HYPOTHERMIA
# Definition

Core body temperature <35°C (95°F)

<table>
<thead>
<tr>
<th>Grade</th>
<th>Temperature</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mild</td>
<td>35-32 °C</td>
</tr>
<tr>
<td>Moderate</td>
<td>32-28 °C</td>
</tr>
<tr>
<td>Severe</td>
<td>&lt;28 °C</td>
</tr>
<tr>
<td>Profound</td>
<td>&lt;24 °C</td>
</tr>
</tbody>
</table>
**ICAR-MEDCOM hypothermia (HT) scale**

<table>
<thead>
<tr>
<th>Hypothermia (HT) stage</th>
<th>Clinical assessment</th>
<th>Expected core temperature, °C (°F)*</th>
</tr>
</thead>
<tbody>
<tr>
<td>HT I</td>
<td>Clear consciousness with shivering</td>
<td>Mild 35-32°C</td>
</tr>
<tr>
<td>HT II</td>
<td>Impaired consciousness with shivering</td>
<td>Moderate 32-28°C</td>
</tr>
<tr>
<td>HT III</td>
<td>Unconsciousness</td>
<td>Severe &lt;28 °C</td>
</tr>
<tr>
<td>HT IV</td>
<td>Apparent death</td>
<td>Profound &lt;24 °C</td>
</tr>
<tr>
<td>HT V</td>
<td>Death due to irreversible hypothermia</td>
<td>Profound &lt;24 °C</td>
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</tbody>
</table>

* Clinical assessment may be used alone to stage hypothermia when core temperature measurement in the field is not available.
† The core temperature at which irreversible hypothermia with death occurs is not well defined. Please refer to UpToDate topics on hypothermia for discussions regarding prehospital declaration of death and withdrawal of resuscitation.

Measuring Core Body Temperature

- Rectal
- Bladder
- Esophageal**
- Tympanic
Epidemiology

- 700 Deaths
- 49%, 65 years or older
- In-hospital mortality: 40% if moderate/severe
- Urban settings majority
Classifications

- **ACUTE**
  - <1hr
    - Sudden rapid cooling
      - Injured alpine climber
Classifications

ACUTE  SUBACUTE  CHRONIC

1-24 hr
- Uninjured climber, stranded
Classifications

- **SUBACUTE**
- **ACUTE**
- **CHRONIC**

>24hr

- Urban winters
  - Psychiatric disorders/Intoxicated
Etiology

- Primary
- Secondary

<table>
<thead>
<tr>
<th>Increased Heat Loss</th>
<th>Decreased Heat Production</th>
<th>Impaired Thermo-regulation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cold exposure</td>
<td>Age Extremes</td>
<td>Peripheral failure</td>
</tr>
<tr>
<td>Iatrogenic (eg, cold fluid infusions, exposure)</td>
<td>Hypoglycemia</td>
<td>Neuropathies/spinal injury</td>
</tr>
<tr>
<td>Induced vasodilation</td>
<td>Malnutrition</td>
<td>Diabetes</td>
</tr>
<tr>
<td>Pharmacologic/toxins</td>
<td>Marasmus</td>
<td>Central or neurologic failure</td>
</tr>
<tr>
<td>Dermatologic (eg, erythrodermas, dermatitis, burns)</td>
<td>Kwashiork or extreme exertion</td>
<td>CNS trauma</td>
</tr>
<tr>
<td></td>
<td>Endocrinologic failure</td>
<td>CVA</td>
</tr>
<tr>
<td></td>
<td>• Hypopituitarism</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Hypoadrenalism</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Hypothyroidism</td>
<td></td>
</tr>
<tr>
<td></td>
<td>DKA/AKA</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Fatigue/exhaustion/trauma</td>
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</table>

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Pathophysiology of Thermoregulation

37°C ± 0.5

Anterior Preoptic Hypothalamus
Temperature Homeostasis

THERMOLYSIS
- Conduction
- Convection**
- Radiation
- Evaporation

THERMOGENESIS

Shivering Thermogenesis
- Skeletal muscle activity
- Heat as byproduct

Nonshivering Thermogenesis
- Autonomic: peripheral vasoconstriction
- Endocrine: thyroid, adrenals
- Adaptive behavioral responses

Increase in BMR
Initial Cooling Phase

ADYNAMIC PHASE

- Tissue Metabolism
- Neuronal Activity

Shivering less effective

30°C
BMR 50%
Dysrythmias

Mild 35-32
Moderate 32-28
Respiratory Changes

• Initial RR increase, then decrease
• Respiratory arrest at 24 °C

• Increased amount/viscosity of lung secretions
• Decreased elasticity and compliance of chest wall
• Reduced oxygen release to tissues
Cardiac Changes

• Initial HR increase, then decrease
• BP falls, Vfib/asystole <28°C

• Death from primary hypothermia is due to failure of myocardial conduction
CNS Changes

- Agitation, shivering
- AMS, no shivering
- $< 30^\circ C$ Pupils dilated, hyporeflexic
- $< 28^\circ C$ Hypertonic coma
  - pseudo rigor mortis
Other Physiologic Changes

- **Kidneys**
  - Impaired concentrating ability, cold-diuresis, significant volume losses

- **MSK**
  - Risk of Rhabdomyolysis

- **Heme**
  - Hemoconcentration, poor circulation
  - Risk of thrombosis, DIC
<table>
<thead>
<tr>
<th>Temperature Range</th>
<th>Clinical Symptoms</th>
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<tbody>
<tr>
<td>Mild 35-32 °C</td>
<td>Tachypnea, Tachycardia, Hyperventilation, Impaired judgement, Ataxia, Shivering, Cold-diuresis</td>
</tr>
<tr>
<td>Moderate 32-28 °C</td>
<td>Bradypnea, Bradycardia, Hypoventilation, CNS depression, AMS, Hyporeflexia, Loss of shivering, Paradoxical undressing, Reduced RBF, Arrhythmia (Afib/junct brady)</td>
</tr>
<tr>
<td>Severe &lt;28 °C</td>
<td>Bradycardic, Hypotension, Pulm edema, oliguria, Coma, Areflexia, Hypertonic Ventricular arrhythmia, Vfib/asystole</td>
</tr>
</tbody>
</table>
Lab Work Up

- Serum cortisol/thyroid (failure to rewarm)

- PEARLS
  - Hct increases 2% for each 1°C drop
  - Insulin is ineffective <30°C
  - Hypothermia obstructs hyperK EKG changes
EKG changes

- Slowed impulse conduction, prolonged intervals
- J point elevation, Osborne wave (V2-V5)
DDx

BEWARE!
If VS and level of consciousness inconsistent with degree of hypothermia, consider DDx

- Hypothyroid
- Adrenal insufficiency
- Sepsis
- NMJ disease
- Malnutrition/thiamine def
- Hypoglycemia
- ETOH abuse/drugs
- CO poisoning
General Principles of Management

- ABCs
- Prevention of further heat loss
- Initiate appropriate rapid rewarming if core temp <35
- Monitor core temp and pulse
- Careful transport to hospital**
Rewarming Methods

- Passive External Rewarming (PER)
- Active External Rewarming (AER)
- Active Internal Rewarming (AIR)

*Based on degree of hypothermia, cardiovascular status
*Step-wise approach
Passive External Rewarming (PER)

- Supplemental method
- Capable of generating body heat—body self-corrects
- Mild hypothermia
  - Blankets
  - Warm room >28°C

* Recommended rewarming rate: 0.5°C - 2°C/hr
Active External Rewarming (AER)

- Moderate (or refractory Mild) Hypothermia
  - Warm water immersion
  - Radiant heat (lamp, electric blanket)
  - Warm packs
  - Forced hot air (bair hugger)

*Rewarming Shock
  - Peripheral vasodilation

*Core Temperature Afterdrop in Chronic Hypothermia
  - Cold acidemic blood thaws in extremities
  - Rewarm trunk BEFORE extremities
Active Internal Rewarming (AIR)

- Core Rewarming
- Severe Hypothermia (or refractory Moderate)

  - Warm humidified oxygen 40-42°C
  - Warm IVF 40-42°C
  - Bladder Irrigation/Gastric Lavage
  - Peritoneal/Pleural irrigation
  - Endovascular rewarming via fem cath
  - Extracorporeal blood rewarming
  - HD
  - Cardiopulmonary Bypass
Arrhythmias

- **Bradycadia, physiologic**
  - Not responsive to atropine
  - no pacing, unless persists beyond warming to >32°C

- **Slow Afib**
  - usually no RVR, resolved with rewarming

- **Ventricular arrhythmia, problematic**
  - Transcutaneous pacing > transvenous
  - Lack of evidence, reasonable to follow ACLS, including defibrillation
  - Trial of defib, otherwise CPR/rewarming
Failure to Rewarm

• Reasonable to treat potential adrenal or thyroid insufficiency
PEARLS

• Hypotension
  o Moderate/severe hypothermia: disproportionately hypotensive
  o Severe dehydration and fluid shifts

• 2 large bore peripheral IVs
  o Large volume

• Warmed isotonic crystalloids 40-42°C

• CVC
  o Femoral to avoid RA irritation

• Refractory
  o Low dose dopamine, 2-5mcg/min
Resuscitation Efforts

• Continued Indefinitely
  o Temperature Goal 32-35°C

When to stop:
• K>10-12
  o Severe cell lysis
• Fibrinogen <50
  o Intravascular thrombosis
• Ammonia > 420
• Body is frozen: chest wall incompressible, or nose and mouth completely blocked by ice
## Summary Rewarming

### Treatment

- **Endotracheal intubation may be necessary in obtunded patients and those with bronchorrhea**
- **Treat hypotension with warmed crystalloid (42°C) initially, dopamine if necessary**
- **Avoid rough movements and activity, which may induce ventricular fibrillation**

Rewarming techniques are based on degree of hypothermia:

- **Mild hypothermia: passive external rewarming**
  - Remove wet clothing, cover with blankets
- **Moderate hypothermia: active external and internal rewarming**
  - Warmed humidified oxygen, forced air warming systems
  - Beware of initial paradoxical drop in core temperature due to return of cold blood from extremities to core circulation
  - Rewarm trunk first to minimize risk of core temperature afterdrop
- **Severe hypothermia: active internal rewarming (active core rewarming) and active external rewarming**
  - Warmed humidified oxygen, warmed IV fluids (42°C)
  - Pleural and peritoneal irrigation with warm saline (40 to 42°C)
  - Extracorporeal options: continuous venovenous rewarming, hemodialysis, continuous arteriovenous rewarming, and cardiopulmonary bypass

### Treatment of arrhythmias

- **Arrhythmias may persist until patient rewarmed**
- **Ignore atrial arrhythmias with slow ventricular response**
- **Ventricular fibrillation a common rhythm**
  - May be precipitated by physical jostling
  - Manage according to ACLS protocol
  - Electrical defibrillation may be attempted but is rarely successful until core temperature is above 30°C
Remember!

- Not Dead, until Warm and Dead

- Neuroprotection from hypothermia may allow meaningful recovery despite prolonged arrest
DERMAL COLD INJURIES & FROSTBITE
Chillblains (Pernio)

• Localized inflammatory lesion
  o Repetitive damp/NONfreezing temperatures

• Hands, ears, feet

• Cutaneous manifestations
  o Within 12 hours
  o Plaques, nodules, ulcerations, vesicles
  o Edema, erythema, cyanosis,
  o Painful, pruritic

• Children/women
  o Raynauds
Trench (Immersion) Foot

- 1914, WWI
- Direct injury to sympathetic nerves and vasculature
- Cold, wet, pressure
- Cutaneous manifestations
  - Hours-Days
  - Pale, mottled, edematous, painful → numb, pulseless, immobile, ulcers
  - Hemorrhagic bullae
  - Unchanged after rewarming
- May progress to gangrene, requiring amputation
Frostnip

• Localized, cold-induced *parasthesias*
  o Superficial vasoconstriction
  o Tingling, pain, numbness

• Reversible
• Complete recovery in 1-2 weeks
Frostbite

- Localized, cold-induced injury
- Freezing of tissues

- Heat loss > local tissue perfusion
  - Freezing point: 4°C

- Irreversible
  - Extent/Duration of freezing
  - Duration of exposure, humidity, wind, altitude, clothing, comorbid medical conditions
Epidemiology

• Inadequate clothing
  o Most preventable cause
  o Head/neck account for 80% heat loss

• Intoxicated persons majority of frostbites in US
  o ETOH
  o Other drugs
Predisposing Factors

- Hypothermia, Trauma
- Disease states
  - Atherosclerosis, arteritis, hypovolemia, diabetes, vascular injury
- Nicotine use
- Prior Frostbite
- Intoxication/Psychiatric Disease
- Dark-skinned people
- People from warmer climates
Interestingly

- Facial, upper airway, esophageal frostbite
- Recreational inhalation of halogenated hydrocarbons
Pathophysiology

- Intra/Extracellular ice crystal formation
- Fluid/electrolyte shifts
- Disrupt cell membrane, Lysis

- Tissue ischemia, necrosis
- Continues with thawing

Thromboxane A2
PG F2-α
Bradykinins
Histamine
Clinical Manifestation

- **Complaints**
  - Numbness, pain, clumsiness

- **Cutaneous Manifestations**
  - Insensate, hard, waxy,
  - Clear or hemorrhagic bullae
  - If delayed, eschar

- **Ears, nose, chins, cheek, fingers, toes**

- **Clinical diagnosis**
  - XR, Technetium scintigraphy, MRI

- **Delayed Demarcation**
  - “Frostbite in January, Amputation in July”
# Classifications of Frostbite

<table>
<thead>
<tr>
<th>Degree</th>
<th>Description</th>
</tr>
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<tbody>
<tr>
<td>1&lt;sup&gt;st&lt;/sup&gt;</td>
<td>Central pallor, anesthesia, surrounding edema</td>
</tr>
<tr>
<td>2&lt;sup&gt;nd&lt;/sup&gt;</td>
<td>Large, clear blisters, surrounding edema/erythema, Extend to digit tips, Within 24h, NO tissue loss</td>
</tr>
<tr>
<td>3&lt;sup&gt;rd&lt;/sup&gt;</td>
<td>Deeper, smaller blisters, Hemorrhagic, more proximal, Eschar</td>
</tr>
<tr>
<td>4&lt;sup&gt;th&lt;/sup&gt;</td>
<td>Muscle, bones, Tissue necrosis, Mummification in 5-10d</td>
</tr>
</tbody>
</table>
What degree?
What degree?
What Degree?
What Degree?
Treatment- Prehospital

- Warm environment
- Pad/splint extremity
- Remove wet clothing
- DO NOT REWARM, avoid refreezing
- Do not rub
- Do not walk on frostbitten feet
Treatment- In Hospital

• Rewarming *PAINFUL
  o Immersion, 37-39°C
  o 15-30min, complete when skin is red/purple, soft

• Thrombolysis
  o Decreased rate of amputation (evidence retrospective, small n)
  o IN SUMMARY
    • Outcomes often poor
    • At high-risk for amputation, within 24h, no C/I: IA tPA+IA heparin
Treatment- Wound Care

- Aspetic conditions
- Nonadherent gauze, first layer
- Padding- fluff dressing
- Padding between digits
- Avoid occlusive dressing
- Allow to dry after rewarming before dressing
Treatment- Blisters

To Debride or Not To Debride?

• Inflammatory mediators within the blister fluid
• Debride large clear blisters that interfere w movement
• Large hemorrhagic bullae aspirated, not debrided
Treatment continued

• Prophylactic Antibiotics?
  NO

• Tetanus?
  YES

• NSAIDS?
  YES

• Surgical consult?
  YES
  • Complications: long-term wound care, debridement, amputation, fasciotomy
Other Complications

- Early
  - Infection
  - Gangrene
  - Autoamputation

- Late
  - Persistent pain/parasthesias
  - Hypersensitivity to cold exposure
  - Re-exposure vasospasm

- Other
  - Scarring, tissue atrophy, arthritis, bony abnormalities
References

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• Headdon W. The management of accidental hypothermia. BMJ 2009; 338: b2085
• Nolan J. Images in Resuscitation: the ECG in hypothermia. Resuscitation 2005; 64:133