Hypothermia

*Hypothermia is defined as core body temperature below 35-36°C, it is further characterized as **mild hypothermia** (36-34° / ATLS 35-32°), **moderate hypothermia** (34-30° / ATLS 32-30°), **severe hypothermia** (< 30° / ATLS < 30°); perioperative hypothermia is associated with increased mortality; mild hypothermia (1-2°C) triples the incidence of morbid cardiac conditions, triples the incidence of surgical wound infections, prolongs hospitalization and significantly increases blood loss and transfusion*

ANESTHETIC CONSIDERATIONS:

- Increased perioperative adverse events
  - Increased cardiac morbidity and mortality
  - Increased blood loss and transfusion requirements
  - Decreased drug metabolism, decreased MAC (slow emergence)
  - Increased infection risk
  - Increased heat loss with pediatric patients, elderly and burn patients
- Consider etiology for hypothermia and reverse any reversible causes
  - Increased heat loss: exposure, vasodilatory drugs (EtOH, toxins), sepsis, iatrogenic (cold IV solutions, cold OR / ER)
  - Decreased heat production: hypothyroidism, hypoglycemia, malnutrition, impaired shivering (GA / neuraxial), extremes of age
  - Impaired regulation: CNS dysfunction (CHI)
- Consider maneuvers to increase temperature
  - Prevent further heat loss
  - Mild hypothermia >34°C: passive external rewarming (warm blankets, remove wet clothing/drapes, warm environment)
  - Moderate hypothermia 30-34 °C: active external rewarming (forced air warmer, warming blanket, warmed IV fluids)
  - Severe hypothermia <30 °C: active internal rewarming (peritoneal lavage, esophageal warming tubes, consider ECMO/CPB)
- ACLS 'Hypothermia' algorithm modifications
  - Gentle handling of patients with hypothermia to prevent preciptation of cardiac dysrhythmias
  - Pulse and breathing checks for 30-45s (extended)
  - If hypothermic and in VFib/pulseless Vtach, defibrillation may be attempted once with immediate CPR following
  - If the patient does not respond to 1 shock, further defibrillation should be deferred until patient's core temperature is >30-32°C
  - If core temperature <30°C, hold administration of vasoactive medications
  - If core temperature 30-32°C, may give vasoactive medications with increased intervals between doses
  - Severe hypothermia <30°C warrants active internal rewarming (pleural lavage, peritoneal lavage, warmed humidified O2 through ETT, CBP, ECMO)
  - If hypothermic for >45-60min, may require volume infusion as warming → vasodilation and intravascular volume depletion

ANESTHETIC GOALS:

- Warm patient (warm air convection most effective) and maintain perioperative normothermia
- Prevent heat loss (pre-warming, increase environmental temperature, decrease exposure, warm fluids etc.)
- Treat arrhythmias
- Minimize postoperative complications

HISTORY

- Guided by patient and surgery
- Directed for etiology if patient is cold upon arrival to OR
  - Type of exposure
  - Duration of exposure
  - Concomitant trauma
  - Concomitant ingestion / intoxication
  - Co-morbid disease
  - Medications

PHYSICAL

- **VITALS** - including GCS, temperature (thermometer which reads below 34 degrees)
- **CVS / RESP** – standard exam (if found down: concern for arrythmias, pulmonary edema and aspiration)
- **GI/GU** – volume status (mild hypothermia can induce a cold diuresis)

INVESTIGATIONS

- Guided by patient Hx and condition
- **Labs**
  - CBC - WBC & platelets may be sequestered; hemoconcentration
  - Lytes - ?hyperkalemia
  - ABG - metabolic acidosis, respiratory alkalosis, or both
  - Glucose
  - aPTT / INR – can be falsely normal (are analyzed at 37 degrees)
  - Amylase – hypothermia-induced pancreatitis
- **Imaging**
  - Should include a EKG (arrhythmias / ischemia)
    - Prolongation of PR, QRS, QT intervals (bradycardia, first degree AV block)
    - ST segment elevation
    - T wave inversions; Osborn wave or J wave (prominent convex deflections at the J point)
    - Atrial fibrillation or sinus bradycardia
    - VF/VT
  - CXR – aspiration, vascular congestion, pulmonary edema

OPTIMIZATION

- Warm up prior to major invasive surgery if possible (decreased coagulopathy when warm)

ANESTHETIC OPTIONS

- Dependant on the surgery.
- Be aware that even though a patient under neuraxial anesthesia may not complain of the feeling of being cold, they may shiver and have a decreased core temperature (which we often do not monitor in an awake patient)

ANESTHETIC SETUP

- **Drugs**
  - Standard emergency drugs
- **Equipment**
  - Routine CAS monitors
  - Increase OR temperature to > 21 degrees or warmer
  - Temperature probe (if concerned use two: esophageal and cutaneous)
    - Most accurate site for measuring core temperature (if no PA catheter) is the distal ⅓ of the esophagus
  - Use a forced air warmer (if not available use 3 regular blankets…heating them up prior to application just makes us feel better, is of very minimal benefit) and warm IV fluids (to body temperature is the best)
  - Use of PNS to monitor the rate of twitch recovery index, will speak to the duration of action

MANAGEMENT OF ANESTHESIA

- **Induction**
  - Guided by patient condition
  - Treat arrythmias as per ACLS guidelines
  - Airway – may need intubation for secretions / decreased LOC
  - Breathing
  - Circulation – fluids / inotropes / pressors
- **Maintenance**
  - Monitor PNS twitch response
  - Monitor U/O
  - Use appropriate warming techniques, prevent further heat loss
  - Diagnose and treat complications
    - Arrhythmias
    - Acidosis
    - Electrolyte abnormalities
    - Coagulation abnormalities
- **Emergence**
  - Ensure full neuromuscular reversal and strong head lift
  - Ensure normothermia at the end of case

DISPOSITION & MONITORING

- Dependent on underlying injuries and body temperature / degree of resuscitation required

COMPLICATIONS

- Postoperative MI morbidity: thermal discomfort is also physiologically stressful because it elevates blood pressure, heart rate, and plasma catecholamine concentrations
- Postoperative residual weakness (prolonged duration of action of NDMB and slower onset of reversal agents)
- Postoperative infection and poor wound healing

PATHOPHYSIOLOGY

- **Mechanisms of heat loss:**
  - **Evaporation**: vaporization of water through both insensible losses and sweat
  - **Radiation**: emission of infrared electromagnetic energy ** most significant method of heat loss
  - **Conduction**: direct transfer of heat to an adjacent, cooler object
  - **Convection**: direct transfer of heat to convective air currents
- Most common mechanisms of accidental hypothermia are convective heat loss to cold air and conductive heat loss to water
- It leads to:
  - Altered cell membrane function
  - Efflux of intracellular fluid
  - Enzymatic dysfunction
  - Electrolyte imbalances (hyperkalemia)
- Cell death results from a combination of above injuries plus crystallization of intra- and extracellular water
- **Physiology**
  - Thermoregulation is made up of afferent sensing, central processing and efferent responses
  - Cold impulses transmitted to CNS via A-delta fibers and warm impulses transmitted via C-fibers
  - Central processing, mainly in the hypothalamus results in voluntary and involuntary efferent responses
    - In unanesthetized patients the progressive response to cold is: vasoconstriction → non-shivering thermogenesis → shivering thermogenesis
      - **Vasoconstriction** reduces cutaneous heat loss
      - **Non-shivering thermogenesis** is minimal in adults but can double metabolic heat production in brown fat of babies and infants
      - **Shivering** (involuntary skeletal muscle activity) significantly increases metabolism and heat production
    - The warm autonomic response is also progressive: sweating → vasodilation

Causes of hypothermia			
Decreased heat production	**Increased heat loss**	**Impaired regulation**	**Other**

Endocrineologic disease Hypopituitarism Hypoadrenalism Hypothyroidsm **Insufficient fuel** Hypoglycemia Malnutrition **Neuromuscular inefficiency** Extremes of age Impaired shivering Inactivity	**Environmental exposure** Cold water immersion Cold water submersion Exposure to cold air **Induced vasodilation** Drugs Alcohol Toxins **Skin disorders** Burns Psoriasis Exfoliative dermatitis **Iatrogenic** Cold infusion Emergent deliveries	**Central** Metabolic Drugs Barbiturates Phenothiazines Insulin TCAs, sedatives, EtOH B-blockers Trauma CVA SAH Parkinsonism Neoplasm Hypothalamic dysfunction Multiple sclerosis Wernicke's encephalopathy Anorexia nervosa **Peripheral** Spinal-cord transaction Neuropathies Diabetes mellitus	Sepsis Pancreatitis Carcinomatosis Uremia Vascular insufficiency

Risk factors associated with death from accidental hypothermia:

- Alcohol use
- Homelessness
- Psychiatric disease
- Elderly

Clinical presentation		
Mild	**Moderate**	**Severe**
• Tachypnea • Tachycardia • Hyperventilation • Ataxia • Dysarthria • Impaired judgment • Shivering • Cold diuresis	• Decreased heart rate • Decreased cardiac output • Hypoventilation • CNS depression • Hyporeflexia • Decreased renal blood flow • Loss of shivering • Atrial fibrillation, junctional bradycardia, other arrhythmias	• Pulmonary edema • Oliguria • Areflexia • Coma • Hypotension • Bradycardia • Ventricular arrhythmias • Asystole

- **Rewarming techniques**
  - **Passive external rewarming**: (for mild hypothermia)
    - Remove wet clothing
    - Cover patient with blankets or other types of insulation
    - Requires physiologic reserve to generate heat by shivering or increasing metabolic rate
  - **Active external rewarming**: (for moderate to severe hypothermia, or for those who fail passive rewarming)
    - Warm blankets
    - Heating pads
    - Radiant heat
    - Warms baths
    - Forced warm air
    - Risk of core temperature **afterdrop**
      - Cold, acidemic blood in the vasoconstricted extremities returns to the core circulation, causing a drop in temperature and pH
      - At the same time peripheral vasodilation may potentially contribute to precipitous hypotension, inadequate coronary perfusion, and ventricular fibrillation
      - This may explain fatal dysrhythmias that sometimes occur during rewarming
      - Re-warm trunk / core prior to extremities
  - **Active internal rewarming**: (for moderate to severe hypothermia)
    - Pleural irrigation
    - Peritoneal irrigation
    - Continuous arteriovenous or venovenous rewarming
    - Hemodialysis
    - Cardiopulmonary bypass
    - Humidified oxygen
    - Warm IV fluids
    - Bladder or GI irrigation
- **Intraoperative hypothermia** → initial rapid ↓ in core temperature, followed by a slow, linear reduction in core temperature
  - Finally, core temperature stabilizes and remains virtually unchanged
- **Initial fall in temperature with GA:**
  - Core temperature represents only about half the body mass (mostly the trunk and head), the remaining mass is typically 2°C to 4°C cooler than the core

- This core-to-peripheral temperature gradient is normally maintained by tonic thermoregulatory vasoconstriction
- Anesthetic-induced vasodilation allows core heat to flow peripherally

- **Pediatric risk factors** for perioperative hypothermia
  - Neonatal period
  - Low ambient operating room temperature
  - Burn injuries
  - General anesthesia with neuraxial anesthesia
    - NA anesthesia has been shown to attenuate the thermogenic response to hypothermia
- **Complications** of perioperative hypothermia
  - Increased rates of wound infection
  - Morbid cardiac events (arrhythmias)
  - Blood loss
    - Hypothermia produces a multifactorial coagulopathy involving defective TXA_2 release, alterations in platelet function, and inhibition of the coagulation cascade
    - Because our coagulation studies are done at 37 degrees, these effects can often be overlooked
  - Length of stay in both recovery and hospital
- Maintaining core temperature at or above 36°C can be beneficial for the patient and cost effective
  - RCT of THR patients showed the hypothermic group, whose mean postoperative temperature was only 1.6°C lower than that of the normothermic group, lost on average 500 mL or 30% more blood
- Unlike infants, heat loss through the head is not an appreciable factor (i.e. is a myth that we lose 50% of our heat through our heads)

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- Faust p 91-92 , Gaba p 163-165, Barash , ACLS/ATLS Handbooks, Miller p 1571-1592, AHA 2005
- DI Sessler - Complications and Treatment of Mild Hypothermia Anesthesiology 2001, 95 : 531-543
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- UPTODATE

(a small section on) Submersion:

- Drowning: mortality secondary to a submersion event
- Near Drowning: term has been abandoned; used to refer to survival after a submersion event with or without loss of consciousness (wet – secondry to aspiration into lungs; dry: hypoxemia secondary to laryngospasm)
- Submersion Injury: new term to describe injury/sequelae secondary to submersion up until death

EPIDEMIOLOGY

- Bimodal: children <5yo (unable to swim), males 15-25 yo
- Risk factors: inability to swim, risk taking behaviour, alcohol and drug use, inadequate adult supervision, hypothermia, concomitant trauma/cva/MI, primary cardiac arrhythmia, hyperventilation prior to shallow dive

PATHOPHYSIOLOGY

- Initially: panic, breathholding, air hunger, struggle to stay above water
- Reflex inspiratory events then occur:
  - Aspiration
    - Distinction between salt and fresh water is no longer important
      - Both types cause V/Q mismatch, decrease compliance, and intrapulmonary shunting → hypoxemia and ultimately end organ hypoxia
    - >11mL/kg aspiration required to have total body volume changes
    - >22mL/kg required to have electrolyte changes
    - unusual for submersion injury patients to aspirate >3-4cc/kg
  - Reflex laryngospasm when water reaches lower respiratory tract

ANESTHETIC CONSIDERATIONS:

- Hypoxia
  - Secondary to aspiration or laryngospasm
  - Decreased pulmonary compliance (lung protective ventilation)
  - V/Q mismatch and shunt
  - Pulmonary edema (NPPE with laryngospasm)
  - End organ hypoxia
- Aspiration
  - Distinction between fresh and salt water not clinically important
- Hypothermia
  - Degree of hypothermia mandates active vs. passive rewarming
  - Remove wet clothing
  - Modified ACLS guidelines for hypothermia
  - No role for induced hypothermia (cerebral protection)
- Hypovolemia
  - cold diuresis
  - mannitol for ICP control
- Cerebral Edema and increased ICP
  - Secondary to hypoxic brain injury
  - Mannitol and hypertonic saline as needed
  - Postural drainage
  - Seizure control
  - Electrolyte and metabolic abnormalities (correct hyper/hypoglycemia, Na, etc.)
  - Avoid NMBAs if possible as they can mask seizure activity