Heat Illness

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Definitions

- Heat illness is any illness caused by the failure of heat regulation
- 2 main types
- Major Heat illness
- Minor Heat illness

Types of Heat Illness

- Major
  - Heat Exhaustion
  - Heat Stroke
- Minor
  - Heat Cramps
  - Heat Syncope
  - Miliaria Rubra
  - Heat Tetany

Epidemiology I

- 4000 deaths/year attributable to heat illness
- 2nd or 3rd most common cause of death in young athletes
- Mortality is 10-75%
- Primary Mortality in the young and old

Epidemiology II

- Risk factors
  - primarily enforced activity in hot environments
  - morbidity and mortality is related to elevated WBGT
  - most episodes of heat stroke are related to the temperature of the *Previous day*

Physiology

- Heat Gain or production
- Heat loss
- Temperature regulation

Heat Gain / Production

- Metabolic reactions in the human body produce heat
- This amounts to 50-60 kcal/hr/m^2
- Or 100 kcal/hr for an average person
- This can raise body temp by 1.1° C/hr
- Heat production is increased 10-20x by exertion

Heat Loss / Transfer

- 4 main mechanisms for heat loss
  - Conduction 2%
  - Convection 10%
  - Radiation 55%
  - Evaporation 30%

Conduction

- The exchange of heat between the body and and object in direct contact
- Least important in human heat transfer
- Can be significant in the obtunded individual

Convection I

- The exchange of heat between the body and a gas or fluid
- Is affected by multiple factors
  - T_{amb}
  - T_{skin}
  - Motion of the gas or fluid
- Provides rationale for insulating clothing

Convection II

- Once $T_{amb} > T_{skin}$ heat loss stops
- Cold water immersion increases convective losses by a factor of 32 compared to cold air
- Flow rate of gas or fluid can affect rate of convection
- Cutaneous capillaries are the determinant of T_{skin}

Radiation I

- Heat transfer between the body and surroundings by electromagnetic waves
- Radiation is dependent solely on the temperature of the radiating body
- Is the primary mechanism of heat loss and gain in many cases
- When $T_{amb} > T_{body}$ the body ***gains*** heat.

Radiation II

- Can also be a mechanism of heat gain
- Solar load is 250 kcal/hr in a nude individual
- 100 kcal/hr in a clothed individual
- Highly pigmented skin absorbs about 20% more heat

Evaporation I

- Heat transfer via vaporization of water
- Occurs if the body is unable to maintain thermal stability using other mechanisms
- Requires sweating
- Heat of vaporization of water is 2.65 j/Kg

Evaporation II

- Vaporization of sweat results in a heat loss of about 580 kcal/l
- Theoretical maximum heat loss is 650 kcal/hr
- At 75 percent humidity evaporative contributions to heat loss fall off rapidly
- Sweat that drips doesn’t cool

Temperature Regulation

- The body uses multiple mechanisms to maintain T_C between 36°-38° C
- Both behavioral and physiologic thermoregulation occurs

Behavioral Thermoregulation

- 2 primary behaviors are used
- Seeking a cool environment
- Fluid intake
- Often these are inadequate

Physiologic Thermoregulation

- Temperature sensation occurs in the skin
- Primary temperature regulation occurs in the hypothalamus
- The main response to heat stress is cutaneous vasodilation and sweating
- There is a linear relationship between T_C and these responses above 37° C

Risk Factors for Heat illness

- Four major risk factors
  - Age
  - Cardiovascular Strain
  - Fluid / Electrolyte Changes
  - Acclimitazation

Age

- The very young and very old have difficulty with behavioral thermoregulation
- Many drugs affect both physiologic and behavioral thermoregulation
- Primary drug offenders are diuretics, vasoactives and sedatives

Cardiovascular Strain I

- The primary mechanisms of heat loss are dependent on an intact cardiovascular system
- Heat causes cutaneous vasodilation
- Exercise causes muscular vasodilation
- Maximum conductance of these systems is 75-85 L/min

Cardiovascular Strain II

- The maximal CO of most people is about 22 L/min
- The groups at high risk for heat illness have a more limited CO
- The increased production of heat and the inability to appropriately transfer heat results in heat illness

Fluid / Electrolyte Imbalance

- Fluid and electrolyte problems in heat illness due to many factors
  - Sweating
  - Unavoidable fluid losses
  - Voluntary Dehydration
  - Thirst Regulation

Acclimatization

- Acclimatization is the physiologic and biochemical adaptation to heat stress
- Occurs generally over 7-10 days
- The rate and degree of acclimatization is enhanced by physical activity
- acclimatization requires an elevated T_C to occurs

Acclimatization II

- Lower temp threshold for sweating
- Sweat volume increases
- Sweat [Na^+] decreases
- Sweating becomes more uniform over body surfaces

Acclimatization III

- Lower temp threshold for cutaneous vasodilation
- Lower heart rate with exercise
- Increased plasma volume
- Increased stroke volume

Acclimatization IV

- 10 days of successive treadmill walks in dry heat decreases final exercise heart rate by 40 bpm and lowers final rectal and skin temps by 1-2°C

Minor Heat Illness

- Heat Cramps
- Heat Edema
- Heat Syncope
- Heat Tetany
- Miliaria Rubra

Heat Cramps I

- Brief, severe muscle cramps occurring in first several days of heat exposure
- Occur in heavily exercising people
- Generally profuse sweating
- Usually undergo hypotonic, large volume fluid replacement
- Hyperventilation not present

Heat Cramps II

- Occur after exercise
- Occur after fluid replacement
- Treatment is low dose salt repletion
- Salt tablets are the work of the devil
  - Gastric irritant
  - Induce vomiting

Heat Edema

- Peripheral, usually dependent edema
- Occurs in individuals who do not normally have edema unless exposed to heat stress
- Primary mechanism is capillary vasodilation and leak
- Resolved by elevation

Heat Syncope

- Syncopal episode due to effective blood volume loss
- Basically orthostatic syncope due to peripheral vasodilation
- Always regain consciousness upon attaining the supine position
- IF they don't, suspect HEATSTROKE

Heat Tetany

- Tetanic carpopedal spasms secondary to hyperventilation
- Due to respiratory alkalosis
- Sx do not correlate with absolute change in pH, pCO_2 or Temp
- Resolve with removal from hot environment

Miliaria Rubra

- Prickly heat
- Due to macerated stratum corneum plugging sweat gland ducts
- Results in an intensely pruritic erythematous rash
- Results in inadequate sweating
- Treat with topical salicylates

Major Heat Illness

- Heat exhaustion
  - Water depletion
  - Salt depletion
- Heat Stroke
  - Classic
  - Exertional

Heat Exhaustion

- 2 types
  - Water depletion
  - Salt depletion
- Develops over 3-5d
- Occurs in unacclimatized people
- is a “manifestation of cardiovascular strain resulting from maintaining normothermia”

Head Exhaustion Dx

- Malaise, fatigue, headache
- Temp usually normal, always < 40°C
- Normal mental function
- Tachycardia
- Orthostatic Hypotension
- Dehydration

Water Depletion Heat Exhaustion

- Usually found in people with restricted access to water
- Combination of voluntary dehydration plus sweat, lung and insensible losses
- Characterized by hypernatremic, hyperosmolar dehydration

Salt Depletion Heat Exhaustion

- Takes longer to develop than water depletion
- Occurs when hypotonic fluid replaces sweat losses
- Hyponatremic, Hypochloremic dehydration
- Risk of Central Pontine Myelinolysis with resuscitation

Heat Exhaustion Therapy I

- Heat Exhaustion is primarily a volume loss problem
- Treat Volume loss first
- Treat electrolyte abnormalities based on lab findings
- If Temp is elevated institute cooling measures

Heat Exhaustion Therapy II

- Mild forms can be treated with oral fluids
- Severe forms require calculation of and careful replacement of salt or water deficit
- Pure forms of salt or water types are rare
- Heat exhaustion often occurs with heat stroke

Heat Stroke

- **Acute Mental Status Changes** associated with elevated body temperature
- Usually of rapid onset
- May occur in the acclimatized or unacclimatized individual
- Is a true medical emergency

Heat Stroke II

- 2 types
  - Classic
  - Exertional
- Treatment is the same

Heat Stroke DX

- ***Always*** have CNS dysfunction
- ***May*** have elevated body temp
- ***May*** have anhidrosis
- ***Always*** have exposure to heat stress
- ***Always*** have elevated SGOT/SGPT
  - these elevations may not be seen at presentation

Classic Heat Stroke

- Usually seen during heat waves
- Victims are usually the old/young/poor
- Victims usually on drugs that interfere with normal thermoregulation
- Usually preceeded by undiagnosed or untreated heat exhaustion
- Due to inability to tolerate exogenous heat

Exertional Heat Stroke

- Occurs anytime
- Victims usually young/healthy males
- Usually no drugs involved
- Preceeded by heavy labor in hot environment
- Results from excessive heat production and inadequate heat dissipation

Heat Stroke Pathophysiology

- Failure of homeostatic thermoregualation
- On a cellular level is thought to be due to severe energy depletion
- Elevated temperature increases all metabolic function
- ATP turnover results in energy depletion and cell injury

Pathophysiology II

- Thermoregulatory response results in splanchnic vasoconstriction
- May result in endotoxin liberation from GI tract
- Heat induced Acute Phase response results in inflammatory mediator release
- Combination of above results in SIRS/Sepsis picture

Systemic Manifestations

- Nearly all systems affected
- CNS
- CVS
- Respiratory
- GI
- GU

CNS Manifestations

- Almost any CNS dysfunction can be seen
- Usually delirium or coma is prominent
- May have focal neuro deficits
- Often have seizures
- May have fixed, dilated pupils and a flat EEG

Cardiovascular Manifestations

- Usually patients are hyperdynamic
- Profoundly tachycardic with low SVR and elevated CO
- CVP is generally elevated
- Usually a picture of RV failure with Sepsis

Respiratory Manifestations

- Respiratory Alkalosis seen in CHS
- May produce tetany

- Lactic Acidosis seen in EHS
- Usually this is well tolerated
- Can result in hyperventilation

GI Manifestations

- Hepatic Transaminases always elevated
- Usually not seen for 12-24 hours
- If not elevated consider another diagnosis
- Diarrhea and vomiting often occur
- These are aggravated by cooling

Renal Manifestations

- Acute Oliguric Renal failure is often seen
- 25% in EHS and 5% in CHS
- Hypovolemia and intense physical activity predispose to Rhabdo.
- In CHS renal failure is usually due to profound hypovolemia

Heat Stroke Therapy I

- ABC
- Cooling Measures
- Consider Other Diagnosis
  - Meningitis / Encephalitis
  - Malignant Hyperthermia
  - Thyroid Storm
  - Hypothalamic Hemorrhage

Cooling Techniques

- Must be started ***immediately***
- Ice water Immersion (0.16°C/min)
- Cool (15-16°) Immersion (0.16°C/min)
- Evaporative Technique (0.06-0.31°C/min)
- Ice packs to groin and axillae and neck
- Cooling blankets don't work fast enough

Evaporative Techniques

- Suspend patient in net or hammock
- Spray with tepid water
- High flow warm air circulation

- Allows for close monitoring and rapid cooling

Heat Stroke Therapy II

- Volume Resuscitate
- Treat Myoglobinuria aggressively
- Treat hypoglycemia
- Treat Seizures
- Stop Active cooling at 39° C
- NO ANTIPYRETICS!

Antipyretics

- Antipyretics generally affect the hypothalamic set point to cause defervescence
- In heat illness the set point is not affected
- Antipyretics have side effects that persons with heat illness are particularly susceptible to and are not therapeutic

Conclusions

- Heat Illness is relatively common
- Heat Illness is often overlooked
- Heat Stroke is a Medical Emergency
- All heat illness is preventable
- Always consider other diagnoses