Objectives

45min lecture, 15min discussion & questions:
• Inspirational case & overview
• Who is cold and dead
• Special circumstances (trauma, drowning, avalanche)
• Step by step resuscitation of severe hypothermia
• Transport issues
• Building the BC chain of survival
Disclosures

• No financial conflicts of interest
• Overzealous desire to build a chain of survival for a rare condition
• At risk for recreational hypothermia
Hypothermia with Apparent Death

- 29y/o F, falls into a frozen creek while skiing
- Trapped under the ice, immersed in flowing water, has an air pocket
- Becomes unconscious after 40 minutes
- Extricated after 80 minutes: lifeless, asystolic, CPR started
- 1 hour flight to hospital
- Arrive in hospital after 130 min downtime after 90min of CPR
Hypothermia with Apparent Death

• On Arrival: K 4.3, pH 6.6, PaO$_2$ 65, PaCO$_2$ 77, Temp 14.4°C, asystole
• Femoral AV Cardiopulmonary Bypass (CPB) started 40 min after arrival (130 min CPR)
• 13.7°C lowest core temp measured (2 min after starting CPB)
• Vfib 10 min after starting CPB
Successful Resuscitation From Apparent Death

• Spont conversion to pulsatile rhythm 15 min after CPB
• CPB stopped after 179 minutes, Temp 36 °C
• ECMO started 4hrs later and cont for 5 days
• 28 day ICU stay complicated by:
  • Renal failure requiring dialysis
  • Coagulopathy
  • Ischemic colitis
  • ICU Polyneuropathy
• Slow return to work as a radiology resident ~6 months later (prev orthopedic resident)

Accidental Hypothermia

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¹University of British Columbia ²European Research Academy of Bolzano ³Internation Federation of Mountain Guides ⁴Innsbruck Medical University

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NEJM – New Recommendations

• Simplified clinical staging & decision making (conscious, decr LOC, unconscious, cardiac arrest)

• Insulate and attempt rewarming for all patients (rescue collapse is common but is not caused by rewarming)

• Hypothermic cardiac arrest or instability requires ECMO/CPB (long transport times are OK)

• Cardiac stability -> minimally invasive rewarming (insulation, external heat & warmed IV fluids)
Figure 1 (facing page). Management and Transport in Accidental Hypothermia.

HT I, HT II, HT III, and HT IV refer to the four stages of hypothermia as defined by the Swiss staging system.\(^\text{10}\) To convert values for temperature to degrees Fahrenheit, multiply by 9/5 and add 32. Obvious signs of irreversible death include decapitation, truncal transection, decomposition of the whole body, and a chest wall that is not compressible (i.e., the whole body is frozen solid). Rigor mortis as well as fixed and dilated pupils may be present in patients with reversible hypothermia. Active external and minimally invasive rewarming techniques include placement of the patient in a warm environment; use of chemical, electrical, or forced-air heating packs or blankets; and parenteral administration of warm fluids (38 to 42°C [100 to 108°F]). A systolic blood pressure of less than 90 mm Hg is a reasonable prehospital estimate of cardiac instability, but for in-hospital decisions, the minimum sufficient circulation for a patient with a core temperature of less than 28°C (82°F) has not been defined. Therefore, it is not known at what point a patient with refractory cardiac instability should be transitioned to extracorporeal membrane oxygenation (ECMO) or cardiopulmonary bypass (CPB). In remote areas, the transport adviser must balance the risk of increased transport time with the potential benefit of treatment in a center that can provide ECMO or CPB. For a patient with cardiac arrest in a remote area, the need for ECMO or CPB can be confirmed by measuring the serum potassium level at an intermediate hospital, ideally en route toward a center that can provide ECMO or CPB. When transfer to such a center is not feasible, active external and alternative internal rewarming techniques should be used. DNR denotes do not resuscitate, IO intraosseous, IV intravenous, and ROSC return of spontaneous circulation.
Accidental Hypothermia Simplified

3 steps:
1. Is CPR required?
2. Determine transport destination
3. Supportive care and rewarm
Cold Patient, No Signs of Life

Possible Causes of Cardiac Arrest:

- Trauma
- Asphyxia
- Hypothermia
- Multi-factorial
1. Is CPR required?

- Patient’s trunk feels cold on examination or core temperature is <35°C
- Vital signs present

   No

   - Obvious signs of irreversible death
     - Valid DNR order
     - Conditions unsafe for rescuer
     - Avalanche burial ≥35 min, airway packed with snow, and asystole

   - No to all
     - Start CPR, do not delay transport
     - Prevent further heat loss
     - Provide airway management and up to 3 doses of epinephrine (at an IV or IO dose of 1 mg) and defibrillation
   - Yes to any
     - Consider termination of CPR
2. Transport decision: Is hypothermia the likely cause of cardiac arrest?

~50% Survival
3. Supportive care & rewarm:
   - quality CPR
   - transport to ECMO
   - prevent heat loss
Cold Patient, Unconscious with Vital Signs
Unconscious with Vital Signs

1. No CPR required

2. Transport to ECMO if hypotension, ventricular arrhythmia or temp < 28°C

3. Careful handling and rewarm
Cold Patient, Conscious
1. No CPR required

2. Consider on-site rewarming if uninjured*

3. Rewarm

*Trauma & hypothermia are a deadly combination. Prevention & rewarming can be lifesaving for hypothermic trauma patients.
Classical Staging

TABLE 5-2 Characteristics of the Four Zones of Hypothermia

<table>
<thead>
<tr>
<th>Stage</th>
<th>Core Temperature °C</th>
<th>°F</th>
<th>Characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mild</td>
<td>37.6</td>
<td>99.7</td>
<td>Normal rectal temperature</td>
</tr>
<tr>
<td></td>
<td>37.0</td>
<td>98.6</td>
<td>Normal oral temperature</td>
</tr>
<tr>
<td></td>
<td>36.0</td>
<td>96.8</td>
<td>Increase in metabolic rate, blood pressure, and shivering muscle tone</td>
</tr>
<tr>
<td></td>
<td>35.0</td>
<td>95.0</td>
<td>Urine temperature 34.8°C (94.6°F); maximal shivering thermogenesis</td>
</tr>
<tr>
<td></td>
<td>34.0</td>
<td>93.2</td>
<td>Development of amnesia, dysarthria, and poor judgment; maladaptive behavior; normal blood pressure; maximal respiratory stimulation; tachycardia; then progressive bradycardia</td>
</tr>
<tr>
<td></td>
<td>33.0</td>
<td>91.4</td>
<td>Development of ataxia and depressed level of consciousness; cerebellar dysfunction; tachycardia; then progressive decrease in respiratory minute volume; cold diuresis</td>
</tr>
<tr>
<td>Moderate</td>
<td>32.0</td>
<td>89.6</td>
<td>Stupor; 25% decrease in oxygen consumption</td>
</tr>
<tr>
<td></td>
<td>31.0</td>
<td>87.8</td>
<td>Extinguished shivering thermogenesis</td>
</tr>
<tr>
<td></td>
<td>30.0</td>
<td>86.0</td>
<td>Development of arrhythmias and other arrhythmias; poikilothermia; pulse and cardiac output two-thirds of normal level ineffective</td>
</tr>
<tr>
<td></td>
<td>29.0</td>
<td>84.2</td>
<td>Progressive decrease in level of consciousness, pulse, and respiration; stupor; hallucinations; paradoxical undressing</td>
</tr>
<tr>
<td>Severe</td>
<td>28.0</td>
<td>82.4</td>
<td>Loss of reflexes and voluntary motion</td>
</tr>
<tr>
<td></td>
<td>27.0</td>
<td>80.6</td>
<td>Major acid-base disturbances; no reflexes or response to pain</td>
</tr>
<tr>
<td></td>
<td>26.0</td>
<td>78.8</td>
<td>Cerebral blood flow one-third of normal level; cerebral vascular autoregulation; cardiac output 45% of normal; pulmonary edema may develop</td>
</tr>
<tr>
<td></td>
<td>25.0</td>
<td>77.2</td>
<td></td>
</tr>
<tr>
<td>Profound</td>
<td>24.0</td>
<td>75.2</td>
<td>Significant hypotension and bradycardia</td>
</tr>
<tr>
<td></td>
<td>23.0</td>
<td>73.4</td>
<td>No corneal or oculocephalic reflexes; areflexia</td>
</tr>
<tr>
<td></td>
<td>22.0</td>
<td>71.6</td>
<td>Maximal risk of ventricular tachycardia; 75% decrease in oxygen consumption</td>
</tr>
<tr>
<td></td>
<td>20.0</td>
<td>68.0</td>
<td>Lowest respiration; cardiovascular electrophysiological activity; pulse 20% of normal</td>
</tr>
<tr>
<td></td>
<td>19.0</td>
<td>66.2</td>
<td>Electrocardiographic silence</td>
</tr>
<tr>
<td></td>
<td>18.0</td>
<td>64.4</td>
<td></td>
</tr>
<tr>
<td></td>
<td>13.7</td>
<td>56.7</td>
<td>Lowest adult accidental hypothermia survival196</td>
</tr>
<tr>
<td></td>
<td>15.0</td>
<td>59.0</td>
<td>Lowest infant accidental hypothermia survival204</td>
</tr>
<tr>
<td></td>
<td>10.0</td>
<td>56.0</td>
<td>92% decrease in oxygen consumption</td>
</tr>
<tr>
<td></td>
<td>9.0</td>
<td>58.2</td>
<td>Lowest therapeutic hypothermia survival205</td>
</tr>
</tbody>
</table>

## Table 2: Staging and Management of Accidental Hypothermia.

<table>
<thead>
<tr>
<th>Stage</th>
<th>Clinical Symptoms</th>
<th>Typical Core Temperature</th>
</tr>
</thead>
<tbody>
<tr>
<td>HT I</td>
<td>Conscious, shivering</td>
<td>35 to 32°C</td>
</tr>
<tr>
<td>HT II</td>
<td>Impaired consciousness, not shivering</td>
<td>&lt;32 to 28°C</td>
</tr>
<tr>
<td>HT III</td>
<td>Unconscious, not shivering, vital signs present</td>
<td>&lt;28 to 24°C</td>
</tr>
<tr>
<td>HT IV</td>
<td>No vital signs</td>
<td>&lt;24°C</td>
</tr>
</tbody>
</table>
Core Temperature Measurement

Problematic:

• Requires calibrated, low-reading thermistor
• Ideally esophageal (distal to carina)
• Rectal (~15cm depth, may lag during rewarming)
• Can’t use oral or IR tympanic

Useful:

• Temp >32°C then hypothermia unlikely the cause of cardiac arrest
• Prognosis: double edged sword*

*lower temperature increases ischemic protection but on average increases morbidity & mortality
Secondary Hypothermia

Table 1. Conditions Associated with Secondary Hypothermia.*

<table>
<thead>
<tr>
<th>Impaired thermoregulation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Central failure</td>
</tr>
<tr>
<td>Anorexia nervosa</td>
</tr>
<tr>
<td>Cerebrovascular accident</td>
</tr>
<tr>
<td>Central nervous system trauma</td>
</tr>
<tr>
<td>Hypothalamic dysfunction</td>
</tr>
<tr>
<td>Metabolic failure</td>
</tr>
<tr>
<td>Neoplasm</td>
</tr>
<tr>
<td>Parkinson’s disease</td>
</tr>
<tr>
<td>Pharmacologic effects</td>
</tr>
<tr>
<td>Subarachnoid hemorrhage</td>
</tr>
<tr>
<td>Toxins</td>
</tr>
<tr>
<td>Peripheral failure</td>
</tr>
<tr>
<td>Acute spinal cord transection</td>
</tr>
<tr>
<td>Decreased heat production</td>
</tr>
<tr>
<td>Neuropathy</td>
</tr>
<tr>
<td>Endocrinologic failure</td>
</tr>
<tr>
<td>Alcoholic or diabetic ketoacidosis</td>
</tr>
<tr>
<td>Hypoadrenalism</td>
</tr>
<tr>
<td>Hypopituitarism</td>
</tr>
<tr>
<td>Lactic acidosis</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Increased heat loss</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dermatologic disorder</td>
</tr>
<tr>
<td>Burns</td>
</tr>
<tr>
<td>Medications and toxins</td>
</tr>
<tr>
<td>Iatrogenic cause</td>
</tr>
<tr>
<td>Emergency childbirth</td>
</tr>
<tr>
<td>Cold infusions</td>
</tr>
<tr>
<td>Heat-stroke treatment</td>
</tr>
<tr>
<td>Other associated clinical states</td>
</tr>
<tr>
<td>Carcinomatosis</td>
</tr>
<tr>
<td>Cardiopulmonary disease</td>
</tr>
<tr>
<td>Major infection (bacterial, viral, parasitic)</td>
</tr>
<tr>
<td>Multisystem trauma</td>
</tr>
<tr>
<td>Shock</td>
</tr>
</tbody>
</table>

* Adapted from Danzl.⁹
Cerebral Oxygen Consumption

Temperature °C

% Cerebral O₂ metabolism (CerO₂M)

Benefit:
• \( \text{CerO}_2\text{M} \sim 6\%/°\text{C} \)

1. CPR provides ~50% of normal cerebral blood flow
2. Below 28°C, outcome may be completely independent of CPR duration


Rubertsson, Resuscitation 2005: 65 357-363
1. Trauma & hypothermia are a lethal combination

**Benefit:**
- $\downarrow$ CerO$_2$M ~6%/°C

**Risks:**
- $\uparrow$ clotting time
- $\uparrow$ bleeding ~16%*
- $\uparrow$ transfusion ~22%*
- $\uparrow$ mortality 2.4*  

* in trauma patients

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Rajagopalan S et al. Anesthesiology 2008;108:71-77
Objectives

• Who is cold and dead
• Special circumstances (trauma, drowning, avalanche)
• Step by step resuscitation of severe hypothermia
• Transport issues
• Building the BC chain of survival
Hypothermia can mimic death

- Fixed & dilated pupils
- Stiffness that resembles rigor mortis
- Respiratory arrest
- Cardiac arrhythmias including asystole
Who is Cold & Dead?

• History of arrest prior to cooling
• Core temp >32°C (hypothermia not the cause)
• Frozen solid (chest not compressible)
• K>12mmol L⁻¹
• Special circumstances
Serum Potassium

K<8 mmol/L:
- no prognostic value
- use history, not K to make decisions

K>8, >10, >12
- possible marker of cell death prior to cooling
- Outliers / Survivors:
  - 2.5yr child K=11.8
  - 13yr child K=9.5
  - 34yr K=7.9
Objectives

• Who is cold and dead
• Special circumstances (trauma, drowning, avalanche)
• Step by step resuscitation of severe hypothermia
• Transport issues
• Building the BC chain of survival
Adjusted Odds of Death:

- Temperature < 35°C: 2.4 (all comers)
- Temperature < 35°C, adjusted for age, ISS, mechanism: 1.5 (isolated head injury)

Hypothermia and Trauma

• Pathologic:
  • Coagulopathy undetected by lab (samples are heated)
  • ‘Minor’ bleeding can be catastrophic
  • Acidosis & arrhythmias
  • Fixed & dilated pupils: head injury, hypothermia or brain death?
  • Surgical cure is compromised….can’t stop the bleeding

• What about Neuroprotection?
  • Shock state deplete ATP stores
  • Decreased hypothermic metabolism offset by traumatic hypermetabolic state & increased bleeding
Special Situations

Cold water drowning:

- **Submersion**: with hypoxic cardiac arrest has a dismal prognosis (exceptional pediatric cases possible)
- **Immersion**: with cooling and hypothermic cardiac arrest prior to submersion has a much better prognosis

Pediatric submersion outlier:

- 2.5yr fell into 5°C creek and pinned underwater for 66 minutes
- 19°C, asystole, 2hr CPR, ECMO, full recovery
Special Situations

Drowning: see Tipton, Resuscitation 2011 for:
- drowning outliers (2 page table)
- Tipton’s proposed rule:
  - >6°C water for >30min DNR
  - <6°C water for >90min DNR

Consider using history (submersion vs. immersion) rather than a rule to make clinical decisions

Pediatric patients that suffer simultaneous rapid cooling and submersion (hypoxic cardiac arrest) may benefit from prolonged resuscitation & extracorporeal rewarming

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Special Situations

Avalanche:

- **<35min** burial: hypothermia is not the cause of cardiac arrest (not enough time to cool below 32°C)
- **>35min** burial: if the airway is patent, hypothermia may be the cause of cardiac arrest
Who is Cold & Dead?

- History of arrest prior to cooling
- Core temp >32°C (hypothermia not the cause)
- Frozen solid (chest not compressible)
- K>12mmol L⁻¹
- Special circumstances: (drowning, trauma, avalanche)
Objectives

- Who is cold and dead
- Special circumstances (trauma, drowning, avalanche)
- Step by step resuscitation of severe hypothermia
- Transport issues
- Building the BC chain of survival
Accidental Hypothermia Simplified

3 steps:
1. Is CPR required?
2. Determine transport destination
3. Supportive care and re-warm
Unconscious with vital signs

Step by Step Resuscitation:

• Active external and minimally invasive rewarming:
  • warm environment or full body insulation
  • chemical, electrical, or forced-air hearing blankets (under & over patient)

• Airway management as required

• Warm (38-42°C) IV fluids titrated to clinical volume status (expect significant volume requirements during rewarming)

• +/- Warm (38-42°C) bladder lavage

• Cardiac monitoring, minimal & cautious movements
Unconscious with vital signs

Not to worry: (should resolve with warming)

• Bradycardia
• Mild hypotension
• Atrial fibrillation

Prepare for cardiac arrest: (ECMO/CPB center)

• Ventricular arrhythmias
• Hypotension out of proportion
• Very low core temperatures....28, 24.....

Not recommended: (incr complications, no benefit)

• body cavity lavage, endovascular devices
• extracorporeal heating systems without CV support
Unconscious with vital signs

Vasopressors:

• Hypothermia causes profound vasoconstriction and myocardial irritability
• Risk of arrhythmia likely greater than benefit early in resuscitation
• If rewarming induced vasodilatation starts causing significant hypotension, reconsider risk / benefit
• Careful if concurrent frostbite
Hypothermic Cardiac Arrest

Step by step resuscitation:

• High quality CPR
• Transport to ECMO/CPB (upto 6hr reasonable if good history)
• Prevent further heat loss
• Trial of electricity +/- epinephrine
• If you truly can’t transport to ECMO/CPB:
  • Thoracic lavage, bladder lavage
Objectives

• Who is cold and dead
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Transport Issues

• Risk of long transport vs. benefit of ECMO/CPB:
  • Duration of CPR not a predictor of outcome
  • Several case reports: ~4hr CPR -> ECMO/CPB
  • Outlier: 6.5hr CPR, no ECMO/CPB (Norway, Artic Med Resuscitation, 1991)

• Effect of age and comorbidities

• Keep patient cold vs. warm
Transport: Age & Comorbidities

- Young healthy patients with cardiac stability:
  - Excellent prognosis with minimally invasive rewarming\(^1\)

- Older patients or those with comorbidities:
  - Higher mortality, uncertain transport risks
  - Evidence to support use of ECMO/CPB if temp <28°C even for patients without cardiac instability\(^2\)


Transport: Cold vs. Warm

• Prehospital rewarming is important to prevent further cooling but is unlikely to significantly rewarm the patient\(^1\)

• Opinion: simplify management by recommending minimally invasive rewarming for all patients (controversial with cardiac arrest patients)

• Risk of Not Rewarming:
  • Further temperature drop increases risk of multi-organ failure, coagulopathy, arrest and death

• Risk of Warming:
  • If brain rewarmed prior to provision of adequate blood flow then neuroprotection may be lost

\(^1\)Lundgren et al. Scandinavian Journal of Trauma, Resuscitation and Emergency Medicine 2011, 19:59
Objectives

• Who is cold and dead
• Special circumstances (trauma, drowning, avalanche)
• Step by step resuscitation of severe hypothermia
• Transport issues
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Next Steps

Hypothermia Chain of Survival in BC:

• BC Clinical Practice Guideline promoting best care for HT I – IV
• Education of front line->quaternary care providers
• BCAS, BCPTN, EPOS & Critical Care Transport Advisers triage potential cases and refer to ECMO providers
• Invest in equipment for prolonged transport of patients in cardiac arrest