Hypothermia in Trauma: Friend or Foe?

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Is hypothermia beneficial or harmful?

- Ongoing controversy
  - Hypothermia can both prolong life, and contribute to death
  - Paucity of studies in trauma patients
    - Current management guidelines based on retrospective studies
Features of mammalian animals

- Warm-blooded
- Hair or fur, 2 pairs of limbs, feeds milk to young

- Homeotherms
  - Active energy expenditure to maintain a constant internal temperature/environment
  - Many physiologic processes optimised to functions within a narrow temperature range
  - All enzymes are temperature-dependent
  - Allows adaptation to a wide range of climatic conditions
Earth by night
Gaining heat

- The body gains heat by "burning up" food; for extra heat, the body "burns up" food at a faster rate.
- Shivering: the rapid, twitching muscle movements release more heat in the body.
- More clothing can be worn so that less heat escapes.
- In cold weather, the blood flow to skin is reduced so that less heat is carried to the surface and lost.
- Exercise: muscles give off heat when they move.

Losing heat

- The body loses heat by conduction, convection, and radiation.
- Sweating has a large cooling effect as liquid evaporates from skin.
- Less clothing can be worn so that more heat escapes.
- In warm weather, the blood flow to skin is increased so that more heat is carried to the surface, where it can escape.
- Heat Production
  - central control
  - preoptic anterior hypothalamus
  - shivering
  - vasoconstriction
  - TSH and ACTH

- Heat Loss
  - convection (5x in 12 mph wind)
  - conduction (10x in wet clothing, 25x in water) [20%]*
  - radiation (head) [60%]*
  - evaporation [20%]*

*[%] normal loss at room temp
Hypothermia: definitions

- Hypothermia: Core temperature $< 35^\circ C$
  - Mild
    - $35 - 32^\circ C$
  - Moderate
    - $32 - 30^\circ C$
  - Severe
    - $< 30^\circ C$

For trauma patients, $T < 32^\circ C$ should be considered severe.
Hypothermia and traumatic injury

- Components of the ‘lethal triad’
  - Hypothermia
  - Coagulopathy
  - Acidosis

- A marker of the limits of physiological reserve
- Concept of ‘damage control’ in trauma surgical management
Deleterious physiologic consequences of hypothermia

- **stress response**
- **immune**
  - possible decreased chemotaxis, phagocytosis, antibody production, and oxidative killing
- **haemopoietic**
  - haemoconcentration
  - cold induced granulocytopenia
  - DIC
  - rightward oxyhemoglobin shift
  - decreased red cell deformability
  - increased blood viscosity
- **cardiac**
  - reduced cardiac output
  - depressed contractility
  - arrhythmias
  - delayed conduction
  - J wave or “Osborne” wave
  - vasoconstriction
- **respiratory**
  - falsely increased PaO₂
  - decreased respiratory rate
- **renal**
  - decreased renal tubular function (cold diuresis)
- **gastrointestinal**
  - elevated amylase
- **hepatic**
  - reduced hepatic function
- **metabolic**
  - falsely decreased pH (if not temperature corrected)
  - decreased adrenal activity
  - decreased metabolism of lactate and citrate
  - hyperkalaemia
  - delayed wound healing
- **neurologic**
  - decreased consciousness progressing to coma
  - absent motor and reflex functions
Hypothermia - pathophysiology

- Rate of heat loss a factor
- Cardiac
  - Initial increase CO then decrease, increase BP then decrease
  - EKG slowed depolarisation, arrhythmia, arrest
- Vascular
  - Impaired coagulation, DIC
- Renal
  - Diuresis, secondary to decreased resorption
Hypothermic coagulopathy

Watts et al, 1998

112 trauma patients: 40 normothermic
72 hypothermic (33-37°C)

- thromboelastography
- PT, aPTT, platelets, CO₂, Hb, Hct, ISS

At T<34°C: significant slowing of enzyme activity, platelet function
No effect on fibrinolysis

? Coagulopathy due to disruption of polymerisation process of platelets and fibrin
Hypothermia - pathophysiology

- pulmonary
  - depressed medullary respiratory centre
  - pulmonary oedema
- metabolic
  - slowed enzymatic reaction velocity --> pumps --> leaks --> lost gradients
  - hyperglycemia secondary to cold inactivation of insulin
Hypothermia - pathophysiology

- CNS
  - 3.3% decrease in cerebral blood flow per 0.5 degree drop
  - confusion -> decreased reflexes -> coma, fixed pupils, areflexia

- No One is Dead ......
Hypothermia and trauma

- Risk Factors
  - Environmental exposure
  - Extrication and transport time
  - Haemorrhage
  - Head injury
  - Drugs and alcohol

71 patients with ISS > 25

mortality:
- T < 34°C: 40%
- T < 33°C: 69%
- T < 32°C: 100%

Controlled for ISS, BP, and fluid volume resuscitation, mortality significantly higher if patient also hypothermic.

A temperature of 32°C identified as being the critical temperature below which survival was zero.
Incidence and effect of hypothermia in seriously injured patients. Luna et al, 1987

94 intubated trauma patients, average ISS 31

<table>
<thead>
<tr>
<th></th>
<th>normothermic</th>
<th>hypothermia</th>
<th>hypothermia</th>
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<tbody>
<tr>
<td></td>
<td>mild</td>
<td>severe</td>
<td></td>
</tr>
<tr>
<td>age (yr)</td>
<td>35</td>
<td>34</td>
<td>35</td>
</tr>
<tr>
<td>ISS</td>
<td>28</td>
<td>29</td>
<td>36</td>
</tr>
<tr>
<td>T (°C)</td>
<td>36.9</td>
<td>35.1</td>
<td>32.2</td>
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<tr>
<td>survival (%)</td>
<td>78</td>
<td>59</td>
<td>41</td>
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</table>
Management of hypothermia

- ATLS/EMST guidelines
  - ABCD
  - **E**: Exposure and Environmental control
    - Prevent further heat loss
    - Initiate proactive measures for heat conservation
Modes of rewarming

- Passive
  - External

- Active
  - External
  - Internal

Continuous arteriovenous rewarming (CAVR)

Femoral arteriovenous bypass with percutaneous catheters placed in the groin of lab dogs
Modified Level 1 rapid infuser with countercurrent heat exchanger
No external pressure support
No systemic heparinisation
Continuous arteriovenous rewarming: report of a new technique for treating hypothermia.
Gentilello and Rifley, 1991

Case report: 28 yr old multitrauma patient

Apnoeic pulseless GCS3 T31.5
Resuscitated, BP 80/- T29.5
CAVR via afferent subclavian vein, efferent femoral artery
Time to rewarm to T35, 85min
Spontaneous respirations, purposeful movt
Discharged independent and ambulatory
Is hypothermia in the victim of major trauma protective or harmful?  Gentilello et al, 1997

Prospective randomised study

Patients: 57 hypothermic ($T_c \leq 34.5^\circ C$) trauma patients admitted to SICU and requiring PA catheter

Randomised to CAVR vs standard rewarming

Endpoints: 1. blood products and fluid requirements in first 24 hours
2. Coagulation and hemodynamics, LOS, mortality
Is hypothermia in the victim of major trauma protective or harmful? Gentilello et al, 1997

<table>
<thead>
<tr>
<th>Table 1. DEMOGRAPHIC INFORMATION*</th>
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<tbody>
<tr>
<td></td>
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<tr>
<td></td>
</tr>
<tr>
<td><strong>SR</strong></td>
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<tr>
<td><strong>n</strong></td>
</tr>
<tr>
<td><strong>Age (yr)</strong></td>
</tr>
<tr>
<td><strong>ED temperature (°C)</strong></td>
</tr>
<tr>
<td><strong>ICU temperature (°C)</strong></td>
</tr>
<tr>
<td><strong>Injury Severity Score</strong></td>
</tr>
<tr>
<td><strong>Gender (male)</strong></td>
</tr>
<tr>
<td><strong>Severe head injury</strong></td>
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<tr>
<td><strong>Severe chest injury</strong></td>
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<tr>
<td><strong>Severe abdominal injury</strong></td>
</tr>
<tr>
<td><strong>Severe extremity injury</strong></td>
</tr>
<tr>
<td><strong>Laparotomy</strong></td>
</tr>
<tr>
<td><strong>Systolic blood pressure</strong></td>
</tr>
<tr>
<td><strong>at start of warming (mmHg)</strong></td>
</tr>
<tr>
<td><strong>Blunt mechanism (%)</strong></td>
</tr>
</tbody>
</table>

SR = standard rewarming; CAVR = continuous arteriovenous rewarming.

* Severe injuries were those classified as having Abbreviated Injury Severity Score ≥3. Pearson chi square for categorical data and Mann-Whitney U test for continuous data.
Is hypothermia in the victim of major trauma protective or harmful?  Gentilello et al, 1997

Figure 1. Schematic depiction of continuous arteriovenous rewarming.
Is hypothermia in the victim of major trauma protective or harmful? Gentilello et al, 1997

<table>
<thead>
<tr>
<th>Table 2. VOLUME REQUIREMENTS</th>
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<tbody>
<tr>
<td></td>
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<tr>
<td>Crystallloid 0–8 hr</td>
</tr>
<tr>
<td>Crystallloid 0–24 hr</td>
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<tr>
<td>Red blood cells 0–8 hr</td>
</tr>
<tr>
<td>Red blood cells 0–24 hr</td>
</tr>
<tr>
<td>FFP 0–8 hr</td>
</tr>
<tr>
<td>FFP 0–24 hr</td>
</tr>
<tr>
<td>Cryoprecipitate 0–8 hr</td>
</tr>
<tr>
<td>Cryoprecipitate 0–24 hr</td>
</tr>
<tr>
<td>Platelets 0–8 hr</td>
</tr>
<tr>
<td>Platelets 0–24 hr</td>
</tr>
<tr>
<td>Total volume 0–8 hr</td>
</tr>
<tr>
<td>Total volume 0–24 hr</td>
</tr>
</tbody>
</table>

FFP = fresh frozen plasma; SR = standard rewarming; CAVR = continuous arteriovenous rewarming.
Is hypothermia in the victim of major trauma protective or harmful?  Gentilello et al, 1997

Table 3. OUTCOMES

<table>
<thead>
<tr>
<th></th>
<th>SR</th>
<th>CAVR</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time to 35 C (hr)</td>
<td>2.4 (±1.3)</td>
<td>1.4 (±1.0)</td>
<td>0.003</td>
</tr>
<tr>
<td>Time to 36 C (hr)</td>
<td>4.2 (±2.4)</td>
<td>2.3 (±2.5)</td>
<td>0.002</td>
</tr>
<tr>
<td>Survival to discharge</td>
<td>14 (50%)</td>
<td>19 (66%)</td>
<td>0.24</td>
</tr>
<tr>
<td>Hospital stay (days) (median)</td>
<td>7.5 (±17.1)</td>
<td>25 (±18.9)</td>
<td>0.018</td>
</tr>
<tr>
<td>Mechanical ventilation (days)</td>
<td>4.5 (±10.3)</td>
<td>6.0 (±16.4)</td>
<td>0.031</td>
</tr>
<tr>
<td>(median)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ARDS</td>
<td>3 (11%)</td>
<td>9 (31%)</td>
<td>0.06</td>
</tr>
<tr>
<td>Sepsis</td>
<td>3 (11%)</td>
<td>4 (14%)</td>
<td>0.72</td>
</tr>
<tr>
<td>Pneumonia</td>
<td>8 (28%)</td>
<td></td>
<td>0.83</td>
</tr>
<tr>
<td>Acute renal failure</td>
<td>1 (4%)</td>
<td>1 (4%)</td>
<td>0.98</td>
</tr>
<tr>
<td>Hepatic failure</td>
<td>1 (4%)</td>
<td>1 (4%)</td>
<td>0.98</td>
</tr>
</tbody>
</table>

SR = standard rewarming; CAVR = continuous arteriovenous rewarming; ARDS = adult respiratory distress syndrome.

* Twelve of 28 control patients and two CAVR patients died before rewarming occurred, and are not included in rewarming times. Chi square for categorical data, Mann-Whitney-U test for continuous data.
Can hypothermia be beneficial?

- Accidental deep hypothermia
- Hypothermic cardiac surgery
- Organ transplantation
- Hypothermic induction in cardiac arrest
Can hypothermia be beneficial in the trauma setting?
Hypothermia and traumatic brain injury

Moderate hypothermia (32-34°C):

- reduction of cerebral ischaemia, oedema, and tissue injury; reduction in metabolic rate
- reduction of excitatory neurotransmitters eg. glutamate
- reduction of post-traumatic inflammatory response
- preservation of blood-brain barrier
- reduction of cytokines

Prospective randomised trial

82 patients with severe CHI (GCS 3-7)
Randomised to hypothermia (cooled to 33°C for 24 hours) or normothermia

Blinded assessment of outcome using the Glasgow Outcome Score at 3, 6, 12 months

GOS: 1-death; 2-vegetative state; 3-severe disability; 4-moderate disability; 5-mild or no disability

Demographics similar between the two groups

No differences in LOS, morbidity or mortality

Neurologic outcomes:
no difference for those who were GCS 3 or 4
significantly greater proportion in hypothermia group with good outcome at 3, 6 and 12 months

Multicentre prospective randomised trial (National Acute Brain Injury Study)

392 patients with severe CHI (GCS 3-8)
Randomised within 6 hours of injury to moderate hypothermia (T 33°C) for 48 hours, or normothermia

Blinded assessment of outcome using the Glasgow Outcome Score at 6 months

Demographics similar between the two groups

More complications in hypothermia group
No difference in mortality

Neurologic outcomes:
  no difference between the two groups

Noted that patients hypothermic on admission had:
  higher ISS
  more likely to be hypotensive
  received more IV fluids
Summary

- Is hypothermia a friend or foe in the injured patient?
  - Foe > friend, but not completely resolved
  - Injured organs and tissues seem unlikely to respond as well to hypothermia

- Prevention of hypothermia still the optimal goal
  - Treatment of hypothermic patients requires further study