

Frostbite

A large, snow-covered tree stands in a winter landscape. The ground is covered in a thick layer of snow, and the sky is a clear, pale blue. The tree's branches are heavily laden with snow, creating a white, textured canopy. The overall scene is serene and cold.

Mark Johnston, RN BSN

Manager, Burn Program

Regions Hospital

St. Paul, MN



QUESTION?

*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

Frostbite Pearl

You can not predict the severity of injury on a frozen extremity.

The skin is ...

- White
- Firm
- Cold

Frostbite Appearance

Before thawing

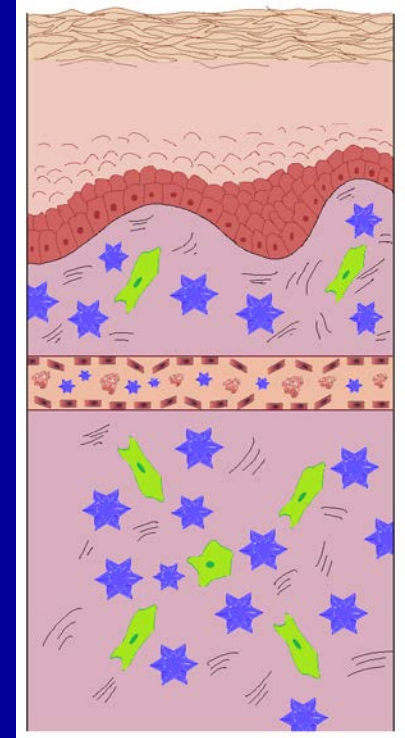
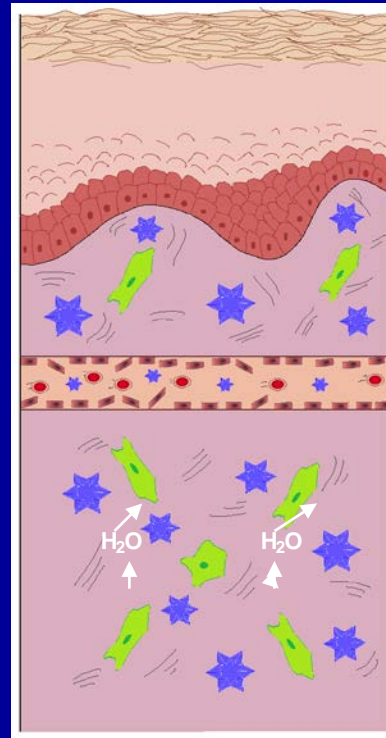
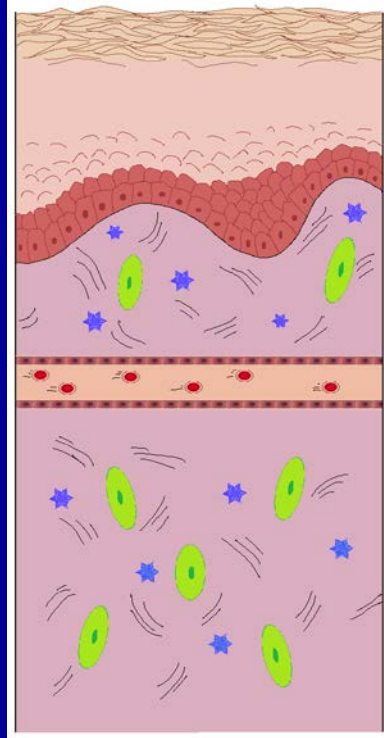
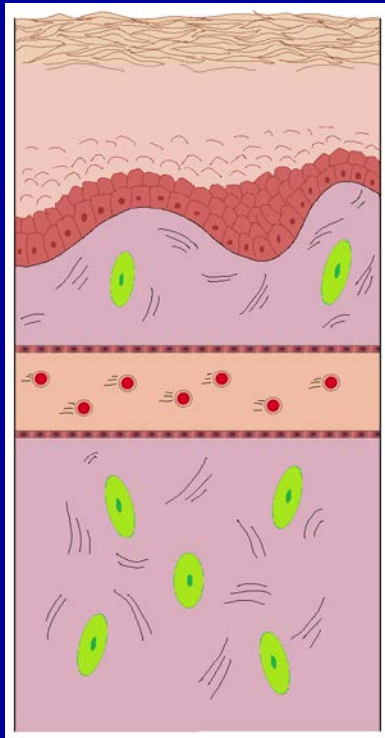


After rapid rewarming



Phases of Frostbite

epidermis



dermis

Cooling skin

50°F to 28°F

Tissue freezing to ambient temp.

Frozen tissue (anoxia)

What type of injury is this?

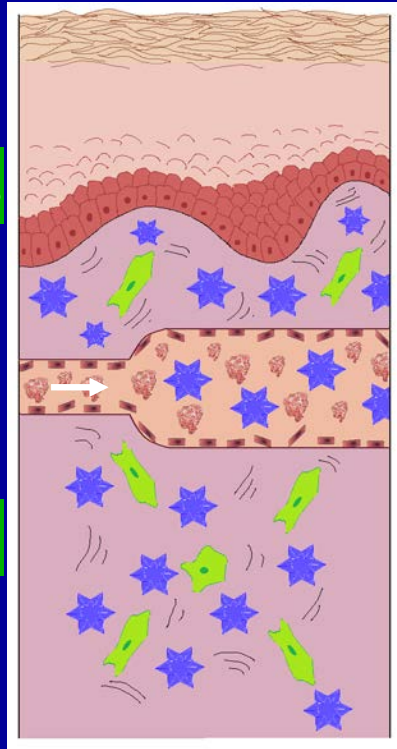
- Freeze injury?
- Location?
- Rapid or slow?



Flash Freeze

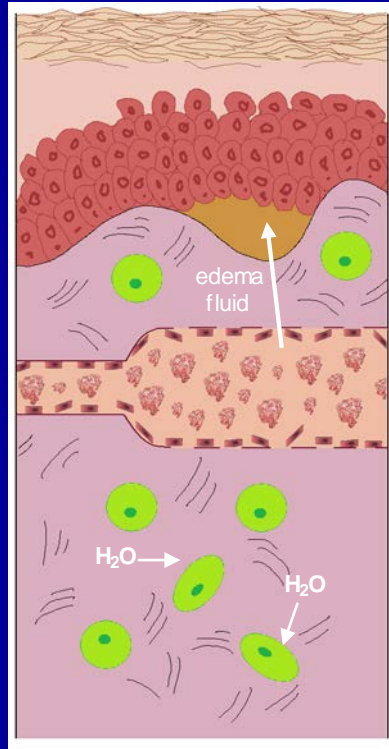
Phases of Frostbite

epidermis

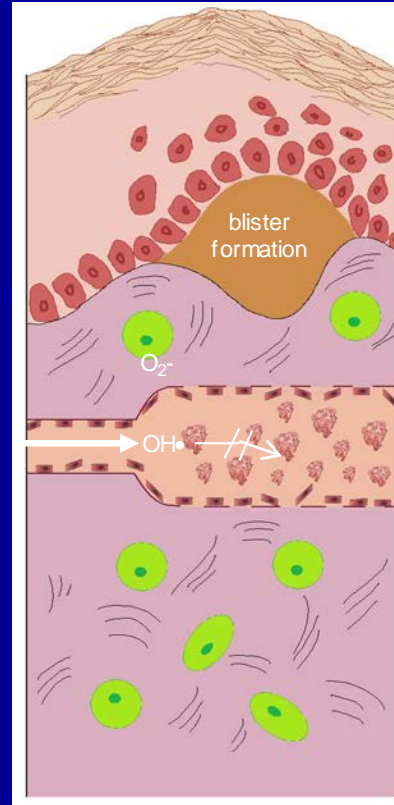


dermis

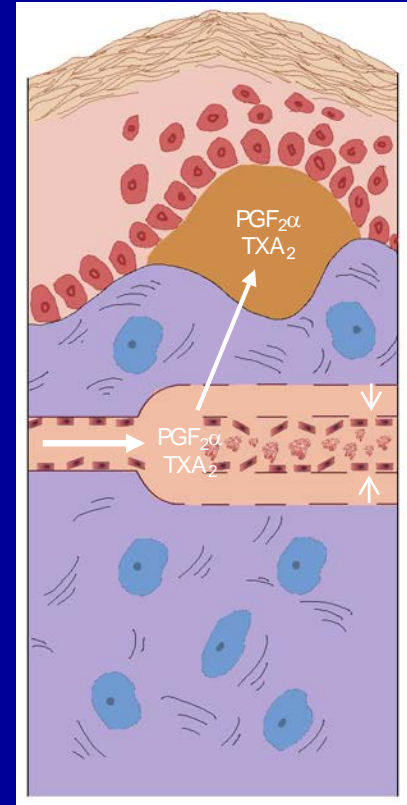
Ambient
temp.
to 28° F



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??



2 11 95

Prognostic Signs in Frostbite

Good Prognosis

- Sensation
- Hyperemia
- 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

C: 4 weeks after injury



B: 5 days after injury



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What should do 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



Frostbite Pearl

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
- Lack 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 → 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

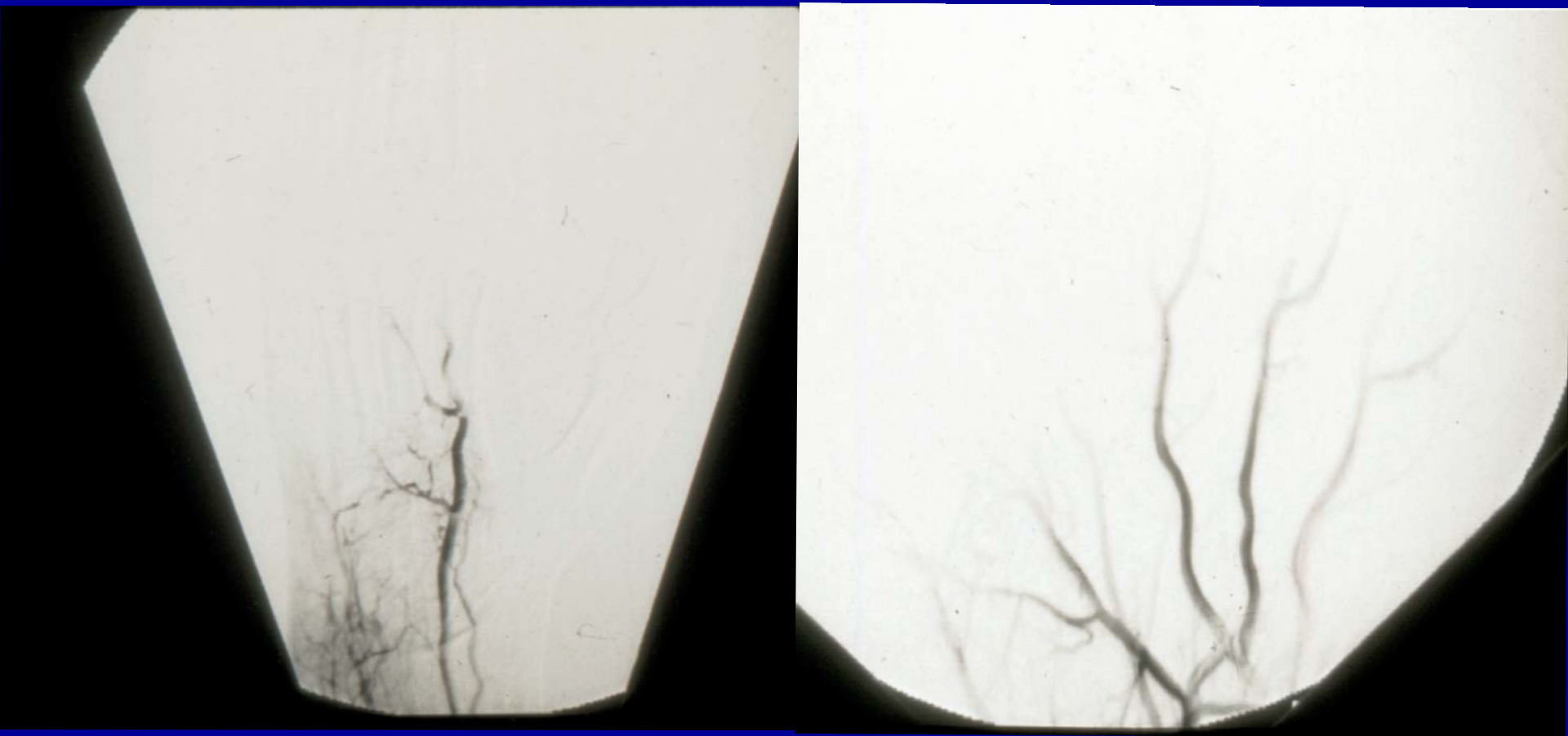
- Urokinase is no longer available
- Streptokinase - less efficient, very antigenic
- Tissue plasminogen activator (TPA) converts plasminogen → plasmin : dissolves clots
- Tenecteplase (TNKase)
 - A TPA that has a higher specificity for fibrin (vs. fibrinogen)



Normal Hand Angiogram



Admission Angiograms DOI



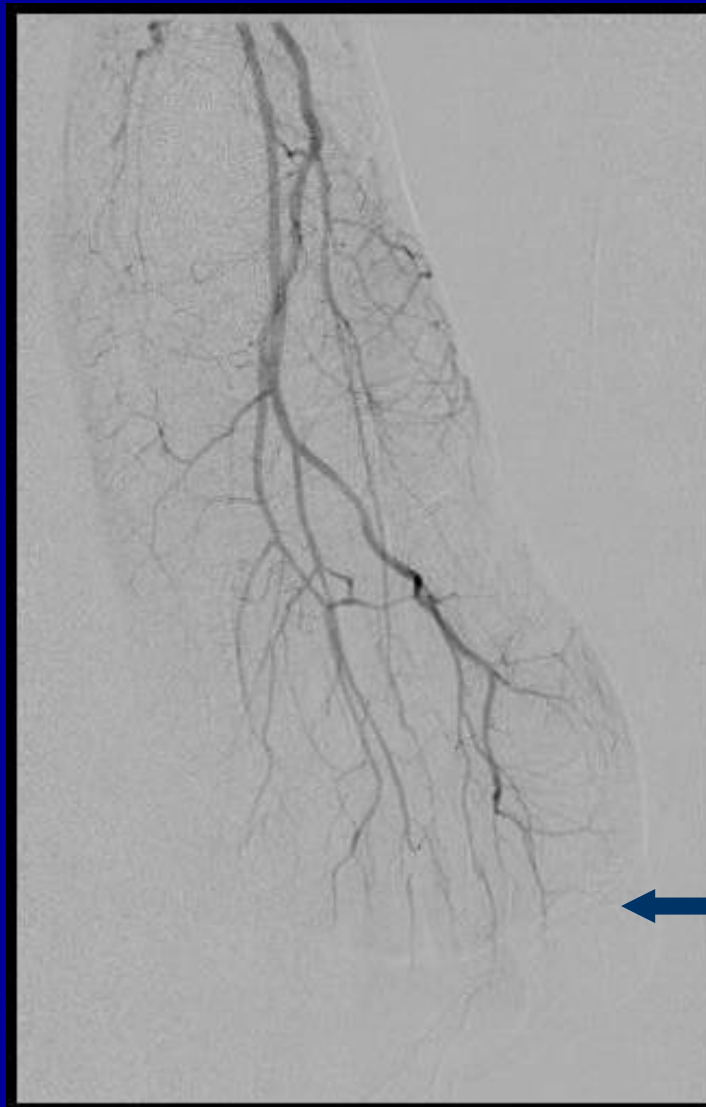
Completion Angiograms PID 3







Initial Images: FB to foot



Right foot

Post 36H lytics



The St. Paul Experience

Contraindications to Thrombolytics

- 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

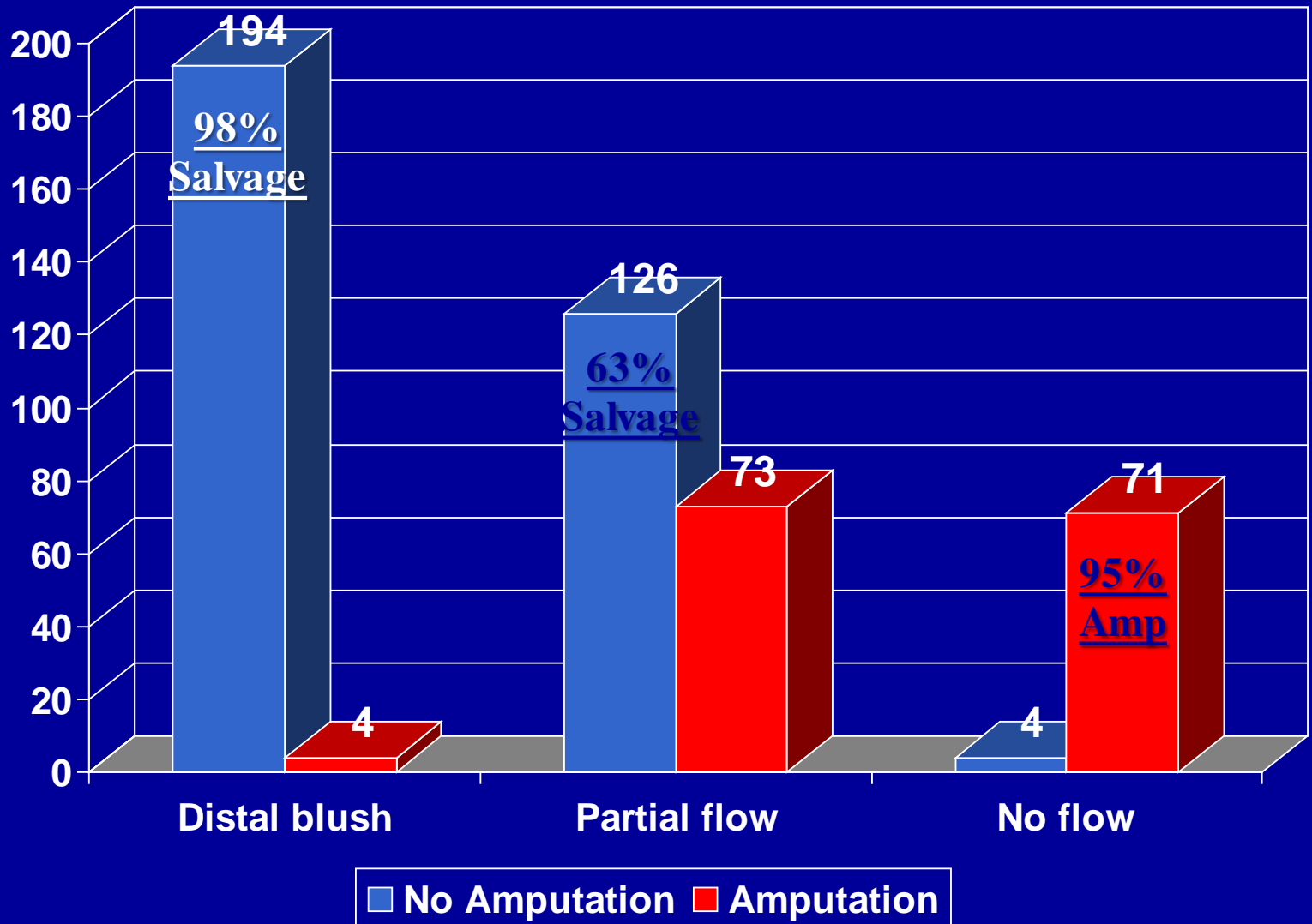
Regions Frostbite Data

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



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 2nd injury)
- Growth plate abnormalities (kids)

Frostbite Sequelae



Frostbite Pearl

*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?

Mark.j.johnston@healthpartners.com

