Frostbite

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At what temperature does both the Fahrenheit & Celsius scales converge? (i.e., the same number)
Welcome to Minnesota
Types of Cold Injuries

• Local cold injury
  – Rapid freezing – cold contact or flash freeze injury
  – Slow freezing – true frostbite
• Systemic hypothermia may be LEATHAL
• 40% of patients with a local cold injury present with synchronous hypothermia
Definition of Systemic Hypothermia

- **Mild** Core temp 90 - 95° F
- **Moderate** Core temp 85 - 90° F
- **Severe** Core temp below 85° F

**Symptomatic definition**
- Mild - shivering, confusion
- Moderate - no shivering, somnolence, combativeness, bradycardia
- Severe - coma, arrhythmias, then asystole
Dangers of Hypothermia

- If frozen extremities are warmed rapidly in a hypothermic patient, the blood returning to the heart is cold.
- The patient’s core temperature drops rapidly and cardiac arrest is a real risk, especially in a hypovolemic patient.
Mild to Moderate Hypothermia

- Immersion in tub is a quick, low tech option
- Contraindications:
  - CPR
  - Unstable fractures
  - Open wounds
  - Hemorrhage
- Warming rates of 15-30° F per hour
Unstable Hypothermia Patient

- Volume expansion with warmed fluid
- Pressors for severe hypotension
- CPR only for asystole, not bradycardia
- Warming options include previous measures
  - Consider cardiopulmonary bypass
  - Warm 10-30° F per hour
- CPR until core temperature is above 92° F
Cold Injuries Have Changed History

- Hannibal crossing the Alps - 218 BC
  - Lost 20,000 of 46,000 men in 15 days
- Napoleon's march to Moscow - 1812
  - Left with 250,000 men, returned with 350
- WW II - US lost 90,000 men
- Korean War - 10% of U.S. casualties due to cold
Who Gets Cold Injuries?

- The intoxicated (alcohol, other drugs)
- The incompetent (mental illness / dementia)
- The infirm (elderly, esp. with falls)
- The insensate (neuropathy or paraplegia)
- The inexperienced (new to cold climates)
- The inducted (wartime increases risk)
- The indigent
Classical Treatment of Frostbite

- Treat systemic hypothermia first
- Rapidly re-warm body part in 104 °F water
  - Rewarming HURTS!
  - Narcotics given intravenously
Rapid Rewarming

- Rapid Rewarming
  - 104°F causes the least damage to frozen tissue
  - Slow warming leads to more ischemia
  - 40 percent of patients thaw their extremities before seeking medical attention
Tissue Response after Thawing

- Digit vessels vasodilate
- Injured endothelial cells swell and embolize into the capillary bed
- The blood vessels develop a progressive thrombosis
- The ischemic skin develops bullae after a few hours, and nail beds become dark
Standard Treatment Protocol for Frostbite During Thawing

- Monitor for hypothermia using a Foley with temperature sensor
- Narcotics IV for pain control
- Oral ibuprofen for one week
- Brief bed rest/elevate extremities
- Deflate bullae
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You can not predict the severity of injury on a frozen extremity.

The skin is …

• White
• Firm
• Cold
Frostbite Appearance

Before thawing

After rapid rewarming
Phases of Frostbite

- **Cooling skin**
- **50°F to 28°F**
- **Tissue freezing to ambient temp.**
- **Frozen tissue (anoxia)**

Epidermis and dermis layers are shown at each phase.
What type of injury is this?

- Freeze injury?
- Location?
- Rapid or slow?

**Flash Freeze**
Phases of Frostbite

- Ambient temp. to 28°F
- 28°F to H₂O bath temp.
- Rewarming complete
- Post-rewarming
Injuries from Frostbite

• Freezing:
  – Cessation of blood flow
  – Ice crystals form and damage cells

• Thawing:
  – Damage to cells if perfusion occurs before ice melts

• Reperfusion:
  – Injured endothelial cells swell and embolize into the capillary bed
  – The blood vessels develop a progressive thrombosis
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You can not predict the severity of injury of a rewarmed extremity with frostbite.

Blisters mean…
• What??
Prognostic Signs in Frostbite

Good Prognosis
- Sensation
- Hyperema
- Warm digits
- Clear blebs

Poor Prognosis
- No sensation
- Cyanosis
- Cool digits
- Hemorrhagic blebs which don’t reach tips
Freeze - Thaw - Refreeze Injury

A: Large blisters absent

B: 5 days after injury

C: 4 weeks after injury
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What should you do with blisters?

- Blister fluid contains inflammatory mediators (TxA2, PgF2α) - Hemorrhagic blisters do not
- Once blister integrity is lost, pendulum swings towards bacterial colonization of damaged skin
- Avoid maceration of surrounding skin
Classical Treatment of Frostbite

- Treat systemic hypothermia first
- Rapidly re-warm body part in 104 °F water with narcotics given intravenously
- **Ibuprofen by mouth for one week**
- **Topical aloe vera gel**
- Elevation, aspiration of skin bullae, padded footwear
Early mobility with LE frostbite

- Early vs Late mobility (at 72H post injury)
- Retrospective,
- Early n=16, Late n=25
  - Lytics: Early 63%, Late 56%
- Cellulitis was equivalent but a trend towards longer LOS from cellulitis with Early (0.067)
- LOS was unchanged (Early 11, Late 12)
Definitive Treatment of Frostbite

- Rewarming
- Observation
- **Delayed Amputations**
  - “Frostbite in January, amputation in July”
Frostbite Injury
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There is NO role for prophylactic antibiotics.

This has been studied in frostbite (as in burns) and found not to prevent infections.
Bone Scan

- Shows perfusion to soft tissues and bone
- Evolution will occur in the first week
  - Better accuracy if repeated in 5-7 days
- Lace anatomic specificity for early OR plan
- Advantages:
  - Decreases infectious risk (1-3 months)
  - Reduces time to maximal functional return
  - Psychological
Angiography

• Gold standard

• Disadvantages:
  – Invasive
  – Bleeding complications
  – Clotting complications
  – Vasospasm complications
Hyperbaric Oxygen

First use in 1963 (Ledingham)

- Case reports of improvement when starting 5-10 days post injury
- Vasoconstriction & decreased blood flow in healthy volunteers
Thrombolytics in Frostbite
Reperfusion Injury with Frostbite

- Digit vessels vasodilate
- Endothelial cells slough
- Progressive blood vessel thrombosis
- The ischemic skin develops bullae after a few hours, and nail beds become dark
Evolution of Lytic Tx for Frostbite

- Streptokinase in frostbite rabbits (1987)
- 1989-94: pilot study at HCMC (Minneapolis) using IA tPA in 6 pts with frostbite with good results (25% comps)
- Since 1994, RCMC/RH pts with severe frostbite undergo angio within 24H \(\rightarrow\) lytics
The St. Paul Experience

- Rapid rewarming
- For digits with reduced blood flow
  - Angiogram
  - tPA and papaverine infusion
  - Repeat angiogram at 24 and 48 hours
- Anticoagulation → Antiplatelet agents
- Late (4-6 wk) amps for mummified digits
Thrombolytic Agents in Frostbite

- Urokinase is no longer available
- Streptokinase - less efficient, very antigenic
- Tissue plasminogen activator (TPA) converts plasminogen → plasmin : dissolves clots
- Tenecteplase (TNKase)
  - A TPA that has a higher specificity for fibrin (vs. fibrinogen)
Normal Hand Angiogram
Admission Angiograms DOI
Completion Angiograms PID 3
Initial Images: FB to foot

Right foot
Post 36H lytics
The St. Paul Experience

Contraindications to Thromboyticcs

- Lack of consent (patient or family)
- Lack of cooperation - catheter trauma
- Child - risk of catheter induced thrombosis
- Recent trauma, CVA, bleeding d/o
- Trauma or recent surgery - risk of bleeding
- > 24H warm ischemia
- Freeze-Thaw-Refreeze
Between 1991-2007, 133 frostbite patients

- 70 angiography, 4 normal studies
  - 66 received intra-arterial lytics
  - 482 digits were found to be at risk

- 67 were treated with our conservative protocol
IA Reperfusion vs Amputation

Digits with Abnormal Initial Angio

- Distal blush: 194 (98% Salvage)
- Partial flow: 126 (63% Salvage)
- No flow: 71 (95% Amputation)
Complications

- Groin hematoma (sheath) (6%)
  - None in the last 9 yrs

- Acute renal failure – (1.5%)

- Compartment Syndrome – (1.5%)
Hospital Charges Following Lytics

Patients

1-7  Mean  $61,600

Patients (1991-2007)

1-66  Mean  $70,085
Summary

- In patients with severe frostbite →
- Rapid rewarming + Thrombolytic Tx if indicated
- Protect from injury (bleeding)
- > 24H of warm ischemic time has no benefit from lytics
  - The cutoff time is unknown
Prognosis

- 70% of digits at risk will be salvaged

- 70% of patients required NO amputations
  - The majority of amps were in nonresponders

- Partial responders typically resulted in a more distal amputation
  - BKA vs. Forefoot Amputation
Does this patient need lytics?

Before thawing

After rewarming
Sequelae of Frostbite

- Cold intolerance with chronic pain (70%)
- Vasospastic attacks
- Joint stiffness, arthritis in 50% of adults
- Re-injury is worse with second cold exposure (2x increased risk of 2\textsuperscript{nd} injury)
- Growth plate abnormalities (kids)
Frostbite Sequelae
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Some patients with successful lytic Tx and still require an amputation.

Chronic pain in the cartilage can debilitate a patient to the point that amputation for pain control is preferable.
Frostbite Treatment Protocol
Questions?

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