful.

*Mechanism of action:*
The primary mechanism of action of hexachlorophene, based on studies with *Bacillus megatherium*, is to inhibit the membrane-bound part of the electron transport chain, respiratory D-lactate dehydrogenase. It induces leakage, causes protoplast lysis, and inhibits respiration.

*Dosing and administration:*
- Apply topically to affected skin as a 3% emulsion.
- For external use only; avoid contact with the eyes. If contact occurs, rinse thoroughly.
- Do not apply to mucous membranes.
- Rinse thoroughly after use.
- Apply to the head and periorbital skin areas only in responsive patients with unanesthetized eyes.
- Do not pour into measuring cups, medicine bottles, or similar containers since they may be mistaken for baby formula or other medications.

*Contraindications:*
- Application to burned or denuded skin.
- Use as an occlusive dressing, wet pack, or lotion.
- Routine prophylactic total body bathing.
- Use as a vaginal pack or tampon, or on any mucous membranes.
- Known primary light sensitivity to halogenated phenol derivatives.
- Known hypersensitivity to hexachlorophene or any ingredient in the formulation.
**Adverse effects:**

- Dermatitis
- Photosensitivity
- Redness and/or
- Mild scaling or dryness of skin

**Desmopressin**

*Indication:* Used off-label for the stabilization of hemodynamics in hypothermic patients with hemorrhage where instant re-warming is hard to achieve or unwanted.

*Mechanism of action* (273):

Desmopressin emulates the actions of endogenous human antidiuretic hormone (ADH). Desmopressin is a structural analogue of ADH modified by deamination of 1-cysteine and substitution of 8-L-arginine by 8-D-arginine. It exerts a dose dependent elevation in von Willebrand factor VIII and t-PA levels which results in shortened activated partial thromboplastin time (aPTT) and bleeding time.

*Contraindication:*

- Hypersensitivity
- Intranasal: Nocturnal enuresis
- Hyponatremia or history of hyponatremia
- Moderate to severe renal impairment (CrCl <50 mL/min)

*Use with caution in:*

- Hypertension
- Children <3 months with hemophilia A or von Willebrand disease
- Coronary artery insufficiency
- Fluid and electrolyte imbalance
- Patients with factor VIII levels <5% or presence of factor VIII antibodies
- Type IIB von Willebrand disease
- Patients with habitual or psychogenic polydipsia (increased risk of hyponatremia)
- Risk of potentially fatal hyponatremia/seizures; may occur with any route of administration
- Use alternative route of administration if changes in the nasal mucosa resulting from edema or scarring occurs
- Patients should be asked to restrict fluid intake from 1 hr before to 8 hr after taking desmopressin tablets; consider intravenous administration if therapeutic response inadequate at maximum recommended oral dose
- Interrupt therapy if patient perform activities associated with increase in water consumption or with acute illness including fever or recurrent vomiting or diarrhea

**Adverse effects:**

- Headache
- GI disorder
- Fatigue
- Abdominal pain
- Nausea
- Rhinitis
- Conjunctivitis
- Edema eyes
- Lacrimation disorder
- Abnormal blood pressure
- Increased heart rate
- Increased blood pressure
- Flushing
- Seizure
- Hyponatremia
- Hyposmolality
- Water intoxication syndrome
- Thromboembolic disorder
- Allergic reaction
- Anaphylaxis

**Calcium chloride**

*Indication*: Electrolyte supplement for hyperkalemia

*Mechanism of action*:
Calcium increases threshold potential, thus restoring normal gradient between threshold potential and resting membrane potential, which is elevated abnormally in hyperkalemia.

*Dosing and administration*: 10% calcium chloride, 500 to 1000 mg given intravenously over a period of 2-5 minutes. Doses should be titrated with constant monitoring of ECG changes during administration; repeat dose if ECG changes do not normalize within 3-5 min.

*Contraindication*:
- Ventricular fibrillation during CPR
- Hypercalcemia
- Digitalis toxicity
- Hypophosphatemia
- Renal calculi
- IM or SC administration
- Pulseless ventricular tachycardia

*Adverse effects*:
- Erythema
- Hypomagnesemia
- Hypophosphatemia
- Hypotension
• Hypercalcemia
• Nausea
• Tissue necrosis at injection site
• Vasodilation
• Weakness
• Renal calculi
• Hot flashes
• Serum amylase increased
• Tingling sensations

Adverse effects of rapid administration:
• Arrhythmia
• Bradycardia
• Calcium taste
• Sense of heat waves
• Ventricular fibrillation

Sodium bicarbonate

Indication: Alkalinizing agent for hyperkalemia

Mechanism of action:
Bicarbonate ion neutralizes hydrogen ions and raises urinary and blood pH. The increases in pH results in a temporary potassium shift from the extracellular to the intracellular environment.

Dosing and administration: Administer 50 mEq of sodium bicarbonate intravenously over a period of 5 minutes.

Contraindication:
• Hypersensitivity
• Metabolic or respiratory alkalosis
• Hypocalcemia
Excessive Cl- loss from vomiting or GI suctioning
Patients at risk of diuretic-induced hypochloremic alkalosis
Hypercarbic acidosis

**Adverse effects:**
- Aggravated CHF
- Cerebral hemorrhage
- Edema
- Hypernatremia
- Hypocalcemia
- Hypokalemia
- Tetany
- Metabolic alkalosis

**Sodium polystyrene sulfonate (Kayexalate enema)**

*Indication:* Treatment of hyperkalemia

*Mechanism of action:*
It promotes exchange of potassium for sodium in GI system. Exchanges sodium for potassium and binds it in gut, primarily in large intestine, decreasing total body potassium.

*Dosing and administration:*
- Kayexalate 15-30 g via enema.
- Onset of action is long when administered via enema.
- Lowers potassium levels over 1-2 h with duration of action of 4-6 h.
- Multiple doses may be needed.

*Contraindication:*
- Hypersensitivity to polystyrene sulfonate resins
- Hypokalemia
- Obstructive bowel disease
Adverse effects:

- GI disturbance
- Constipation
- Hypokalemia
- Hypocalcemia
- Hypomagnesemia
- Sodium retention
- Nausea
- Vomiting
- GI tract ulceration or necrosis, which could lead to perforation
- Fecal impaction after rectal administration (especially in children)

Glucose plus insulin

*Indication*: Antidote to hyperkalemia

*Mechanism of action*:

The purpose for the administration of glucose with insulin is to facilitate the cellular uptake of glucose into the cell, which brings potassium with it.

*Dosing and administration*: Glucose given with 10 units of regular insulin and an ampule of D50.

SUMMARY

Accidental hypothermia is a failure in thermoregulatory function. It is a fairly common condition among those who are homeless, sick, and extensively exposed to external cold environment such as climbers, campers, and outdoor enthusiasts in the northern hemisphere.

There are four types of hypothermia discussed in Part I and Part II of this hypothermia study series, according to the Swiss staging system, namely: HT I, HT II, HT III, and HT IV. HT I is the mildest form of hypothermia.
characterized by shivering and consciousness while HT IV is the most severe and life-threatening of all four types, which is characterized by the absence of vital signs and consciousness. Field assessment of hypothermic victims involves checking for vital signs such as the pulse, heartbeat, temperature, blood pressure, and respiration.

When extricating victims out from under deep snow or cold waters, care must be exercised not to use jerky movements since these can precipitate ventricular fibrillation. Mild hypothermia is not fatal, and can easily be treated using passive and active external re-warming measures. Passive re-warming methods include using spaced blankets and ordinary blankets. These materials provide insulation, preventing further heat loss. They are only useful in cases of mild hypothermia.

Active external re-warming includes the use of heating pads, radiant heat, water bottles, warm water immersion, and forced air re-warming devices. In the case of moderate to severe hypothermia, an immediate decision must be made whether to transport the patient to the nearest hospital immediately or drop by an intermediate hospital with ECMO or CPB capabilities en route to the destination hospital. Severe hypothermia may be treated using active internal re-warming methods, some of which require highly invasive procedures. Examples include extracorporeal re-warming, hemodialysis, and lavage of the peritoneal, bladder, gastric, and mediastinal cavities.

Hypothermia may be accompanied by many mental and physical complications and associated dysfunctions, including terminal burrowing and paradoxical undressing (discussed in Part I), core after-drop, delayed hypotension, arrhythmias, hypoglycemia, dehydration, hyperkalemia, bleeding diathesis, rhabdomyolysis, physical injuries, and infection. Physical injuries involve the peripheral extremities including frostbites, frostnips, chilblains, and trench foot. These are treated according to their severity, ranging from simple re-warming measures to amputation and other surgical interventions.
The production and inhibition of body heat is regulated by the hypothalamus. Body heat is lost to the environment via heat transfer. Heat transfer can occur via convection, conduction, evaporation, and radiation.

Frostbites are usually managed in burn units with frostbite management capabilities. Patients are usually managed with topical anti-bacterials, analgesics (both narcotics and non-narcotics), tetanus prophylaxis, and tissue plasminogen activators. The prognosis for hypothermia is very positive in mild cases. In the absence of cardiac arrest, even patients who experienced moderate to severe hypothermia have good prognosis. Frostbites are generally mild injuries, except for the severe ones, where auto-amputation and infection occurs frequently.

**DEFINITION OF TERMS**

**Adrenal insufficiency:** An endocrine disorder wherein the adrenal glands do not produce adequate amounts of steroid hormones such as cortisol and aldosterone.

**Anoxic:** An abnormal condition characterized by low amount of oxygen in the body tissues.

**Arteriovenous anastomoses:** A blood vessel that connects an arteriole directly to a venule.

**Asystole:** A cardiac standstill with no cardiac output and no ventricular depolarization.

**Bradycardia:** A slow heart rate of less than 60 beats per minute.

**Chilblains:** These are small, itchy, painful lumps that develop on the skin due to capillary injuries. They develop as an abnormal response to cold.
Circadian rhythm: The body’s natural clock, which dictates the patterns of physiological and behavioral processes over a 24-hour period.

Core temperature after-drop: Refers to the phenomenon of continuous core temperature decline despite re-warming efforts.

Debridement: Refers to the surgical removal of unhealthy tissue from a wound to promote healing.

Defibrillation: Defibrillation is a process in which an electronic device gives an electric shock to the heart. This helps reestablish normal contraction rhythms in a heart having dangerous arrhythmia or in cardiac arrest. In recent years small portable defibrillators have become available.

Eschar: Refers to dead tissue that sheds off from healthy skin following injuries such frostbites, burns and pressure wounds.

Frostbite: A medical condition wherein peripheral tissues (e.g. foot, fingers, toes) sustain localized damage due to severe cold.

Frostnip: An initial stage of frostbite characterized by a reddish and very cold skin due to its frozen surface.

Gangrene: Refers to a type of tissue death which occurs due to loss of blood supply.

Hyperkalemia: Refers to condition wherein the potassium level in the blood which higher than normal.

Hypocapnia: It refers to a condition wherein the level of carbon dioxide in the blood is lower than normal which can result from acapnia.

Hypokalemia: Refers to a condition wherein there is lower than normal level of potassium in the bloodstream.
**Hypothermia:** A medical emergency that happens when the body loses heat faster than it can produce it, causing a dangerously low core temperature.

**Hypopituitarism:** An endocrine syndrome characterized by inadequate pituitary hormone production. It usually is a result of disorders involving the pituitary gland, hypothalamus, or surrounding structures.

**Ischemia:** Refers to a condition wherein the blood flow (and thus oxygen) is restricted or reduced in a part of the body.

**Mountain frostbite:** Refers to an injury characterized by frozen tissue, hypoxia and general body dehydration.

**Normothermia:** A condition of normal body temperature.

**Paradoxical undressing:** It refers to the phenomenon of removing all articles of clothing shortly before death due to severe hypothermia.

**Poikilothermic:** An organism having a body temperature that fluctuates with the temperature of its surroundings.

**Return of Spontaneous Circulation (ROSC):** Refers to the automatic resumption of sustained perfusing cardiac activity associated with significant respiratory effort after cardiac arrest. Signs of ROSC include breathing, coughing, or movement and a palpable pulse or a measurable blood pressure.

**Set point:** The temperature level at which there is a balance between heat loss and heat production.

**Terminal burrowing:** It refers to the phenomenon of crawling into small confined spaces after removing all articles of clothing (paradoxical undressing) shortly before death due to severe hypothermia.

**Thermogenesis:** It refers to the process of heat production in humans.
**Thermoregulation**: Also known as temperature homeostasis. It refers to the process that allows the human body to maintain its core internal temperature.

**Thoracotomy**: Refers to a surgical incision into the pleural space of the chest to access the lungs, heart and other adjacent organs or insertion of mechanical ventilation.

**Trench foot**: Also known as immersion foot. It refers to an injury of the skin, blood vessels, and nerves of the feet due to prolonged exposure to cold and wet terrains.

Please take time to help the NURSECE4LESS.COM course planners evaluate nursing knowledge needs met following completion of this course by completing the self-assessment Knowledge Questions *after* reading the article. Correct Answers, page 102.
1) Which of the following drugs is used in the emergency treatment of chilblains?
   a) Dexamethasone
   b) Nifedipine
   c) Betamethasone
   d) Procainamide

2) Which of the following electrolytes are affected significantly during re-warming efforts on a hypothermic patient?
   a) Sodium
   b) Potassium
   c) Magnesium
   d) Chloride

3) Which of the following are characteristics of third degree frostbites?
   a) Blood-filled blisters
   b) Milky blisters
   c) Mottled skin
   d) Rubbery skin texture

4) Which of the following drugs may be useful in preventing or treating arrhythmias in hypothermic patients?
   a) Lidocaine
   b) Atropine
   c) Bretylium
   d) Nifedipine

5) All of the following patient factors must be present prior to the initiation of passive re-warming methods except:
   a) Intact thermoregulatory mechanisms
   b) Normally functioning endocrine system
   c) Sufficient glycogen stores to create endogenous heat
   d) Loss of consciousness
6) Which of the following is an example of active internal re-warming measure?
   a) Use of devices that expel warm air placed over the patient’s trunk  
   b) Inhalation therapy  
   c) Use of warm blankets  
   d) Warm water immersion

7) Which of the following is the most effective active internal re-warming method?
   a) Extracorporeal re-warming  
   b) Inhalation therapy  
   c) Administration of warm intravenous fluids  
   d) Body cavity lavage

8) Which of the following re-warming methods do not present a risk of core temperature after-drop?
   a) Use of blankets  
   b) Use of heating pads  
   c) Inhalation therapy  
   d) Warm water immersion

9) Which of the following measures are involved in the pre-thaw stage treatment of frostbites?
   a) Rapid re-warming  
   b) Administration prophylactic antibacterials  
   c) Removal of wet clothing  
   d) Psychological support

10) Eschars treated with surgical amputation.  
     a) True  
     b) False
11) Which type of frostbite refers to an injury characterized by frozen tissue, hypoxia and general body dehydration?
   a) Frost nip
   b) 3rd degree frostbite
   c) Mountain frostbite
   d) 1st degree frostbite

12) Which drug emulates the actions of endogenous human antidiuretic hormone?
   a) Vasopressin
   b) Desmopressin
   c) Calcium chloride
   d) Nifedipine

13) Which drug is used as a prophylactic measure against digital amputations in severe frostbite injuries?
   a) Reserpine
   b) Bretylium
   c) Tetanus toxoid
   d) Alteplase

14) Hypothermic patients with stable hemodynamic need active external and minimally invasive re-warming which may include all of the following except:
   a) Placement in a warm environment
   b) Application of chemical, electrical, forced-air heating packs/blankets
   c) Initiation of CPB
   d) Administration of warm parenteral fluids.
Correct Answers:

1) Which of the following drugs is used in the emergency treatment of chilblains?
   c) Nifedipine

2) Which of the following electrolytes are affected significantly during rewarming efforts on a hypothermic patient?
   b) Potassium

3) Which of the following are characteristics of third degree frostbites?
   a) Blood-filled blisters

4) Which of the following drugs may be useful in preventing or treating arrhythmias in hypothermic patients?
   c) Bretylium

5) All of the following patient factors must be present prior to the initiation of passive rewarming methods except:
   d) Loss of consciousness

6) Which of the following is an example of active internal rewarming measure?
   b) Inhalation therapy

7) Which of the following is the most effective active internal rewarming method?
   a) Extracorporeal rewarming

8) Which of the following rewarming methods do not present a risk of core temperature after-drop?
   a) Use of blankets

9) Which of the following measures are involved in the pre-thaw stage treatment of frostbites?
   c) Removal of wet clothing

10) Eschars treated with surgical amputation.
    b) False
11) Which type of frostbite refers to an injury characterized by frozen tissue, hypoxia and general body dehydration?
   c) **Mountain frostbite**

12) Which drug emulates the actions of endogenous human antidiuretic hormone?
   b) **Desmopressin**

13) Which drug is used as a prophylactic measure against digital amputations in severe frostbite injuries?
   d) **Alteplase**

14) Hypothermic patients with stable hemodynamic need active external and minimally invasive re-warming which may include all of the following except:
   c) **Initiation of CPB**
Footnotes:


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