Frostbite

- **True tissue freezing**
- **Heat loss sufficient to permit ice formations in tissues**
Frostbite Is a Disease of Wars—Past and Present

- Xenophon: 400 B.C. Armenia
- Napoleon: 1812 - 1813 - retreat from Moscow
- World Wars I and II, Korean War
- Falkland Island (Malvinas): 1982
Barron de Larrey
(Surgeon General of French Army) 1812 - 1813
- Observed bad affects of excessive heat
- Recommended slow rewarming
- Recognized danger of freeze—thaw—refreeze
- Rapid rewarming proven more effective in Alaska in 1950s
Epidemiology

- Incidents unknown
- More prevalent during military campaigns
- Risk in mountaineering, polar exploration, winter sports
- Hundreds of cases from individual urban areas
Humans Are Tropical Animals

- Unclothed, resting person - neutral environmental temperature is 28°C (82°F)
- Doubling metabolic rate - decreases this only to 20°C (68°F)
- Arctic Fox - thermoneutral about -40°C (-40°F)
Response to Cold

- Peripheral cooling of blood activates hypothalamus
- Increased metabolic rate
- Peripheral vasoconstriction
- Behavioral adaptations (clothing/shelter)
The Skin

- Radiative heat loss
- Blood flow far exceeds nutritional needs
  - Increases as much as 35 fold in response to heat
  - Decreases to as little as one tenth in response to cold
- Variation is greatest in acral areas (fingers, toes, ears, nose)
  - “Life or Limb” response
Cold Induced Vasodilation: The “Hunting Response”

- Maximal of vasoconstriction at 15° C (59° F)
- At 10° C (50° F) vasodilation in 5 - 10 minute cycles
- Cycles are stronger and faster in cold-adapted people
Ho. July the 2nd, 1929. Similar curve from Anger R2, during immersion in crushed ice showing very prolonged and large oscillations of temperature. Water unstirred.

Figure 5. From Lewis, T. Observations Upon The Reactions of the Vessels of the Human Skin to Cold; Heart 15 May 1930 p. 183. “Temperature curve during cold water immersion, demonstrating the ‘rise and fall’ response, gradually decreasing, The ‘hunting’ response of Lewis.”
Phases of Freezing Injury

- Prefreeze phase
- Freeze - thaw phase
- Vascular stasis phase
- Progressive or late ischemic phase
Simplified Scheme of Freezing Injury

- Cooling - Supercooling - Freezing stage
- Vascular stage: Thawing (Rewarming) and post-thaw stage
Cooling Stage
*(Prefreeze Phase)*

- Cold–induced vasoconstriction
- Cold–induced vasodilatation (CI VD)
- Skin sensation lost at 10°C (50 °F)
- Micro vascular construction
- Trans-endothelial plasma leakage
Supercooling - Freezing Stage

- Pattern of ice formations depends on rate of freezing
- Skin must be supercooled to -4°C (25°F) for crystals to form
- Extracellular ice forms first unless freezing is very rapid
- Intra- and extracellular changes
- Cell shrinkage
Freezing Stage
continued

- Cell membrane damage
- Impaired micro vascular function
- Endothelial injury
- Injury to non-skin tissue
Vascular Stage
*Thawing (Rewarming)*

- Depends on rewarming method
- Hyperemia, ischemia, cyanosis or total circulatory failure
- Blebs may appear
- Reperfusion injury
- Prostaglandins and thromboxane; proteolytic enzymes
Vascular Stage

Post—Thaw

- Microvascular damage determines result
  - recovery of circulation or
  - thrombosis, ischemia, necrosis, gangrene

- Intercellular ice and tissue death if refrozen
What Determines the Extent of the Injury?

- Type and duration of cold contact
- Contact with thermal conductors
- Wind chill index
## Equivalent Temperature (°F)

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**WIND CHILL CHART**
Behavioral Risk Factors

- Mental illness
- Alcohol and drugs
- Fear, apathy, panic
Physiological Risk Factors

- Individual factors
- Dehydration and hypovolemia
- Hypoxia, other injuries and hypothermia
- Skin and circulatory problems
Mechanical Factors

- Inadequate clothing
- Tight or wet clothing or boots
- Immobility
- Mechanical damage
Prevention of Frostbite

- Food and fluid intake
- Clothing and shelter
- Avoid contact with cold objects
Alaska Freezing Injuries
Part 1

- True frostbite, superficial or deep
- Immersion injury followed by freezing (a disaster)
- Freeze—thaw—refreeze (a disaster)
Alaskan Freezing Injuries

Part 2

- High-altitude injury
- Compartment pressure followed by freezing
- Fracture or dislocation followed by freezing
- Hypothermia with extremity freezing injury
Alaskan Freezing Injuries
Part 3

- Freezing superimposed with small vessel disease
- Freezing injury in children
- Congenital deformity with freezing
- Frostbite with burns
Initial Symptoms of Frostbite

Severity related to extent of the injury

- Extremities: ears, nose, penis and scrotum
  - Numbness
  - Clumsiness
Symptoms Following Rewarming

- Intense pain initially
- Throbbing pain—begins at two days, last weeks or months
- Symptoms worse with warmth
- Tingling, burning and electric shock sensations
- Sensory loss lasts three years
Initial Signs of Frostbite

- Deceptively benign—variable appearance
- Most thawed in prehospital phase
- After rapid rewarming
  - Hyperemia
  - Return of sensation until blebs form
Prognostics Signs

Favorable

- Normal sensations, color, warm
- Edema formation within 3 hours
- Early formation of clear blebs to digital tips

Unfavorable

- No edema formation
- Late formation of small, dark blebs
Classification of Frostbite Injuries

- **Mild or superficial (no tissue loss)**
- **Severe or deep (with tissue loss)**
- **Historical classification**
  - 1st to 4th degree
  - Not clinically useful
Methods of Thawing

- **Rapid rewarming in warm water (37-41°C)** optimum method
- **Gradual thawing**—often unavoidable
- **Harmful methods**
  - Delayed thawing with ice or snow
  - Excessive heat
Prehospital Care

- Supportive care for trauma—dehydration
- Avoid heat loss
- If frozen and rescue near
  - keep frozen unless warm water thaw with no danger of refreezing
- If already thawed—avoid refreezing
Emergency Department Care

- **History and physical**
- **If freezing only**
  - Rewarm in warm water bath
  - If swelling—consider fasciotomy
- **If hypothermia**
  - Treat hypothermia
  - Hospitalized if hypothermia plus frostbite
Classification and Disposition

- **Superficial** - Home care
- **Deep superficial** - Homecare or hospitalize
- **Deep or swelling present**—Hospitalize
Overview of Hospital Treatment

- Imaging studies
- Wound care
- Nutrition
- Pharmacology
- Sympathetic block or surgery as needed
Principles of Hospital Treatment

- Patient care and comfort
- Meticulous wound care
- Elevation of injured extremities
- Maximum mobility
Special Considerations

- Vigorous IV fluids if patient recently at altitude or extreme cold
- Keep superficial blebs intact, initially
- Consider sympathetic block
Nursing Care Plan

Goal: patient compliance - optimal results

Plan/ action:

1. H+P: impact of injury
2. patient needs; explained regimen
3. tailored care, support
4. discharge planning
Admitting Orders

1. Routine vitals
2. I&O  X 24 hours
3. Activity for upper extremities: OOB prn hallway lower extremity: wheelchair or crutches
4. Foot cradle to bed, elevate feet on 2 pillows
5. Elevate hands on 2 pillows or with stockinette slings
6. Dress extremity with sterile stockinette
7. High calcium, high-protein diet
8. Push fluids PO
9. IV D5 0.5NS 125 cc/hr x 24 hours
10. Td 0.5 cc IM adults (DT 0.5 cc IM pediatric)
Admitting Orders
continued

11. Phenoxybenzamine 10 mg po BID x 3 days, then 10 mg daily x 3 days (?)
12. Vitamins C 500 mg TID
13. Stresstab with zinc 1 daily
14. ASA 325 mg PO daily x 10 days
15. Dextran 40 (LMW) 25 cc/hr via IV infusion pump
Admitting Orders
continued

16. Labs; CBC, SMA 12, UA
17. Technetium\textsuperscript{99} or scan and plain film of affected part
18. Whirlpool BID 20 minutes at 93-95° F with Hibiclens
   • Rinse and dry post whirlpool
   • feet may be opened to air beneath bed cradle
   • culture opened draining wounds
19. Consent to photograph
20. Appropriate consults
Ongoing Care

- Repeat technetium scan after 2-3 days
- If tissue loss - allow demarcation
- Watch for liquefaction necrosis
  - If fever, treat for sepsis
  - If no response, amputate
Sequelae

- Excessive sweating
- Painful, cold, numb extremities
- Abnormal skin color
- Joint stiffness
- Biofeedback/psychotherapy
Immersion Injury
(Trench Foot)

- Peripheral non-freezing cold injury
- Develops in hours to days
- Tissue loss possible
- Differs from warm immersion injuries
Stages of injury

- Pre-hyperemic (post initial warming)
- Hyperemic
- Post-hyperemic
Epidemiology

- Marine immersion
- Wilderness survival with walking
- Homeless and mentally ill
Prevention and Treatment

- Marine safety
- Wilderness safety
- Rescue - treat hypothermia
- Hospital treatment - similar to frostbite
Frostnip

- Superficial ice crystals
- Vasoconstriction
- No tissue loss
Chilblains 
(Pernio)

- Local skin reaction to wet, non-freezing cold
- Lesions itch and burn
- No tissue loss
- Female predominance
Cold Sensitivity

- Raynaud’s phenomenon
- Cryoglobulins
- Cold urticaria