Environmental Injuries

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The Most Dangerous Drug Combination...
Testosterone and Alcohol!
The most likely victims...

Accidental Hypothermia
Blizzard of 1979

Definition of Hypothermia
- Subnormal T° when the body is unable to generate sufficient heat to sustain normal functions
- Core Temperature < 95°F (35°C)

Most Important Temperatures
- 95°F (35°C) Hyper/Goofy
- 90°F (32°C) Shivering Stops
- 80°F (26.5°C) Vfib, Coma
- 65°F (18°C) Asystole

Thermoregulation
- The body uses a Poikilothermic shell to maintain a Homeothermic core
- Maintains core T° w/in 1.8°F (1°C)
- Hypothalamus
- Skin

Constant T° 96.8-100.4°F
Thermoregulation
The 2 most important factors

- Shivering (10x increase)
- Initiated by low skin temperature
- Warming the skin can abolish shivering!
- Peripheral vasoconstriction
- Sequesters heat

Only 3 Causes!

- Decreased Heat Production
- Increased Heat Loss
- Impaired Thermoregulation

Predisposing Factors
Decreased Production

- Endocrine problems
  - Thyroid
  - Adrenal Axis
- Malnutrition
- Neuromuscular disease

Predisposing Factors
Increased Loss

- Radiation
- Evaporation
- Conduction
- Convection
  - Depends on conducting material
  - **Depends on wind velocity**
**Predisposing Factors**

**Impaired Regulation**
- CNS injury
- Hypothalamic injuries
- Peripheral Injury
  - Atherosclerosis
  - Neuropathy
- Interfering Agents

**Systemic Responses**

_CNS_
- $T^* < 90^\circ F$ (34°C)
  - Hyperactivity, excitability, recklessness
- $T^* < 80^\circ F$ (27°C)
  - Loss of voluntary motion and reflexes
- $T^* < 75^\circ F$ (24°C)
  - Loss of corneal & oculocephalic reflexes
  - The patient can look dead!

**Cardiovascular**
- Above 90°F (32°C): Excitatory
  - Tachycardia, Hypertension
- Below 90°F (32°C): Inhibitory response
  - Bradycardia at level of pacemaker cells
  - Atrial and ventricular dysrhythmias
    - Atrial Fib
    - Vasodilatation

**The Infamous Osborn Wave**

_A form of early repolarization_
- Elevated “J” Point
- “The Hypothermic Hump”
**Systemic Responses**

**Pulmonary**

- Initially tachypnea is seen
- T°< 90°F (32°C) RR can fall to 5-10

Minute volume falls proportional to metabolic rate

**Renal**

- Cold diuresis occurs early
- Central hypervolemia
- ADH suppression
- T°< 90°F (32°C): Kidney function declines

**Hematologic**

- Cold coagulopathy can produce significant bleeding
- Occurs by 2 mechanisms

- Platelet Issues
- Thrombocytopenia
- Platelet dysfunction
- Coagulopathy
- Dysfunction
Question?

Although bleeding occurs, the measured PT and PTT are usually normal - Why does this happen?

Question?

Do people really take off their clothes when freezing to death?

Cold Water Immersion - Hmm?

Image from Chicago Tribune

Cold Water Immersion

- Heat loss in cold water is 20-30 times that of air!
- Many additional factors come into play in cold water immersion!
Cold Water Death!

- Death may occur in only 15 minutes but NOT from hypothermia
- Cardiac dysrhythmias—“Sudden Disappearance”
- Breathing abnormalities
  - Gasp, Hyperventilation
- Muscular dysfunction

January 13, 1982  Air Florida Flight 90

In water for 1 hour and 45 minutes before rescue!

Hypothermia Effects

- Video 1: Air Florida Flight 90

“Seconds from Disaster—The crash of Air Florida Flight 90
Video from National Geographic

Jimmy Tontlewicz

“A heroic story of survival”

On Jan. 15, while sledding with his father, Jimmy plunged into the icy waters of Lake Michigan. When rescuers pulled him out, he had been submerged for at least 20 minutes and had no discernible heartbeat, pulse or breathing. In Chicago last week doctors said Jimmy is progressing so well that they hope to send him home this month.
Management and Rewarming of a Hypothermic Patient

Emergency Medicine Dogma

You’re not dead until you’re...

Warm and dead

Unless...

...You’re already dead!
Death!
- Still dead with $T^\circ > 32^\circ C (90^\circ F)$
- Serum potassium $> 10$
- Documented and verified DNR orders!

Treatment
Do Primary/Secondary Survey
Evaluate for other treatable conditions

Rewarming

Most Important Rule
If the core temperature is less than 90°F (32°C) and shivering has stopped, YOU MUST ADD HEAT to the core!
Rewarming is Additive

Rewarming: Passive
- Insulate and allow shivering to raise body temperature
- Appropriate for mild hypothermia
- Core Temperature > 32°C/90°F
- Healthy individuals

Rewarming: Active

ADD HEAT!

Rewarming: Core Rewarming
- Often VERY complicated to perform
- Supplies heat directly to the core
- Necessary for most patients with a core temp < 90°F
- Fast!
Treatment: Core Rewarming

- Heated Humidified Air
- Heat to 45°C/113°F
- 2-3°F rise in T/hr
- Indicated for ALL significantly hypothermic patients

What About heated IVFs?

Is heated IVF an effective rewarming method?

NO!

Why is This?

70 Kg person is 60% water:

= 42 L of fluid

If 42 L of fluid is at 85°F and you add 1 additional L of fluid at 110°F...How much difference does it make?

Only 0.3°C/0.6°F per Liter
**Treatment: Core Rewarming**
- Heated irrigation of body cavities
- Abdominal Irrigation ("TPL")
  - ~3°F/hr
- Thoracic Irrigation
  - Very effective (up to 10°F/hr)
  - Ant/post chest tubes

**Treatment: Thoracic Irrigation**
- Video 2: Thoracic Irrigation

**Treatment: Therapeutic Peritoneal Lavage**

**Treatment: Rewarming**
- Extracorporeal Blood Rewarming
- Fem-Fem Bypass
- CAVR-Level 1 Infuser
- V V R
- Dialysis with a heat exchanger
**Microwaves?**

- Treatment: Sinus Bradycardia
  - Physiologically normal at T < 93°F/34°C
  - Don’t treat it—Self-limited

**Treatment: Atrial Fibrillation**
- Occurs Commonly at T < 86°F (30°C)
- The rate is SLOW!
- Resolves with treatment of Hypothermia

**Treatment: Ventricular Fib**
- Occurs < 28°C/83.5°F
- Lidocaine is ineffective
- Rewarm and defibrillate every few degrees
**Treatment: Asystole**

- Occurs physiologically at $T < 65^\circ F/18^\circ C$
- May occur spontaneously
- Only responds to rewarming

**Other Treatments**

- CPR
- Only when no detectable pulse
- Pressor agents
- Caution with cardiac stimulation

**Heat-Related Illness**

_“I’m Feelin’ Hot, Hot, Hot!”_

**Statistics**

- About 500 die each year in the U.S.
- Hard to know exact number because it’s often under-reported
- August 2003: at least 35,000 died in Europe
Chicago, August, 1995

All tolled, 760 people, mostly the elderly and poor died that summer

Pathogenesis of Heat Illness

- Exogenous heat gain
- Endogenous heat production
- Decreased dissipation

Pathogenesis: Exogenous Gain

- Environmental temperature
  - Sun, workplace, home, sauna

Wet Bulb Globe Temperature!
A Weighted Average...

- 10%: Dry, shaded thermometer
- 70%: Wet thermometer
- 20%: Unshaded black globe
### Pathogenesis: Endogenous Production

- Basal metabolism: 50-60 kcal/hr/m²
- 1°C/hr increase in T° if we had no mechanism for dissipation!

**20x Increase in heat production is seen during exercise!**

### Pathogenesis: Endogenous Production

- What are some other causes...
  - Hyperthyroidism
  - Neuroleptic Malignant Syndrome
  - Malignant Hyperthermia
  - Cocaine, Amphetamines, MDMA, LSD
  - Fever

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### Pathogenesis: Decreased Dissipation

- **Yeah...But it’s a dry heat!**

- Dehydration is the *most significant factor* affecting the ability to dissipate heat!

### Decreased Dissipation: Dehydration

- **Limits Sweating**
  - Volume overrides heat dissipation
  - Impairs CV function
  - Insensible water loss
    - 1.5L/day (2% BW)
    - Exercise: 1-2 L/hr
  - Maximum gastric emptying
    - 1-1.5 L/Hr
**QUESTION?**

How much of the lost fluid does thirst alone replace?

Only about 2/3 of the needed fluids

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**Spectrum of Illness**

- Heat Edema
- Heat Cramps
- Heat Syncope
- Prickly Heat
- Heat Exhaustion
- Heat Stroke

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**Heat Exhaustion**

- Flulike symptoms – malaise, headache, weakness, nausea, anorexia, vomiting
- Tachycardia, orthostatic hypotension
- Sweating is generally present
- Temperature is < 40°C (104°F)
- Mental status and neurologic exam are normal

**Heat Exhaustion**

- Cool shaded environment
- Oral rehydration if capable but may need IVF due to large amounts of volume lost as sweat
- Cooling is not necessary but it can make the patient feel better
What is the Most Important Thing to Tell a Discharged Heat Exhaustion Patient???

Heat Stress

For

48 Hours

Heat Stroke

• Catastrophic, life-threatening emergency
• Failure of thermoregulatory mechanisms
• Multisystem tissue/organ damage
• Damage is a function of $T^\circ$ max and duration of $T^\circ$ elevation

Heat Stroke

• Temperature $>$ 40.5°C (105°F)
• MENTAL STATUS CHANGES:
  Hallmark is severe CNS dysfunction
  • Confusion
  • Delirium
  • Seizures
  • Coma
Multi-Organ Dysfunction

- Encephalopathy
- Rhabdomyolysis
- Acute renal failure
- ARDS
- Myocardial/hepatocellular/pancreatic
- Intestinal ischemia/infarction
- Bleeding complications – DIC

Heat Stroke: *Area of Confusion*

- Can the temperature be less than 105°F and still be heat stroke??

Heat Stroke: *Area of Confusion*

- Anhydrosis (sweat cessation)
  - Sweat gland fatigue
  - Dehydration
  - Sweating can persist to T° > 42°C (108°F)

Classic (Epidemic) Heat Stroke

- Excess heat gain, impaired loss
- Occurs during heat waves
- Elderly, very young, poor, debilitated
- +/- inciting medications
- *Sweating is less likely*
Exertional Heat Stroke

- XS heat production, overwhelmed loss mechanisms
- Young, healthy, athletes, military, etc.
- Worse systemic involvement
- Rhabdo, ARF, coagulopathy, hypoglycemia
- More likely to still be sweating

How long can it take a runner in 100% humidity at 85°F to develop heat stroke?

Vikings football player dies of heat stroke
August 2, 2001 Posted: 6:26 AM EDT (1026 GMT)

Korey Stringer died early Wednesday of heat stroke

EDEN PRAIRIE, Minnesota (CNN) -- Pro Bowl offensive lineman Korey Stringer of the Minnesota Vikings died of heat stroke early Wednesday, the

__4, 335-pound Stringer, 27, died at St. Joseph’s Hospital -- Mayo Health System in Mankato, where the team holds its practices.__

__Stringer began exhibiting signs of heat stroke, including weakness and rapid breathing, after a morning practice session Tuesday.__

__How long can it take a runner in 100% humidity at 85°F to develop heat stroke?__

Heat Stroke Claims Local Football Player
August 12, 2005

OKLAHOMA CITY -- Medical examiners said that an autopsy done on Douglass High School football player Chris Stewart Friday determined that the 17-year-old died from heat stroke.

Stewart collapsed at a Tuesday practice, in 95-degree heat. He was taken to the hospital with elevated blood pressure and body temperature and with some brain swelling. He was also an honor student.

Services are pending, but expected to be Wednesday at 11 a.m.

Treatment: Cooling

- Evaporative cooling (Khogali method)
- 15°C (59°F) mist + Fan 45°C (113°F)
- 0.06°C (0.1°F)/min
The Evaporative Method

TX: Cooling:
Ice/Cold Water Immersion

- 0.13-0.16°C decrease/min (0.23-0.28°F)

Aggressive Resuscitation

Treatment

- ABCs
- IVF – treat volume depletion
- Avoid shivering
  - Benzodiazepines for seizures/shivering
- Dantrolene is ineffective
- Monitor for complications and treat
### Good Prognosis
- Recovery of central nervous system function during cooling
- Expected in the majority of patients who receive prompt and aggressive treatment

### Poor Prognosis
- Coagulopathy with liver hepatocyte damage
  - AST > 1000 U/L
- Lactic acidosis in classic form
- Rectal temperature > 108° F
- Prolonged coma
Dysbarism

- All the pathologic changes caused by altered environmental pressure
  - Altitude-related event
  - Underwater diving accident
  - Blast injury that produces an overpressure effect

Types

- Barotrauma – Expansion of trapped gases
- Decompression sickness – Gas bubble disease

Pressure

Top of Atmosphere

- 14.7 psi
- 33 ft seawater
- 10 m seawater
- 1 atm
- 760 mmHg
- 760 Torr

Pressure

- At 33 ft of seawater
Flying

- Most commercial aircraft are pressurized to 8000 ft
- 0.73 ATA
- FiO₂ 21% but functionally less molecules of oxygen per breath ~ 16% FiO₂

Gas Laws: Boyle’s Law

- “The volume of a gas is inversely proportional to the pressure exerted upon it”

Depth | Pressure
--- | ---
0 ft | 1 ata
33 ft | 2 ata
66 ft | 3 ata

Consequences of Pressure

Middle Ear Squeeze - Barotitis media

- Most common diving-related barotrauma
- Failure to equalize
- Too rapid descent or infection/inflammation
- TM is pushed inward and can rupture
Other Barotrauma

- Barosinusitis
- Barodontalgia
- Alternobaric vertigo
- Face mask squeeze

Scuba Rule # 1

Never Hold Your Breath!

Breath-holding Kills

Blowing Bubbles

Exogenous Entry of Air

Air Embolism  Pneumothorax

33 ft

66 ft
Pulmonary Over-Pressurization

- Can get:
  - Pneumothorax, pneumomediastinum, SQ emphysema, rupture into pulmonary vein causing air embolism
  - Simple pneumothorax may progress to tension on further ascent

Air-Gas Embolism (AGE)

- Bubbles enter the pulmonary venous circulation from ruptured alveoli
- Usually develops right after diver surfaces
  - Sudden LOC = Air embolus until proven otherwise
- Cardiac
  - Ischemia—dysrhythmias, cardiac arrest
- Neurologic
  - LOC, confusion, stroke-like sx

Cerebral Air-Gas Embolism—CAGE

Hyperbaric Oxygen and Bubble Reduction

- As pressure increases, the bubble size decreases and O₂ replaces the inert gas in the bubble (N₂), which promotes diffusion
### Air Embolism

- Recompression in hyperbaric chamber
- Transport supine
- 100% oxygen, intubate PRN
- IVF
- Aspirin for antiplatelet activity if not bleeding
- Lidocaine

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### Decompression Sickness (DCS)

- **Henry’s Law:** “The amount of gas (O₂ and N₂) dissolved in a liquid (blood plasma) is proportional to its partial pressure”

<table>
<thead>
<tr>
<th>Depth</th>
<th>Pressure</th>
</tr>
</thead>
<tbody>
<tr>
<td>66 ft</td>
<td>3 ata</td>
</tr>
<tr>
<td>66 ft</td>
<td>2 ata</td>
</tr>
<tr>
<td>33 ft</td>
<td>1 ata</td>
</tr>
</tbody>
</table>

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### DCS

- The longer and deeper the dive, the more nitrogen gas will be accumulated in the body
DCS

Slow ascent allows for compensation

Type I DCS

- Periarticular joint pain is the most common symptom of DCS
- Dull, deep ache that is mild then more intense
- Palpable tenderness
- “The Bends”

Type I DCS

- Cutaneous
  - Pruritus
  - Cutis marmorata
  - Hyperemia
  - Orange peel
  - Lymphedema
- Fatigue, especially if severe

Type II DCS = 10-15%

- Nervous system
- Pulmonary system (< 2%)
Neurologic DCS

- Spinal cord is most common site
- Lower thoracic and lumbar regions
- Low back pain
- "heaviness" in legs
- Paresthesias
- Possible bladder or anal sphincter dysfunction
- Brain – variety of symptoms and difficult to distinguish from AGE
  - Scotomata, headache, confusion, dysphasia

Pulmonary DCS

- “The Chokes”
- May begin immediately after dive but often takes up to 12 hours to develop
- Triad – shortness of breath, cough, and substernal chest pain or chest tightness
- Cyanosis, tachypnea, and tachycardia

DCS Treatment

- ABCs
- 100% oxygen
- IVF
- Recompression therapy
- Divers Alert Network (DAN): 919-684-8111
- 75-85% have good results when recognition and treatment are prompt

Delivery of Therapy

- Monoplace Chambers
  - Single patient