Frostbite in January, Operate in June?

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Subclass of cold exposure injuries

• Non-freezing injuries

• Freezing injuries
  → Frostbite

• Most common age group: 20-39 years
History

- 1st reported case: pre-Columbian mummy found in the Chilean mountains (estimated 5,000 years ago)
- In war, cold temperature is sometimes the bigger enemy (lessons learned by Napoleon and Hitler)
- Recent descriptions
  - Wars (Korean, Falklands)
  - Civilian experience (homeless, outdoor sports)

Recent advances

- Harrold Meryman (Yale, 1956)
  → described mechanics of freezing
- William Mills Jr. (Anchorage, 1960's)
  → Beneficial role for rapid re-warming
- McCauley and Robson (U. Chicago, 1983)
  → Protocol for re-warming, wound care, anti-inflammatory agents
- Saffle (U. Utah, 2007)
  → Potential benefits of t-PA adjunctive therapy

Frostbite injury is:

1. Immediate: direct cellular damage due to freezing
2. Progressive: tissue ischemia
Pathophysiology

• Freezing point of skin -3.7 to -4.8°C (due to electrolyte content)

• Skin temperature cooling
  – 28°C: cool
  – 20°C: pain
  – 10°C: numb

Stages of freezing

• Cold-induced vasoconstriction and vasodilation ("Hunting response")
• Extracellular freezing occurs first
• Disruption of endothelial integrity
• Intracellular freezing as temperature ↓
• Thrombosis in vessels
• Tissue anoxia

Stages of re-warming

• Extracellular ice crystals melt
• Edema formation
• Free radicals cause more endothelial injury
• Epidermal blisters
• Prostaglandins and thromboxane cause platelet aggregation, worsening skin ischemia
**Behavioral risk factors**

You are NOT where you’re supposed to be:

- Homeless
  - Inadequate clothing and shelter
  - Psychiatric illness
- Motor vehicle breakdown
- Exercise in cold temperature, wind chill conditions, at high altitude

**Host factors**

- Previous frostbite
- Race: Blacks more susceptible (military studies)
- Women cool faster than men
- Systemic hypothermia
- Alcohol and other drug use
- Thin skin (very young and older adults)
- Poor peripheral circulation
  - Diabetes, arteriosclerosis, vasculitis, Raynaud’s
  - Vasoconstrictive drugs (smoking)
  - Dehydration

**Mechanical risk factors**

- ↓ Circulation: constricting clothes (i.e. too many socks)
- ↑ heat loss: sweating, wet clothes, heat conductive materials (i.e. rings on fingers)
- Immobility
Guidelines for prevention

• Be aware of temperature and wind chill factor when exercising
• Loose, layered, windproof clothing
• Avoid decreasing blood flow to extremities (tight shoe laces, backpack straps etc…)
• Frequent sock changes (advocated by military)

Ready for the COLD

• Keep clothing: **Clean**
• Avoid: **Overheating**
• Wear clothing in: **Layers**
• Keep clothing: **Dry**

1st degree

• Pallor warms to redness
• No blisters or necrosis
• Occasionally superficial skin loss (5–10 days later)
2nd degree

- Insensate
- Pallor warms to blistering
- Early: vesicles with clear fluid
- Late: desquamation and black eschar

Climber in Alaska

3rd degree

- Frozen
- Pallor warms to hemorrhagic blisters
- Blue-grey discoloration

Homeless man

4th degree

- Rigid extremity
- Little edema
- Early: mottled, deep red or cyanotic
- Late: dry, black and mummified

Young man was depressed, wandered in the woods 1/10/10, found 1/29/10
Treatment priorities

- Admit the patient
- Aggressively treat systemic hypothermia, other injuries
- Local complications: compartment syndrome, gangrene
- Systemic complications: sepsis, acute kidney injury, myoglobinuria, hyperkalemia

Rewarming

- Rapidly rewarm the affected areas in warm water
- Actual temperature recommended varies
  - 37–39°C (99–102°F) for 15–30 min
  - 40–42°C (104–108°F) for 15–30 min
- Thawing must be complete
- Avoid repeating freeze-thaw cycle

Wound care

- Debride clear or white blisters
- Leave hemorrhagic blisters intact
- Elevate extremity
- Careful about pressure on affected areas (splints, end of bed, socks)
- Padding between toes/fingers
- Anti-tetanus prophylaxis
- IV opiates
- NSAIDS
Therapies to limit the zone of injury

- Most are case reports or case series
  - Hyperbaric oxygen
  - Lumbar sympathectomy (decreases pain, but may increase swelling)
  - Epidural catheter may achieve same goal
  - Pentoxifylline (↑RBC deformability, ↓viscosity, platelet aggregation)
  - Vasodilators
  - Thrombolytic therapy (t-PA) within 24 hours of injury

University of Utah t-PA experience

- 32 patients over 10 years (1996-2005)
- Unit adopted angiography and t-PA protocol in 2001

Table 1. Angiographic Status of Patients Treated With t-PA Compared With 50 Other Patients Injured by Freefalling

<table>
<thead>
<tr>
<th>Agent</th>
<th>No. of Patients</th>
<th>No. of Angiograms</th>
<th>Changes Seen</th>
<th>No. of Patients</th>
<th>Changes Seen</th>
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<tr>
<td>No agent</td>
<td>25</td>
<td>34</td>
<td>5</td>
<td>3</td>
<td>2</td>
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<tr>
<td>t-PA administration</td>
<td>78</td>
<td>70</td>
<td>66 (88)</td>
<td>54 (70)</td>
<td>31 (59)</td>
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<tr>
<td>Total</td>
<td>103</td>
<td>104</td>
<td>71 (68)</td>
<td>80 (78)</td>
<td>62 (75)</td>
</tr>
</tbody>
</table>

Bruen, Arch Surg 2007

University of Utah t-PA results

Bruen, Arch Surg 2007
Other dramatic t-PA results

Utah t-PA protocol

- Catheter into femoral or brachial artery → angiography
- 2-4 mg t-PA bolus
- Continuous infusion: 1mg/hr t-PA + 500 units/hr of heparin
- In ICU, monitor:
  - fibrinogen
  - catheter site
- Repeat angiography at 12, 24 hours

Surgical adage:

“Frostbite in January, operate in July”
When and how much to amputate

- Unless you had to amputate early, allow for demarcation of zone of injury (late)
- Auto-amputation
- Surgical amputation
- Level of amputation depends on:
  - Skin integrity (easy to see)
  - Blood flow (pulses, doppler signals, +/- angio)
  - Viable and functional soft tissue (physical exam, +/- technetium scan)

Technetium-labeled scan

Post-amputation care

- Multidisciplinary rehabilitation team
- Prosthesis
- Special custom-made footwear for foot amputations
- Prevention of second injury
Late sequelae

- altered vasomotor function
- Neuropathy, numb extremity
- Chronic pain
- joint articular cartilage changes
- Prone to reinjury
- in children, growth defects caused by epiphyseal plate damage

Pigment mismatch

Injury presentation

Truck broke down in Montana, spent night outside, January 2010
Viability clearly demarcated

April 2010

Partial digit amputations

Viable edges, fish-mouth closure
Questions (true/false)

1. The highest incidence of frostbite is in older adults because they have thin skin
2. Wear multiple layers of socks when you go out in the cold
3. When you’re stuck in the woods with early toe frostbite, cup your hand and blow on the toes to warm them up
4. Frostbite in January, operate in June