HYPOTHERMIA & COAGULOPATHY IN TRAUMA

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BRIEF OUTLINE

• Definition and causes – “accidental” hypothermia
• Implications of hypothermia in trauma patients
• Physics & heat transfer
• Physiology & heat transfer
• Prevention & treatment of hypothermia
• Physiological effects of hypothermia

DEFINITION & CAUSES

Accidental hypothermia
Accidental hypothermia occurs in patients who have a normal thermoregulatory mechanism but become hypothermic because of extremely cold stress (e.g., immersion or lost in the wilderness).
What are the mechanisms and factors contributing to this patient’s hypothermia?

HYPOTHERMIA

Predisposing Factors to Hypothermia:
- Patient Age
- Patient Health
- Medications
- Prolonged or Intense Exposure
- Co-existing Weather Conditions

DEFINITION & CAUSES

Classification of hypothermia based on severity:
- mild hypothermia: core temperatures ranging between 32°C and 35°C (90°F-95°F)
- moderate hypothermia between 28°C and 32°C (82°F-90°F)
- severe hypothermia defined by temperatures less than 28°C (82°F).
Hypothermia in trauma victims: an ominous predictor of survival.
Jurkovich GJ, Greiser WB, Luterman A, Curreri PW.

Abstract
Hypothermia in trauma patients is generally considered an ominous sign, although the actual temperature at which hypothermia affects survival is ill-defined. In this study, the impact of body core hypothermia on outcome in 71 adult trauma patients with Injury Severity Scores (ISS) greater than or equal to 25 was analyzed. Forty-two per cent of the patients had a core temperature (Tc) below 34 degrees C, 23% below 33 degrees C, and 13% below 32 degrees C. The mortality of hypothermia patients was consistently greater than those who remained warm, regardless of index core temperature. Mortality if Tc less than 34 degrees C = 40%, less than 33 degrees C = 69%, less than 32 degrees C = 100%, whereas mortality if Tc greater than or equal to 34 degrees C = 7%, and greater than or equal to 32 degrees C = 10%. Mortality and the incidence of hypothermia increased with higher ISS, massive fluid resuscitation, and the presence of shock. Within each subgroup (i.e., greater ISS, massive fluid administration, shock) the mortality of hypothermic patients was significantly higher than those who remained warm. No patient whose core temperature fell below 32 degrees C survived.

1. Mortality and the incidence of hypothermia increased with higher ISS, massive fluid resuscitation, and the presence of shock.
2. Within each subgroup (i.e., greater ISS, massive fluid administration, shock) the mortality of hypothermic patients was significantly higher than those who remained warm.
3. No patient whose core temperature fell below 32 degrees C survived.

A balance of heat production (thermogenesis) and heat dissipation (thermolysis).

Hypothalamus (endocrine gland) controls heat conservation and dissipation via the autonomic nervous and endocrine systems.
Thermogenesis depends on glycogen (sugar) and O2 metabolism; so heat production is decreased in traumatized patients. Heat conversation usually occurs through vasoconstriction, which eventual produces behavioral changes.

What are the mechanisms and factors contributing to this patient’s hypothermia?

Heat loss results from:
- Conduction
- Convection
- Radiation
- Evaporation
CONDUCTION

- Heat loss occurs due to direct contact of the body with a cooler object.
- Heat flows from higher temperature matter to lower temperature matter.

CONVECTION

- Heat loss occurs due to air currents passing over the body.
- Heat must first be conducted to the air before convection can occur.

RADIATION

- Heat loss results from infrared rays.
- All objects not at absolute zero will radiate heat to the atmosphere.
EVAPORATION

- Heat loss occurs as water evaporates from the skin.
- Heat loss occurs as water evaporates from the lungs during respiration.

PHYSIOLOGY OF HEAT EXCHANGE/TRANSFER

Even when inactive, an adult male must lose heat at a rate of about 90 watts as a result of his basal metabolism. One implication of the model is that radiation is the most important heat transfer mechanism at ordinary room temperatures. The second implication is that we have evolved into “heat losers.”

SIGNS AND SYMPTOMS

MILD Hypothermia:
- Lethargy
- Shivering
- Lack of Coordination
- Pale, cold, dry skin
- Early rise in blood pressure, heart, and respiratory rates.
SIGNS AND SYMPTOMS

SEVERE Hypothermia:
- No shivering
- Heart rhythm problems
- Cardiac arrest
- Loss of voluntary muscle control
- Low blood pressure
- Undetectable pulse and respirations

PRE-HOSPITAL TREATMENT

1. Remove wet garments
2. Protect against further heat loss and wind chill.
4. Avoid rough handling.
5. Monitor the core temperature.
6. Monitor the cardiac rhythm.

IS HYPOTHERMIA EASIER TO PREVENT OR TO TREAT? OR DOES IT EVEN MATTER?
REWARMING

- Rewarming of the SEVERE hypothermia patient is best carried out in the hospital setting using a pre-defined protocol, unless travel time exceeds 15 minutes.
- Most patients who die during active rewarming die from ventricular fibrillation.

REWARMING

Application of external heat in the prehospital setting is usually not effective and not recommended because:
  - More heat transferrence is required than generally possible in the prehospital setting.
  - Application of external heat may cause “rewarming shock.”

REWARMING SHOCK

- Occurs due to peripheral reflex vasodilation.
- Causes the return of cooled blood and metabolic acids from the extremities.
- May cause a paradoxical afterdrop in the core temperature further worsening hypothermia.
- Can be prevented in the prehospital setting by using warmed IV fluids during active rewarming.
## REWARMING TECHNIQUES

<table>
<thead>
<tr>
<th>Passive</th>
<th>Active (continued...)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Surrounding temperature (variable)</td>
<td>Internal</td>
</tr>
<tr>
<td>Dry patient</td>
<td>Intravenous liquids (variable)</td>
</tr>
<tr>
<td>Shivering</td>
<td>Lavages (2–4 °C)</td>
</tr>
<tr>
<td>Clothing/blanket/Polyethylene cover (variable)</td>
<td>Warmed inhalational agents (0.5–1.2 °C)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Active</th>
<th>Extracorporeal</th>
</tr>
</thead>
<tbody>
<tr>
<td>External</td>
<td>Haemodialysis (2–3 °C)</td>
</tr>
<tr>
<td>Immersion in warm bath (2–4 °C)</td>
<td>Continuous arteriovenous rewarming (3–4 °C)</td>
</tr>
<tr>
<td>External convection heater</td>
<td>Continuous venovenous rewarming (variable)</td>
</tr>
<tr>
<td>Forced air blanket (1–2.5 °C)</td>
<td>Cardiopulmonary bypass (7–10 °C)</td>
</tr>
<tr>
<td>Mattress</td>
<td></td>
</tr>
<tr>
<td>Forced-air (1–2.5 °C)</td>
<td></td>
</tr>
<tr>
<td>Trans-warmer gel (0.5–0.7 °C)</td>
<td></td>
</tr>
<tr>
<td>Circulating water (0.2–0.6 °C)</td>
<td></td>
</tr>
<tr>
<td>Carbon-fiber resistive heating</td>
<td></td>
</tr>
</tbody>
</table>
**REWARMING TECHNIQUES**

**Passive**
- Surrounding temperature (variable)
- Dry patient
- Shivering
- Clothing/blanket/Polyethylene cover (variable)

**Active**
- Immersion in warm bath (2–4 °C)
- External convection heater
- Mattress
- Forced-air (1–2.5 °C)
- Trans-warmer gel (0.5–0.7 °C)
- Circulating water (0.2–0.9 °C)
- Carbon-fibre resistive heating

**Active (continued...)**
- Intravenous liquids (variable)
- Warmed inhalational agents (0.5–1.2 °C)
- Active intravascular re-warming device (1.5–2 °C)

**Extracorporeal**
- Haemodialysis (2–3 °C)
- Continuous arteriovenous re-warming (3–4 °C)
- Continuous venovenous re-warming (variable)
- Cardiopulmonary bypass (7–10 °C)

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**REWARMING PROTOCOL**

**Hypothermia**

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**PHYSICS OF HEAT EXCHANGE/TRANSFER**

**IT EASIER TO PREVENT TRAUMA/SHOCK ASSOCIATED HYPOTHERMIA THAN IT IS TO TREAT ESTABLISHED HYPOTHERMIA**
IS ACTIVE REWARMING BENEFICIAL?

Is Hypothermia in the Victim of Major Trauma Protective or Harmful?: A Randomized, Prospective Study
Annals of Surgery
Issue: Volume 226(4), October 1997, pp 439-449


REWARMING TECHNIQUES

EXTERNAL METHODS OF ACTIVE REWARMING:
CAVR & CVVR

IS ACTIVE REWARMING BENEFICIAL?
IS ACTIVE REWARMING BENEFICIAL?

CARDIAC ARREST

Other Clinical Concerns:

• Resuscitation of cardiac arrest due to hypothermia is only successful when the patient is being re-warmed.
• The hypothermic cardiac arrest patient is not DEAD until he is WARM and DEAD!

HYPOTHERMIA AND TRAUMA

Other Clinical Concerns:

• Hypothermia is common, even in persons with minor trauma.
• Hypothermia can worsen infectious complications of abdominal trauma.
• Hypothermic trauma patients suffer increased blood loss compared to their normothermic cohorts.
• Maintaining normothermia requires ATP, a substance in short supply in the hypoxic cells of a hypoperfused patient. Therefore, hypothermia becomes more difficult to reverse than primary/accidental hypothermia alone.
COAGULOPATHY

Increase blood loss secondary to:

• Temperature-induced coagulopathy (bleeding or clotting disorders)
• Altered and reduced platelet function
• Increased platelet sequestration
• Decreased activation of coagulation cascade
• Increased need for transfusion of red blood cells, platelets, and plasma

HYPOTHERMIA EFFECT ON BLOOD LOSS

Hypothermia in massive transfusion: Have we been paying enough attention to it?
Journal of Trauma and Acute Care Surgery
73(2):486-491, August 2012.

EFFECT OF EARLY RESUSCITATION ON HYPOTHERMIA INDUCED COAGULOPATHY

LETHAL TRIAD

HYPOTHERMIA EFFECT ON BLOOD LOSS

Evolving beyond the vicious triad: Differential mediation of traumatic coagulopathy by injury, shock and resuscitation.

Journal of Trauma and Acute Care Surgery 78(3):516-523, March 2015.

HYPOTHERMIA INDUCED COAGULOPATHY

<table>
<thead>
<tr>
<th>Variable</th>
<th>n=1421</th>
<th>n=254</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nosocomial Infection</td>
<td>125 (44.5)</td>
<td>34 (28.8)</td>
<td>0.066</td>
</tr>
<tr>
<td>Mortality</td>
<td>105 (34.7)</td>
<td>53 (20.8)</td>
<td>0.003</td>
</tr>
<tr>
<td>Complicated Outcome</td>
<td>124 (9.4)</td>
<td>120 (47.2)</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>

HYPOTHERMIA AND AFFECT ON OUTCOME

- Survival is possible with aggressive resuscitation and rapid rewarming in injured patients with core temperature below 32°C
- Data from Host Response to Injury and Inflammation study demonstrated survival of 20.8% with active rewarming for all patients with hypothermia.
## HYPOTHERMIA AND AFFECT ON OUTCOME

<table>
<thead>
<tr>
<th>Complicated Outcome</th>
<th>Odd Ratio (95% CI)</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>1.02 (1.01-1.03)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>BMI</td>
<td>1.03 (1.01-1.05)</td>
<td>0.004</td>
</tr>
<tr>
<td>RBC (units)</td>
<td>1.14 (1.07-1.21)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>ISS</td>
<td>1.06 (1.05-1.08)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Hypothermia</td>
<td>2.29 (1.39-3.76)</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>

Hypothermia not an independent predictor for mortality.

## ISSUES IN HYPOTHERMIA

Considerations in Emergency Care:

“Based upon our findings, accidental hypothermia poses a relevant problem in the prehospital treatment of trauma patients. It is not limited to a special season of the year.”


- Hypothermia occurs frequently, and is an unrecognized problem.
- Hypothermia associated with increased complications, and increased mortality.
- Rapid treatment of hypothermia improves coagulopathy, decreases amount of blood transfusion, and reduces risk of organ dysfunction.

CONCLUSION