Environmental Injuries

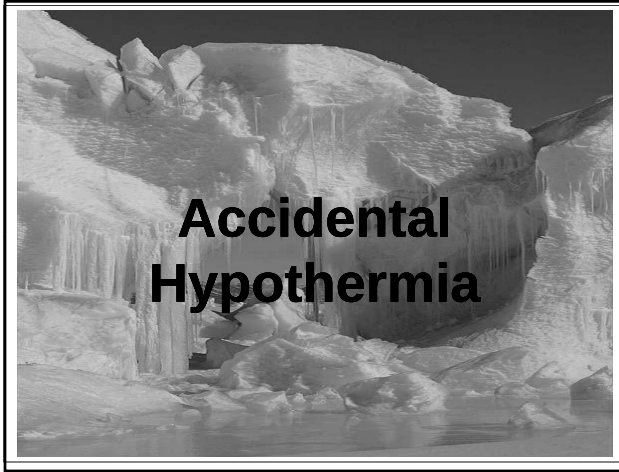
Colin G. Kaide, MD, FACEP, FAAEM, UHM
Associate Professor of Emergency Medicine
Board-Certified Specialist in Hyperbaric Medicine
Specialist in Wound Care
The Ohio State University Wexner Medical Center

The Most Dangerous Drug Combination…

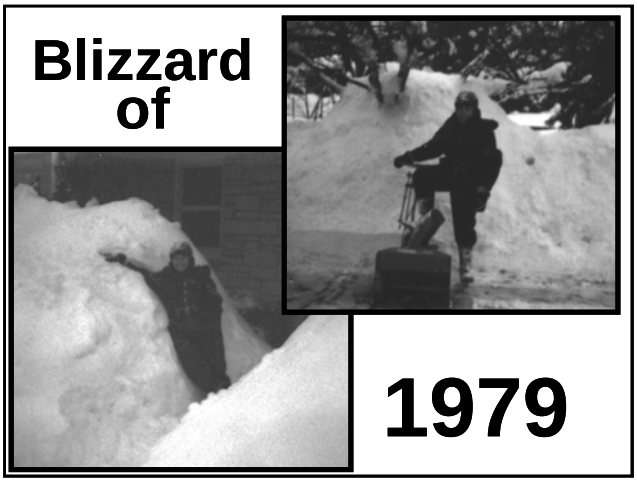
Testosterone and Alcohol!

The most likely victims…

Photo: Ralf Roletschek



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

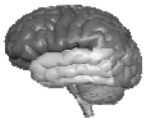
Predisposing Factors

Impaired Regulation

- CNS injury
  - Hypothalamic injuries
- Peripheral Injury
  - Atherosclerosis
  - Neuropathy
- Interfering Agents

Systemic Responses

CNS



- T°< 90°F (34°C)
  - Hyperactivity, excitability, recklessness
- T°< 80°F (27°C)
  - Loss of voluntary motion and reflexes
- T°< 75°F (24°C)
  - Loss of corneal & oculocephalic reflexes

The patient can look dead!

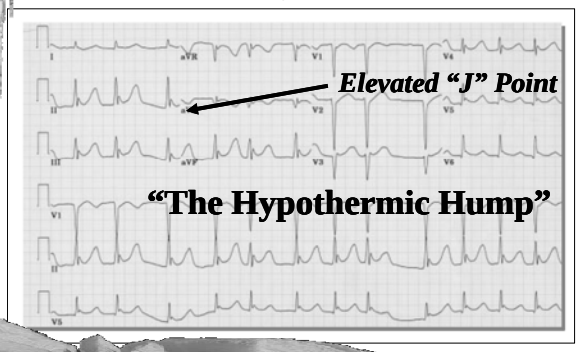
Systemic Responses

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



Systemic Responses
Pulmonary

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

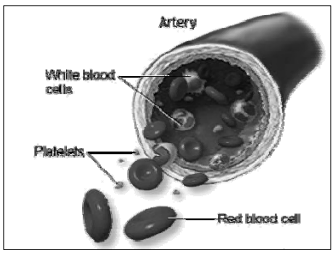
Minute volume falls proportional to metabolic rate

Systemic Responses
Renal

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

Systemic Responses
Hematologic

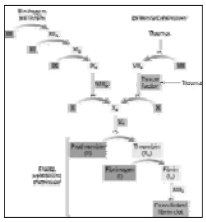
- Cold coagulopathy can produce significant bleeding
- Occurs by 2 mechanisms



Systemic Responses
Hematologic

- **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?

Image from Ponder High School

Cold Water Immersion- Hmmm?

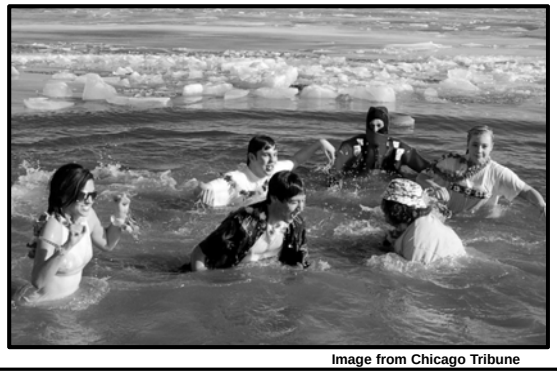


Image from Chicago Tribune

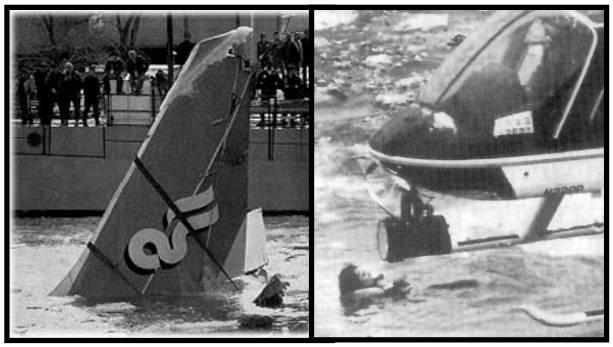
Cold Water Immersion

- **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 <u>may</u> 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!

News Story - Chicago Tribune

Hypothermia Effects

- Video 1: Air Florida Flight 90

"Seconds from Disaster--The crash of Air Florida Flight 90

Video from National Geographic

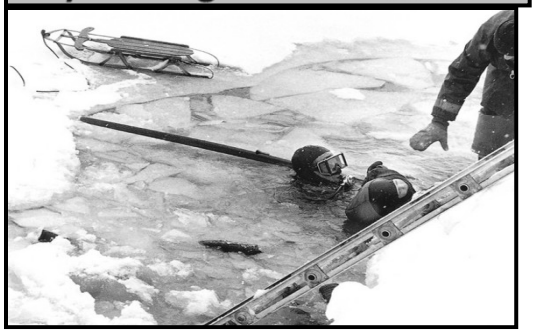
Jimmy Tontlewicz

"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.

Diver lifts four-year-old Jimmy Tontlewicz out of Lake Michigan

In icy lake for 20 minutes, boy brought back to life



News Story - Chicago Tribune

Management and Rewarming of a Hypothermic Patient

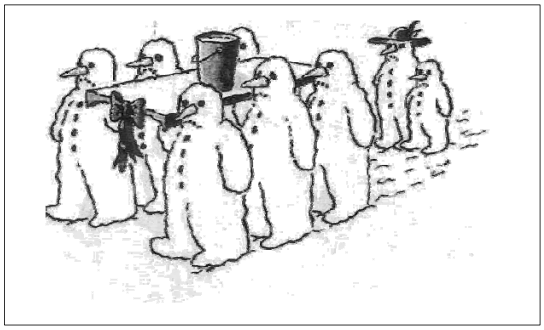
Emergency Medicine Dogma

- You're not dead until you're...

Warm and dead

Unless...

...You're already dead!



Drawn by friend-Kestutis Boyev

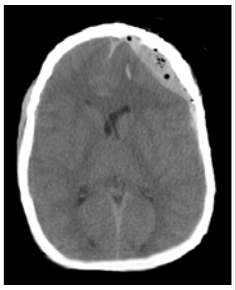
Death!

- Still dead with T°> 32°C (90°F)
- Serum potassium > 10
- ***Documented and verified DNR orders!***

Treatment

Do Primary/Secondary Survey

Evaluate for other treatable conditions



College newspaper: Daily Illini

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°
- Fast!

Treatment: Core Rewarming

- **Heated Humidified Air**
  - Heat to 45°C/113°F
  - 2-3°F rise in T°/hr
  - Indicated for <u>ALL</u> 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

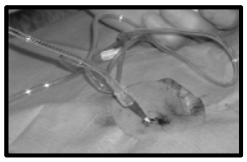
If 42 L of fluid is at 85°F and you add 1 additional L of fluid at 110°F...How much difference does it make?

Only 0.3°C/0.6°F per Liter

Treatment: Core Rewarming

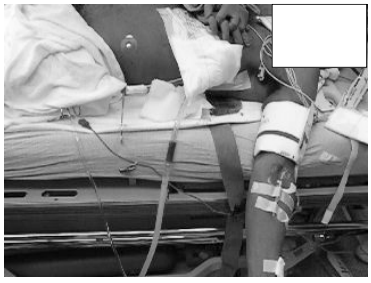
- Heated irrigation of body cavities
  - Abdominal Irrigation ("TPL")
    - ~3°F/hr
  - Thoracic Irrigation
    - Very effective (up to 10°F/hr)
    - Ant/post chest tubes

Treatment: Therapeutic Peritoneal Lavage



Treatment: Thoracic Irrigation

- Video 2: Thoracic Irrigation



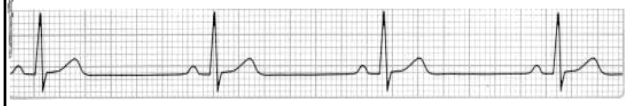
Treatment: Rewarming

- Extracorporeal Blood Rewarming
  - Fem-Fem Bypass
  - CAVR-Level 1 Infuser
  - V V R
  - Dialysis with a heat exchanger

Microwaves?

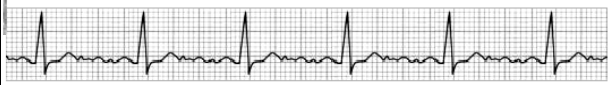
Treatment: Sinus Bradycardia

- Physiologically normal at T < 93°F/34°C
- Don't treat it—Self-limited



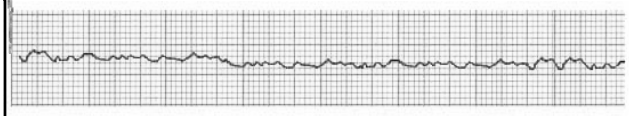
Treatment: Atrial Fibrillation

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



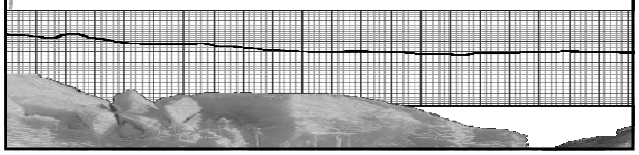
Treatment: Ventricular Fib

- Occurs < 28°C/83.5°F
- Lidocaine is ineffective
- Rewarm and defibrillate every few degrees



Treatment: Asystole

- Occurs physiologically at T < 65°F/18°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

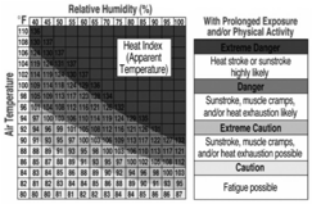
I'm Feelin Hot, Hot , Hot!

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

Photo: Daniel Schwen



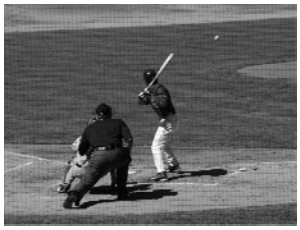
All tolled, 760 people, mostly the elderly and poor died that summer

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/m^2
  - 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

Pathogenesis: Decreased Dissipation

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

Decreased Dissipation: Dehydration

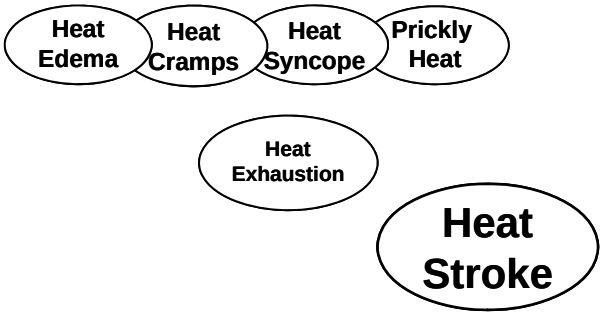
- Limits Sweating
  - Volume overrides heat dissipation
- Impairs CV function
- Insensible water loss
  - 1.5L/day (2% BW)
  - Exercise: 1-2 L/hr
- Maximum gastric emptying
  - 1-1.5 L/Hr

QUESTION?

How much of the lost fluid does thirst alone replace?

Only about 2/3 of the needed fluids

Spectrum of Illness



Heat Exhaustion

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

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**

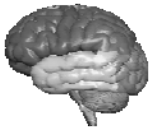
What is the Most Important Thing to Tell a Discharged Heat Exhaustion Patient???

Heat Stroke

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

Heat Stroke

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



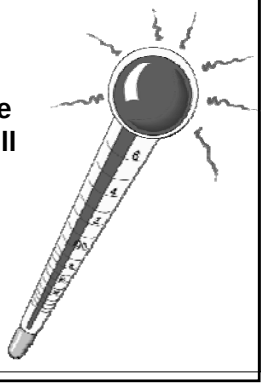
Multi-Organ Dysfunction

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

www.gearfuse.com

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*

politicalhumor.com

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?

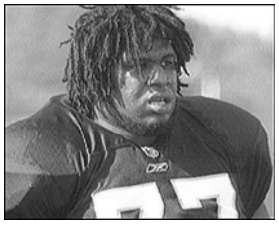


Image from CNN

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

URIE, Minnesota (CNN) -- Pro Bowl ineman Korey Stringer of the Minnesota ed of heat stroke early Wednesday, the

4, 335-pound Stringer, 27, died at St. Joseph's Hospital -- Mayo Health Mankato, where the team holds its practices.

came as dangerously hot weather continued to pose a problem for the central United States. Temperatures were expected to reach as high as 100 degrees in Iowa and Illinois on Wednesday.

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

Image from CNN

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 ee heat. He was taken to the hospital levated blood pressure and body ature and with some brain swelling.
r, Stewart was projected to be a on the Trojans offensive line, and his members said they were unaware of e-existing medical conditions Stewart ave had.
was also an honor student.
s 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**

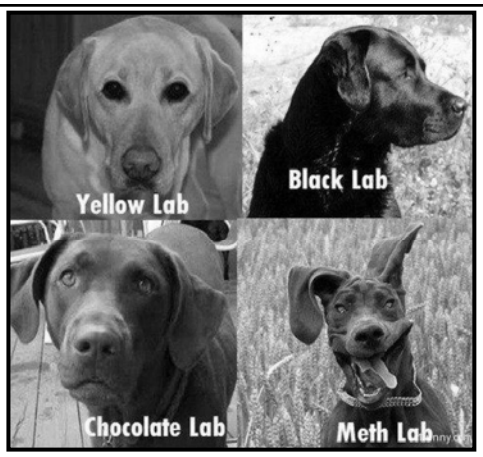
Good Prognosis

- 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

Don't Forget Your Furry Friends!



photowebster

Dysbarism

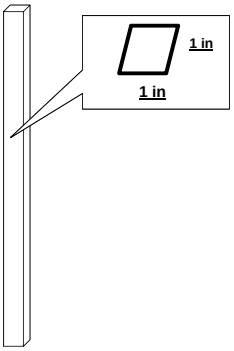
- All the pathologic changes caused by altered environmental pressure
  - Altitude-related event
  - Underwater diving accident
  - Blast injury that produces an overpressure effect

Types

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

Pressure

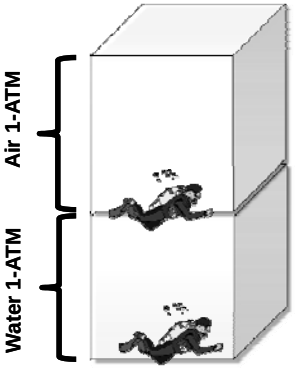
Top of Atmosphere



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

Pressure

- At 33 ft of seawater

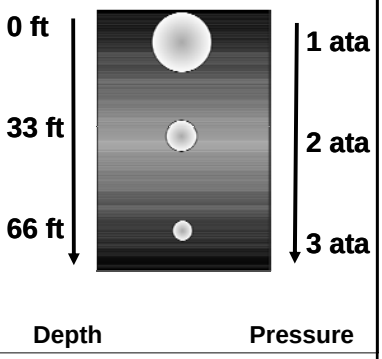


Flying

- Most commercial aircraft are pressurized to 8000 ft
- 0.73 ATA
- FiO_2 21% but functionally less molecules of oxygen per breath ~ 16% FiO_2

Gas Laws: Boyle's Law

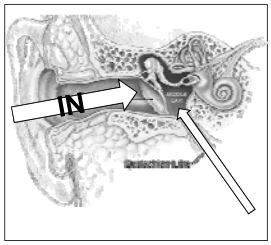
- "The volume of a gas is inversely proportional to the pressure exerted upon it"



Consequences of Pressure

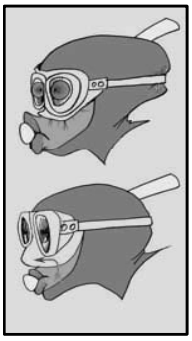
Middle Ear Squeeze-
Barotitis media

- 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



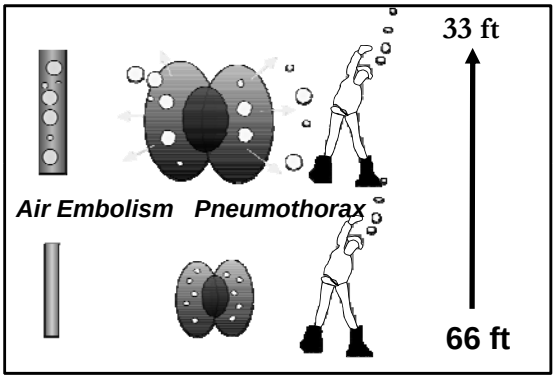
Scuba Rule # 1

Never Hold
Your Breath!

Breath-holding Kills

Blowing Bubbles

Exogenous Entry of Air



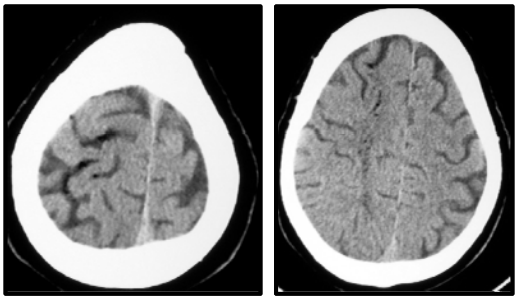
Pulmonary Over-Pressurization

- 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)

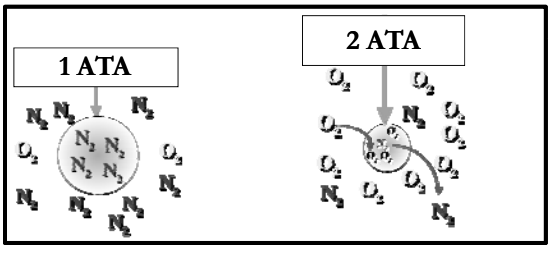
- Bubbles enter the pulmonary venous circulation from ruptured alveoli
- Usually develops right after diver surfaces
  - Sudden LOC = Air embolus until proven otherwise
- Cardiac
  - Ischemia—dysrhythmias, cardiac arrest
- Neurologic
  - LOC, confusion, stroke-like sx

Cerebral Air-Gas Embolism—CAGE



Hyperbaric Oxygen and Bubble Reduction

- As pressure increases, the bubble size decreases and O_2 replaces the inert gas in the bubble (N_2), which promotes diffusion

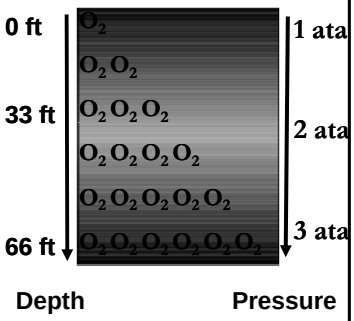


Air Embolism

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

Decompression Sickness (DCS)

- Henry's Law: "The amount of gas (O_2 and N_2) dissolved in a liquid (blood plasma) is proportional to its partial pressure"



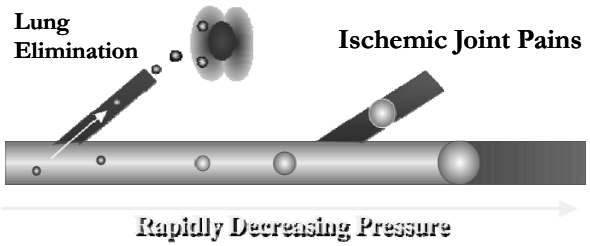
DCS

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

DCS

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"

Public domain in the United States

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

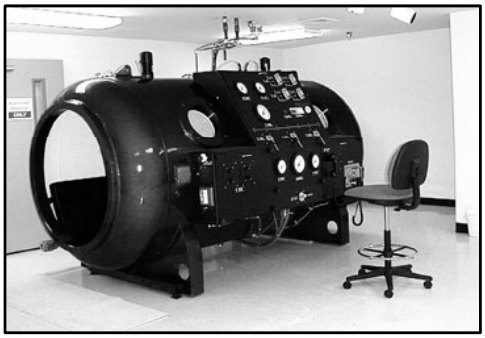
DCS Treatment

- 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

Multiplace Chamber



Multiplace Chambers