Environmental Emergencies
Introduction to
Heat and Cold Injury
Heat Stroke

Lecture 16

Outcomes

At this lecture's completion, the learner will be able to:

- Describe the incidence, morbidity and mortality associated with environmental emergencies (5-10.2)
- Identify risk factors predisposing to environmental emergencies (5-10.3)
- Discuss the physiology of temperature homeostasis and the pathophysiology of environmental emergencies (5-10.7 - 5-10.84)
- Discuss the assessment findings associated with various of environmental emergencies (5-10.20 - 5-10.84)
- Correlate abnormal findings with clinical significance in patients with of environmental emergencies (5-10.25 - 5-10.84)
- Integrate pathophysiology, physical findings, and treatment for patients with environmental emergencies (5-10.33 - 5-10.84)

Epidemiology

- In US : 1000 - 5000 environmental deaths annually
  - elderly : account for half of these environmental deaths
- Hypothermia : > 700 deaths / year
- Heat stroke : > 400 deaths / year
  - Incidence under-reported in the elderly
    - Elderly have underlying illnesses
    - Reported cause of death often listed as non-environmental
    - Heat stroke deaths under-reported in past
      - may actually be > > 4000
    - May continue to increase with global warming
      (see: Bouchama A, Knochel JP . Heat Stroke.
      N Engl J Med. June 2002; 346: 1978-1988) [ABEM LLSA- required]
  - 2nd leading cause - in young athletes

Environmental Emergencies

- Environment
  - surrounding external factors affecting growth of an organism
- Core Temperature
  - temp. of deep tissues
  - 99.6 F ; 37.6 C (rectal)
  - 98.6 F ; 37 C (oral)
- Basal Metabolic Rate
  - 50 kcal/m^2/ h = ***2^0 F / hr***
- Steady State Metabolism
  - little variance of the core temp
    - about 1^0 fluctuation

Heat Generation

- External
  - Shivering
  - Absorption
    - Via thermal gradient
      - Difference between body & environmental temp
      - Influenced by: ambient temp, infrared radiation, relative humidity
- Internal
  - Cellular metabolism
    - Sympathetic response : immediate heat increase
  - Thermatogenesis - primarily in fatty tissue

Heat Loss

- Radiation - infrared rays
  - 60% of heat loss in the naked patient (BSA in ped pt.s)
  - > loss from the head
- Conduction - moving heat through a conductive medium
  - direct contact with cooler objects
  - in air : 2% heat loss
  - in H_2O : 25 X greater than in air (i.e., 50%)
- Convection - heat loss to air currents in a liquid / gas
  - wind-chill heat loss
- Evaporation - conversion from liquid to gas (lungs; skin)
  - Goes only "one - way." Only heat loss ; no heat gain
  - skin
    - up to 600 mL / d

Control Mechanisms

- Hypothalamus- primary control mechanism
  - "thermostat:" controls metabolism and temp.
- Temperature Receptors
  - skin: mostly cold. thus detect mainly cold
  - deep / afferent: assess core temp.
    - respond: mainly to cold
    - locations: SC, viscera, great vessels
- Acclimatization
  - takes ***days to weeks***
  - ↑ aldolsterone
    - a ↓ Na^+ loss in sweat + urine
  - Becoming a "better sweater"
    - at lower temperatures
    - at higher rate

Heat Elimination

Hypothalamus: 5 mechanisms

- Vasodilatation
  - sympathetic inhibition
- Perspiration
  - whenever core T^o rises above normal
  - ineffective whenever relative humidity > 75%
- Decreased Heat Production
  - inhibition of shivering and thermatogenesis
- Increased CO
  - increased blood flow through skin
- Increased RR
  - eliminates heat by means of loss of warmed air + evaporation

Heat Preservation

- Vasoconstriction
  - sympathetic nervous system
  - keeps blood near the body core
- Increased heat production
  - Thermogenesis
    - shivering
    - hypothalamus - primary shiver center
  - Sympathetic stimulation
    - Epi, NE
    - immediate increase in metabolism → heat production

Heat Related Illnesses

Non-Abnormally high body temperature

- Heat rash (prickly heat)
- Heat edema
- Heat syncope
- Heat tetany
- Heat exhaustion [Core $T^0 < 37^0C$, or $> 37^0C$, but $< 40^0C$]

Abnormally high body temperature

- Heat Stroke
  - Core T^0 above 400 and CNS dysfunction

Spectrum of Heat Related Illnesses

Severity	Disorder	Pathophysiology and treatment
Minor (normal core temp)	Heat cramps Heat edema Heat ***syncope*** Prickly heat	Due to "local" decreased Na^+ No diuretics. Tx: elevation Na^+ and volume ; cool down ; rest Sweat gland irritation. No Tx
Moderate (core temp slightly up, down; or nl)	Heat exhaustion	Moderate to marked Na^+ and volume.
Severe (core temp: over 40^0 C / 104^0 F)	Heat stroke	***CNS dysfunction*** Multiple organ-failure (organs with the lowest melting pt: brain and liver)

Heat Cramps

- Pathophysiology
  - Dilutional hyponatremia
    - sweating profusely
    - but replacing volume with hypotonic solution
  - Hyperventilation, possibly related
- Sx. + signs :
  - Painful skeletal muscle contractions

Heat Cramps Presentation

- Mentally ***alert***
- Cramps
  - Arms
  - Legs
  - Thigh
  - Calves
- tachycardia
- diaphoresis
- normal core T^{o}
- ***normal*** BP
- Hx. of athletic event

Heat Cramps

- Treatment
  - Remove pt. From hot environment
  - Rest
  - PO / IV hydration
    - use *isotonic* solution
    - *not* hypertonic solution
    - if PO hydration : electrolyte solutions, not water
  - Most pt.s respond rapidly to Tx

Heat Exhaustion

- The most common heat-related illness
- Mild to moderate illness
- Pathophysiology
  - Na^{+} and H_2O losses, during exercise, in high heat
  - Venous pooling leads to ↓ venous return → ↓ CO

Clinical Presentation

- Hx: poor fluid intake
- N, V
- Malaise
- HA
- HR ↑
- Mentation : ***alert***
- Orthostatic hypotension
- Diaphoresis; urine output ↓

Heat Exhaustion Tx

- If there is any doubt exists about severity, then:
  - aggressively Tx for heat stroke
- Move pt to cool environment
- If elevated body T^{o}, cool pt, with :
  - Misting with room temp. H_2O
  - Fan (promoting evaporation)
- Correct volume / electrolyte imbalances
  - NS / LR

H_2O Intoxication

Pathophysiology

- Drinking water faster than sweating
- Dilutional hyponatremia

Clinical presentation

- Similar to heat exhaustion; but may have ALOC

Treatment

- ALOC: IV NS
- Responsive: eat salt-rich foods ; WHO solution

Heat Edema

- Swollen dependent extremities in hot environment
  - Usually a non-acclimatized, elderly pt.
- Pathophysiology
  - Vasodilatation
  - Increased pooling of interstitial fluids
  - Relative hypovolemia
- Tx
  - Elevate dependent extremities
  - Severe: compressive stockings
- Warning: do **NOT** administer diuretics
  - may exacerbate hypovolemia

Heat Syncope

- Pathophysiology
  - Volume depletion
  - Vasodilatation
  - Decreased vasomotor tone
- Clinical Setting
  - Elderly
  - Poorly acclimatized
- Tx
  - Rest ; rehydration PO or IV
  - Technically: this is classified as minor, but must *R/O serious causes (cardiac, neuro, etc.)*

Heat Tetany

- Associated with hyperventilation during heat illness
- Caused by central stimulation of respiration
- Clinical presentation
  - carpopedal spasm
  - paresthesias of extremities & perioral area
- Tx
  - treat hyperventilation with cooling
  - rehydrate

Heat Stroke

True life threatening emergency

- Uncompensated hyperthermia
  - results in cell death + physiologic collapse
- Core T^o > 40 C or 104 F and CNS dysfunction
- The hallmark of heat stroke: ***ALOC***

- The presence of sweat - ***in no way rules out heat stroke .***
- Anhydrosis [dry skin of classic/elderly heat stroke] is not necessary for the diagnosis of heat stroke. In exertional heat stroke the skin is wet.

Heat Injury Definitions

Heat wave:

- ***3*** or more consecutive days
- During which air temperature is > 32.2 ^{0} C (***90***^{0}F)

Hyperthermia

- Rise in the body temperature above the hypothalamic set point

  resulting in multiorgan dysfunction
  - in which encephalopathy predominates"

Failure of Attempts to Counter Heat Injury

Heat stroke results from:

- Failure of thermoregulation
- Failure of acclimation
- Exaggeration of the acute phase response
- Failure of "heat shock proteins" to protect against cardiovascular, mesenteric endotoxic, and coagulation responses of heat stroke

Heat Stroke Pathophysiology

- "Hyperthermia that results in:

  multiorgan dysfunction
  - in which encephalopathy predominates"

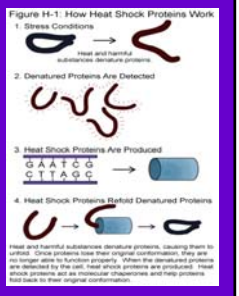
"Heat-shock" or "Stress" Proteins

Interleukin-6

- Anti-inflammatory cytokine
- Reducer of heat-inflicted damage
- Facilitator of repair
- Inhibitor of harmful heat stroke cascade of injuries

For article: *Heat therapy … improve …cancer treatments,"* see:
http://www.sciencenews.org/articles/20061014/bob10.asp

- ***Cancer researchers*** warm the tumor to 40° - 43°C (104° to 109°F) and keep it there for about 1 hr. Patients typically get treatment 1-2/wk in conjunction with radiation or chemotherapy.
- And hyperthermia also harnessed in less direct way: by exploiting its effects on the immune system. Several studies have suggested … heating the whole body might increase cancer vaccines' effectiveness by making the immune system a more efficient fighter.



Types of Heat Stroke

- Classic [the elderly in Chicago, 1997]
  - exposure to high ambient temp. + humidity
  - often chronically ill +/or impoverished individual
  - Epidemic; heat wave; elderly or very young (< 4 y)
  - often no diaphoresis ; "classic, dry heat stroke"
    - illness ***not*** necessarily preceded by exertion
- Exertional
  - young, healthy individuals
  - overwhelmed from strenuous exertion
  - often ***diaphoretic*** due to exertion preceding illness
  - at greater risk for rhabdomyolysis & hypoglycemia

Clinical Presentations

- Often no sweat - but may be diaphoretic
- CNS disturbances- the ***sine qua non***
- Shock
- Aniscoria [unequal pupils]
- Ataxia
- Tachycardia then bradycardia
- Hyperventilation
- Seizures: 75%

Diagnosis of Heat Stroke

Visual diagnosis

- the *hallmark* of heat stroke:
  - **ALOC**

Temp: 108 degrees

February 17, 2003

Heat Stroke Complications

- Respiratory alkalosis (in both classic and exertional heat stroke)
- Metabolic acidosis (a lactic acidosis in exertional heat stroke)
- Rhabdomyolysis
- Arrhythmias
- Renal failure
- Hepatic / pancreatic damage
- Coagulopathy
- Sepsis

Heat Stroke Tx

- High flow O_2 ; 2 large bore IV WO
- Rapid Cooling
  - Most efficient and practical:
    evaporation and convection [wind-chill]
    - Clothes off
    - Douse with room-temp water
    - Fan the patient
  - Icepacks : controversial
    - Not as effective; may distract from more beneficial Tx
  - Shivering - will raise the core temp.
    - treat with benzodiazepines PRN

Heat Stroke - Differential Dx

- "Virus"
- "He's taken something [drugs]"
- Sepsis
- Meningitis
- Encephalitis
- Malaria
- Toxins

Clinical Setting: Heat Illnesses

- Alcohol
- ASA
- Amphetamines / cocaine
- Antidepressants
  - Li, TCA
- Anticholinergics
  - antihistamines
- Antipsychotics
  - phenothiazines
- Antihypertensives
  - diuretics
- Adipose
- Antiemetics
  - compazine
- Age
  - elderly , < 4 y/o
- Ambient T°, humidity
- Athletic, occupation
- Attitude
  - competitive
- Acclimatization
- Asthma
  - ß adrenergics →

metabolism ↑ → heat ↑

Classic vs Exertional Heat Stroke

	Classic	Exertional
Age	< 4 ; > 75 yr old	Young
Epidemiology	Epidemic; heat wave ; poor; socially isolated	Athletic exertion; drug use
PMH	Chronic disease	Healthy
Medications	Antihypertensives Diuretics Beta blockers +/or Ca++ blockers Anticholinergics ß adrenergics	Amphetamine - like drugs Cocaine Methamphetamine Ephedra (ma huang) MDMA (ecstasy) ß adrenergics
VS / Skin	↑ HR ; ↑ RR. Dry	↑ HR ; ↑ RR. Wet
Complications	Rare	Common (multi-organ failure) Rhabdo; K+ DIC; liver + renal failure

Heat-Related Deaths in the US

Chicago, 1995:

- *Heat-Related Deaths during the July 1995 Heat Wave in Chicago* C. Semenza, Ph.D., M.P.H., et al , NEJM Volume 335:84-90, July 11, 1996
- During one record-setting heat wave in Chicago in July 1995: greater than 700 excess deaths
- Vulnerable populations: poor and socially isolated

See :

- Eric Klinenberg *Heat Wave: A Social Autopsy of Disaster in Chicago*
- Eric Klinenberg interview: http://www.press.uchicago.edu/Misc/Chicago/443213in.html

Europe August, 2003

- Temperatures unprecedented [in all of recorded history]
- In France, over **14,000** excess deaths [due to heat related deaths] reported
- Total deaths for Europe : approx. 20,000
- In Paris, number of deaths increased by 140%
- Demonstrates : populations susceptible to extreme heat even wealthy, well educated populations susceptible to extreme heat
- Cannot assume physiologic adaptation can avert health effects of rising temperatures
- Climate [changes have] at least doubled the risk of heat wave [deaths] such as the 2003 European heat wave

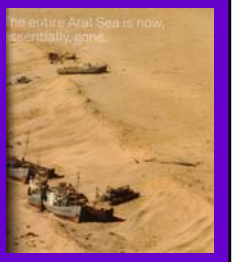
Modified from: http://www.cmaj.ca/cgi/content/full/172/4/501

From:
An Inconvenient Truth
p. 72, source IPCC

India 2003

Heat-Related Deaths in India

- Areas of India experienced temperatures almost 10 degrees higher than the seasonal average
- Heat wave deaths: over 1,065 people [probably grossly underreported].
- Some areas recorded T° s over 50°C (122° F)
- Summer monsoons, and their cooling effect, were missing



From: *An Inconvenient Truth*
p. 244. former fishing fleet in the Aral Sea, Kazakhstan

- See: BBC NEWS :http://news.bbc.co.uk/go/pr/fr/-/1/hi/world/south_asia/2956490.stmPublished: 2003/06/03 17:09:05 GMT
- And 2006: http://www.usatoday.com/weather/news/2006-05-09-india-heat_x.htm

FYI

$H^+ + HCO_3^- \leftrightarrow H_2O + CO_2$

Artic ice cap measurements by the US Navy to guide nuclear submarine surfacing. Note the precipitous drop in ice thickness since the '70's (ibid p.143)

Shifting seasons and emerging infectious disease vectors. Note as the days of frost decrease, the numbers of invasive species increase. (ibid p.154)

Alaskan winter tundra. Note the decrease in the number of days that the tundra is solid enough to drive on. The annual average temperatures are rising more rapidly in the Artic than anywhere else in the world. (ibid p.135)

Emergency Management

Municipal Heat Wave Response Plans

- 1/3 cities lacked any written heat hazard planning [1.]
- In most reviewed plans: heat response was coordinated by public safety or ***emergency management*** offices, [and ***not*** the health department].
- Planning central principles: (1) identification of lead agency and participating organizations; (2) consistent, standardized warning system activated and deactivated according to weather conditions; (3) communication and public education; (4) response activities targeting high-risk populations; (5) data collection and evaluation; and (6) revision of the plan.

See: [1.] *Municipal Heat Wave Response Plans* , Susan M. Bernard, JD, DrPH, MPH and Michael A. McGeehin, PhD, MSPH, September 2004, Vol 94, No. 9 American Journal of Public Health 1520-1522. (Michael McGeehin is with the Div of Environmental Hazards and Health Effects, CDC)

Summary

- Incidence of heat stroke: and why it is likely to ***increase***.
- Heat stroke morbidity and mortality, and risk factors predisposing to environmental emergencies - especially heat emergencies (***classical vs exertional heat stroke***)
- Thermoregulatory homeostasis and acclimation. The pathophysiology of heat emergencies and the molecular and cellular consequences of the homeostasis being overwhelmed by medications, street drugs, hypermetabolic dz.s, poor cardiac output states, overwhelming "cytochyme-storm"
- ***History*** and ***physical findings*** associated with heat disorders and clinical significance of abnormal ***mental status***
- Critical importance of early, ***rapid cooling*** and the most effective method of methods to achieve this.
- Which communities are most vulnerable. And practical implications for ***emergency management*** of ***heat wave*** emergencies that will present in some communities

Notes

References

- Semenza, Ph.D., M.P.H., et al . *Heat-Related Deaths during the July 1995 Heat Wave in Chicago* C., NEJM Volume 335:84-90, July 11, 1996
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