Topic review

Heat emergencies

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Heat emergencies

- Represent a continuum of disorders from heat cramps to heat stress that, when severe, culminate in heat stroke.
- In most circumstances, heat emergencies can be avoided through common sense, public education, and prevention.

Epidermiology

- Varies with the weather
  - During heat wave and severe droughts > fatality rates spike
- From 1999-2003, average of 688 heat-related deaths per year reported from U.S.
- Heat wave in summer 2003 caused estimated 14,800 deaths in France
- In Russian heat wave in 2010 caused estimated 15,000 deaths
- Heat stroke less likely in persons who live in warmer climate

Thermoregulation

- Homeostasis requires stable temperature
  - ~98.6ºF (96.8-100.4 F/36-38°C)
- Control mechanism
  - Hypothalamus
  - Peripheral thermoreceptors
- Balance between heat production and heat loss

Mechanism of heat transfer

- Conduction
  - The transfer of heat energy from warmer to cooler objects by direct physical contact
- Convection
  - heat transfer by air or liquid moving across the surface of an object
- Radiation
  - the transfer of heat by electromagnetic waves from a warmer object to a colder object
- Evaporation
  - Heat loss by vaporization of water, or sweat

Response to heat stress

- Decreased heat production
  - Inhibit sympathetic outflow from posterior hypothalamus (increase effects of parasympathetic from anterior hypothalamus > decrease vascular tone)
- Dilatation of blood vessels
- Increased sweat production
  - Elevate cholinergic stimulation (normally occur when core temperature > 37°C)
- Behavioral heat control

Medication

- Notable drugs interfere with heat-removal mechanism
  - Anticholinergic agents : impaired sweating and cardiovascular response to heat
  - Diuretics : volume depletion and decreased cardiac output
  - Phenothiazine : anticholinergic properties and deplete central stores of dopamine > interfere with hypothalamic thermoregulatory center
  - Beta blockers
  - Calcium channel blockers

Medication

- Notable drugs interfere with heat-removal mechanism
  - Beta blockers and Calcium channel blockers : decrease the cardiovascular response to heat and reduce peripheral blood flow and the ability to sweat
  - Sympathomimetic drugs : cutaneous vasoconstriction and inhibit sweating

Miscellaneous

- Alcohol
  - inhibits secretion of antidiuretic hormone, which leads to dehydration, and blunts the psychological heat-avoidance response
- Heroine, amphetamines and cocaine
  - disrupt the function of endogenous endorphins and adrenocorticotropic hormones that are involved in heat adaptation mechanisms
  - Amphetamines and cocaine also increase muscle activity and lead to heat production

Acclimation

- Adaptation of body environmental changes that involve both physiologic and biochemical adjustments that allow an individual to withstand heat stresses that would otherwise result in substantial morbidity and mortality

Acclimation

- Lowers the thermal set point in the hypothalamus
  - sweating at lower core temperature and increase maximal rate of sweat production and sustained for longer period
- Increase aldosterone secretion
  - sodium conservation results from more efficient reabsorption from the sweat
- Plasma volume expands
- Heart rate decrease for heat load
- Exercise tolerance improves
- Dilatation of cutaneous blood vessel at lower temperature

Acclimation

- Acclimation can be achieved over 7 days to several weeks
- Moderate exercise in a hot, dry environment for 60 to 100 minutes each day is probably the optimal approach to achieve acclimation
- To maintain heat and exercise-induced adaptive responses, heat exposure needs to continue intermittently at least on 4-day intervals
- Once removed from the hot environment, the body will de-acclimate to the original physiologic parameters within 1 to 2 weeks

Heat Induced Illness

- Results from
  - Increase in body temperature outside normal range > prolonged efforts to compensate
  - Excessive heat direct toxic to cells > release inflammatory cytokines and damage vascular endothelium > activate coagulation cascade > DIC
  - Denaturation of proteins > interruption cellular process > cells death
  - As temperature rises, cellular damage occurs more quickly and extensively

Models of heat injury

- Classic heat injury
  - Occurs during periods of high environmental heat stress
  - Depends on environmental temperature and humidity levels
  - Often slow increase in core temperature (hours to days)
  - Volume and electrolytes disturbance are common
  - Typically elderly, living alone without social support and without air-conditioning
- Exertional heat injury
- Confinement hyperpyrexia

Models of heat injury

- Exertional heat injury
  - Heat production and heat gain from the environment exceed the capacity of heat removal processes
  - Affects who participating in athletic events or performing jobs under conditions of high heat stress
  - Risk factor : dehydration, concurrent illness, obesity, wearing to much clothes and poor cardiovascular fitness
  - Without an efficient cooling mechanism, progressive dehydration and hyperpyrexia continue to the level of cardiovascular and metabolic failure

Models of heat injury

- Confinement hyperpyrexia
  - Non-exertional hyperpyrexia
  - Exposed to heat in enclosed space
  - Such as children left inside closed vehicles or workers are occupationally exposed to heat inside enclosed spaces
  - Non-ventilated compartments in a hot environment may reach temperatures of 54°C to 60°C (129.2°F to 140.0°F) in < 10 minutes

Minor heat illness

- Heat edema
  - Self-limited process manifested by mild swelling of the feet, ankles, and hands within the first few days of exposure to a hot environment
  - Often by non-acclimatized individuals esp.in elderly or in healthy persons with long periods of sitting or standing
  - History and physical examination are usually sufficient to exclude systemic causes of edema
  - No further testing or treatment except removal from heat source is needed
  - Diuretics are not effective and can predispose to volume depletion, electrolyte abnormalities, or more serious heat emergencies

Minor heat illness

- Heat cramps
  - Brief, intermittent and often severe muscle cramps typically in muscles fatigued by heavy work
  - Related to salt deficiency
  - Most common in first day of work in hot environment
  - Commonly develop in persons who produce large thermal sweat and drink copious amount of hypotonic fluid

Minor heat illness

- Heat cramps

Box 141-2 Heat Cramps: Essentials of Diagnosis

Cramps of most worked muscles
Usually occur after exertion
Copious sweating during exertion
Copious hypotonic fluid replacement during exertion
Hyperventilation not present in cool environment

Minor heat illness

- Heat cramps
  - Most common victims : athletes, roofters, steel workers, coal miners and field workers
  - Occur after exercise when victims is relaxing
  - Hyponatremia and hypochloremia from large production of sweat (mostly in severe case)
  - Rhabdomyolysis is rare and occurs secondary to diffuse and protracted muscle spasm

Minor heat illness

- Heat cramps
  - Treatment consists of fluid and salt replacement (PO or IV)
    - 0.1% to 0.2% saline solution, electrolyte solution drinks (sports drinks) in mild case
    - more severe symptoms require IV rehydration with normal saline
  - Rest in cool environment
  - Prevented by maintaining adequate dietary salt intake or by drinking commercial electrolyte beverages

Minor heat illness

- Heat syncope
  - Temporary loss of conscious in hot and humid environment
  - Individuals adapt to hot, humid environment by dilatation of cutaneous vessels to deliver heat to body surface > peripheral intravascular pool > increase skin vascular volume esp.lower extremities > inadequate central venous return > decrease in cardiac output and inadequate cerebral perfusion
  - Most common in elderly
  - Assumption of horizontal position is curative

Minor heat illness

- Prickly heat
  - Pruritic, maculopapular, and erythematous rash over normally clothed areas of the body (*lichen tropicus*, *miliaria rubra*, or *heat rash)*

Minor heat illness

- Prickly heat
  - Acute inflammation of the sweat ducts caused by blockage of the sweat pores
  - The sweat ducts become dilated under pressure and ultimately rupture, producing superficial vesicles in the skin on a red base
  - Can be treated successfully with antihistamines. Wearing clean, light, and loose-fitting clothing and avoiding sweat-generating situations
  - Chlorhexidine in a light cream or salicylic acid cleaning may provide some relief

Heat exhaustion/stress

- Clinical syndrome characterized by volume depletion occurs under condition of heat stress in two different ways, through water depletion and through sodium depletion

Heat exhaustion/stress

- Water depletion tends to occur in the elderly and in persons working in hot environments with inadequate water replacement
- Salt depletion heat exhaustion tends to occur in un-acclimatized individuals who replace fluid losses with large amounts of hypotonic solutions

Heat exhaustion/stress

- Clinical features
  - Weakness/fatigue
  - Frontal headache
  - Vertigo
  - Nausea and vomiting
  - Occasionally muscle cramps
  - Orthostatic hypotension/syncope
  - Profuse sweating
  - Usually normal core temperature or below 40°C
  - No signs of CNS impairment

Heat exhaustion/stress

Box 141-3 Heat Exhaustion: Diagnosis

Vague malaise, fatigue, headache
Core temperature often normal; if elevated, below 40° C (104° F)
Mental function essentially intact; no coma or seizures
Tachycardia, orthostatic hypotension, clinical dehydration (may occur)
Other major illness ruled out
If in doubt, treat as heatstroke

Heat exhaustion/stress

- Laboratory studies
  - Hemoconcentration
  - Electrolytes abnormalities depend on ration off fluid and electrolyte losses to intake
    - Hypernatremia in patients who had no fluid intake
    - Isotonic hypovolemia in those who partly rehydrate with salt-containing fluids
  - Hepatic transaminitis (several thousand units)

Heat exhaustion/stress

- Treatment
  - Removal from the heat-stressed environment
  - Mild heat stress may be treated with oral electrolyte solutions
  - Rapid infusion of moderate amounts of IV fluids in patients who demonstrate significant tissue hypoperfusion
  - Choice of IV solution should be guided by laboratory determinations (isotonic salt solutions may be used until specific electrolyte abnormalities are identified)
  - Heat stress can progress to heat stroke even after patient removed from the hot environment

Heat exhaustion/stress

Box 141-4 Heat Exhaustion: Treatment

Rest
Cool environment
Assess volume status (orthostatic changes, blood urea nitrogen level, hematocrit, serum sodium concentration)
Fluid replacement: normal saline to replete volume if the patient is orthostatic; replace free water deficits slowly to avoid cerebral edema
Healthy young patients are usually treated as outpatients; consider admission if the patient is elderly, has significant electrolyte abnormalities, or would be at risk for recurrence if discharged

Heat stroke

- Acute life-threatening emergency with high mortality results from elevation of the body temperature to the extreme levels (usually higher than 40.5°C/105°F), producing multisystem tissue damage and multi-organ failure accompanied by CNS dysfunction

Heat stroke

- Physiology
  - Inability to sustain thermoregulatory mechanisms, resulting in increase core temperature and clinical of heat stroke
  - Heat stress creates heavy demands on cardiovascular system > circulatory failure
  - Prolong heat stress produce increase skin blood flow (peripheral vasodilatation) and reduction of thermal gradient between the core and skin

Heat stroke

- Physiology
  - At first functional hypovolemia is avoided by compensatory vasoconstriction of the splanchnic and renal vasculature > cause N/V and diarrhea due to splanchnic and renal ischemia
  - Hepatic damage : centri-lobular necrosis with extensive cholestasis

Heat stroke

- Physiology
  - If severe heat stress continues, compensatory splanchnic vasoconstriction eventually fail > failure to perfuse skin with heated blood from the core results in increase rate of heat storage which produce elevated intracranial pressure, and when combined with reduction in mean arterial pressure > decrease in cerebral blood flow results in major CNS dysfunction

Heat stroke

- Classification
  - Classic (non-exertional) heat stroke : more common in younger children who are unable to escape from hot environments and those with underlying chronic medical conditions that impair thermoregulation
  - Exertional heat stroke : generally occurs in healthy individuals who engage in heavy exercise during periods of high temperature and humidity. Typical patients are athletes and military recruits in basic training

Heat stroke

- Clinical features
  - The diagnostic criteria are elevated core temperature (≥40°C) and (CNS) abnormalities following environmental heat exposure
  - Children with elevated body temperature and CNS abnormalities should be treated as victims of heat stroke

Heat stroke

Box 141-5 Heatstroke: Diagnosis

Exposure to heat stress, endogenous or exogenous
Signs of severe central nervous system dysfunction (coma, seizures, delirium)
Core temperature usually above 40.5° C (105° F), but may be lower
Hot skin common, and sweating may persist
Marked elevation of hepatic transaminases

Heat stroke

- CNS manifestations
  - Impaired judgment
  - inappropriate behavior
- Children commonly present with more significant neurologic symptoms such as
  - seizures
  - delirium
  - hallucinations
  - ataxia
  - coma

Heat stroke

- Other clinical manifestations
  - Tachycardia
  - Tachypnea
  - The skin may be flushed and warm or diaphoretic
  - Vomiting and diarrhea also common
  - Those patients with coagulopathy may demonstrate
    - purpura
    - hemoptysis
    - hematemesis
    - melena
    - hematochezia

Heat stroke

- Diagnostic evaluation
  - **Clinical assessment**
  - The diagnosis of heat stroke is based upon a careful history and physical examination and exclusion of other process

Heat stroke

TABLE 210-2 Differential Diagnosis of Heat Stroke

Infection	*Neurologic*
Sepsis syndrome	Hypothalamic bleeding or infarct
Meningitis	Cerebrovascular accident
Encephalitis	Status epilepticus
Malaria	*Toxicologic*
Typhoid	Anticholinergic toxidrome
Tetanus	Sympathomimetic overdose
Endocrine	Salicylate overdose
Thyroid storm	Serotonin syndrome
Pheochromocytoma	Malignant hyperthermia
Diabetic ketoacidosis	Neuroleptic malignant syndrome
	Withdrawal syndromes—alcohol and benzodiazepine withdrawal

Heat stroke

- Diagnostic studies are directed toward detecting end-organ damage and excluding other diseases

Heat stroke

- Laboratory evaluation
  - Rapid blood glucose to identify hypoglycemia
  - Blood gas (venous or arterial) to evaluate for the presence and severity of metabolic acidosis
  - CBC, Coagulogram and Serum electrolytes
  - Liver enzymes to assess for liver injury

Heat stroke

- Laboratory evaluation
  - Urea and creatinine to identify prerenal azotemia or renal failure resulting from myoglobinuria
  - Serum CK ionized or total calcium, and phosphate to detect rhabdomyolysis, hypocalcemia and hyperphosphatemia
  - Urine rapid dipstick and urinalysis to diagnose myoglobinuria
  - Toxicologic screening for drugs of abuse or prescribed medications

Heat stroke

- Chest radiograph
  - Helps identify pulmonary edema and is useful in patients for whom pulmonary aspiration is a concern
- Electrocardiogram
  - Obtained in patients with electrolyte abnormalities (eg. hyperkalemia, hypokalemia, hypocalcemia) and/or rhabdomyolysis
- Computated tomography
  - Obtained if a child has persistently altered mental status despite cooling or shows signs of increased intracranial pressure suggestive of cerebral edema or intracranial hemorrhage

Heat stroke

- Goal of therapy are immediate cooling and aggressive support of organ system function

Heat stroke

- Prehospital care
  - Remove the patient from the hot environment immediately
  - Perform standard resuscitation measures
  - Start cooling by removing clothing and implementing one of the following methods
    - spray the patient with water and provide airflow over the patient (Ideally but not always practical)
    - place wet towels or sheets over the patient's body
    - place ice on the patient
  - Administer a bolus of normal saline (1 to 2 L) if hypotension is present

Heat stroke

- ED management
  - Initial resuscitation
    - Administer IV fluids at a rate that ensures adequate urine output
    - Consider invasive monitoring in elderly or in patients with cardiovascular disease
    - Check glucose levels
    - Monitor core temperature

Heat stroke

- ED management
  - Cooling Techniques
    - Only physical methods of cooling are recommended
    - The primary physical cooling procedure is one that allows easy patient access, readily available, tolerated well by the patient, and effective
    - The goal is to reduce the core temperature to approximately 39°C (102.2°F) and to avoid overshoot hypothermia
    - If the initial cooling method used does not lower temperature quickly, try another method

Heat stroke

- ED management
  - Cooling Techniques
    - Evaporative cooling
      - Remove patient clothing and spray cool water (~15°C [59°F]) on most of the patient's body
      - Directing a fan over the patient facilitates evaporation
      - Hypothermic overshoot > shivering which results in more heat production, and peripheral vasoconstriction that will impair evaporation (Treated primarily with short-acting BDZ)
      - Inability of cardiac electrodes to adhere to the skin

Heat stroke

- ED management
  - Cooling Techniques
    - Immersion cooling
      - placing the undressed patient into a tub of ice water deep enough to cover the trunk and extremities (keeping head out of water)
      - Shivering, displacement of monitoring leads, and inability to perform defibrillation or resuscitative procedures
      - Massage with ice water is an alternative for patients who cannot tolerate immersion
    - Invasive cooling measures
    - Other cooling measures

Heat stroke

- ED management
  - Cooling Techniques
    - Invasive cooling measures
      - When evaporation or immersion methods are not sufficient
      - Most rapid method is cardiopulmonary bypass (Lack of availability)
      - Cold water gastric lavage, cold water urinary bladder lavage, and cold water rectal lavage (require cooperation, invasive, water intoxication)
      - Cold water peritoneal lavage (effectiveness has not been validated)
    - Other cooling measures

Heat stroke

- ED management
  - Cooling Techniques
    - Other cooling measures
      - Cooling blankets (slowly, not be main treatment)
      - Cold IV infusion not consider effective treatment
      - Applying ice packs to the neck, axillae, and groin does not lower temperature quickly enough to be used alone
      - No studies on the effectiveness of antipyretics

Heat stroke

TABLE 210-3 Summary of Cooling Techniques

Cooling Method	Advantages	Disadvantages	Recommendations
Evaporative cooling	Provides effective cooling	Can cause shivering	Strongly recommended
	Readily available	Less effective in humid environments	
	Practical	Makes it difficult to maintain electrode positions	
	Well tolerated		
Immersion cooling	Provides effective cooling	Can cause shivering	Recommended
		Poorly tolerated	
		Not compatible with resuscitation settings	
Ice packs on neck, axillae, and groin	Practical	Cooling times longer than other modalities	Can be used as adjunct cooling method
	Can be added to other cooling methods	Poorly tolerated	
Cardiopulmonary bypass	Provides fast and effective cooling	Invasive	Recommended in severe or resistant cases when available
		Not readily available	
		Setup is labor intensive	
Cooling blankets	Easy to apply	Have limited cooling efficacy	Not recommended when other methods available
		Impede use of other cooling methods	
Cold water gastric, urinary bladder, rectal, or peritoneal lavage	—	Invasive	Effectiveness and safety not established
		Labor intensive	
		May lead to water intoxication	
		Human experience is limited	

Heat stroke

- Complications
  - Hypotension
    - If a 20 cc/kg fluid bolus does not result in improvement, considered Dopamine or Dobutamine (Norepinephrine may impede cooling by redirecting blood flow away from skin)
  - Fluid and electrolytes abnormalities
    - Vary depending on the type of onset and duration of the disorder, any underlying disease (especially cardiovascular disease), and any prior use of medications
  - Hematologic disorders
    - Apparent clinically and on laboratory evaluation (such as purpura, petechiae, GI/renal/pulmonary hemorrhage, thrombocytopenia and DIC)

Heat stroke

- Complications
  - Thermal injury to the liver
    - Centri-lobular necrosis
    - Elevate liver enzyme, peaking 24-72 hrs after thermal insult
    - Almost always fully recovery
  - Renal failure
    - From direct thermal injury, rhabdomyolysis or volume depletion
    - Oliguria, microscopic hematuria
    - Early volumeexpansion decreases the detrimental renal effects of heat stroke
  - ARDS
  - Seizures

Heat stroke

- Complications
  - ARDS
    - Requires respiratory support until cooling has been accomplished
    - Cardiac muscle injury may also occur
  - Seizures
    - may occur during cooling and can be controlled with benzodiazepines

Heat stroke

TABLE 210-4 Complications of Heat Stroke

	Early	Late
Vital signs	Hypotension	—
	Hypothermic overshoot	
	Hyperthermic rebound	
Muscular	Rhabdomyolysis	—
Neurologic	Delirium/coma	Cerebral edema
	Seizure	Encephalopathy
		Persistent neurologic deficit
Cardiac	Heart failure	Myocardial injury
Pulmonary	Pulmonary edema	Acute respiratory distress syndrome
Renal	Oliguria	Renal failure, rhabdomyolysis
GI	—	Intestinal ischemia or infarction
		Pancreatic injury
		Hepatic dysfunction
Metabolic	Hypokalemia	Hyperkalemia
	Hypernatremia	Hypocalcemia
	Hyponatremia	Hyperuricemia
Hematologic	—	Thrombocytopenia
		Disseminated intravascular coagulation

Prevention

- Decreasing or rescheduling strenuous activity for cooler parts of the day
- Wearing light and loose-fitting clothing
- Increasing carbohydrate intake and decreasing protein intake to decrease endogenous heat production
- Drinking plenty of fluids, even when not thirsty
- Avoiding alcoholic beverages
- Avoiding direct sunlight

TABLE 210-1 Signs and Symptoms of Heat Emergencies

Heat Cramps	Heat Stress	Heat Stroke
Muscle cramps	Symptoms seen in heat cramps plus:	Symptoms seen in heat stress plus:
Normal to mildly elevated temperature	Normal to elevated temperature (<40°C [<104°F])	Elevated temperature (>40°C [>104°F])
Sweating	Nausea, vomiting, headache, malaise, dizziness	Neurologic abnormalities: inappropriate behavior, confusion, delirium, ataxia, coma, seizures
	Orthostatic hypotension	Anhidrosis or sweating

Clinical features of heat stroke and heat exhaustion*

	Heat stroke	Heat exhaustion
Core body temperature	>40°C (104°F)[Δ]	≤40°C (104°F)
Mental status	Abnormal mental status (eg, obtunded, coma, delirium, hallucinations, seizures, ataxia, slurred speech)	Normal mental status, dizziness, or mild confusion that rapidly normalizes within 30 minutes of treatment. May see syncope with rapid recovery of alertness.
Airway and breathing	May be compromised due to altered mental status, tachypneic	Clear airway, may be tachypneic
Circulation	Tachycardia with hypotension, moderate to severe dehydration	Tachycardia with normal blood pressure, mild to moderate dehydration
Skin findings	Dry skin (classic heat stroke) or sweating (exertional heat stroke)	Sweating
Other clinical features	▪ Vomiting ▪ Diarrhea ▪ Clinical and laboratory findings of DIC, rhabdomyolysis, acute renal failure, cardiogenic shock, and liver failure	▪ Nausea, vomiting ▪ Headache ▪ Fatigue, weakness ▪ In some patients, hyponatremia or hypernatremia

Take Home Message

- Children with elevated body temperature and CNS abnormalities should be treated as victims of heat stroke
- Rectal temperature is the most commonly obtained core temperature measurement
- Morbidity or mortality are directly related to duration and degree of hyperthermia
- The institution of prehospital cooling should not delay timely transportation to definitive care
- The most effective method of lowering the core body temperature quickly is the use of cardiopulmonary bypass