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Frostbite

Objectives

- Physiology of Frostbite
- Stages of Care
- Recommendations for Optimal Healing

Physiology of Thermal Injury

Pre-freezing

- Superficial skin reaches less than 50˚F (10 ˚C)
- “Hunting Reaction”
- Constriction of microvasculature System
- Increased viscosity of vascular contents

Direct Cell Damage

- Skin tissue less than 28˚F (-2˚C)
- Extracellular ice crystals form
- Intracellular dehydration
- ↑ intracellular electrolyte concentrations
- Cellular collapse
- Membrane ruptures
- Cellular death

Physiology of Thermal Injury cont.

Indirect Cell Damage (during re-warming)

- Microthrombi
- ↑ blood viscosity
- Edema formation
- Progressive Dermal Ischemia
- Tissue death
- Nerve and muscle may be affected

- Note: Edema expected to resolve approximately 72 hours from onset. Gangrenous tissue may be present within 9 days

Prognostic Indicators

Favorable

- Sensation to pin prick
- Normal skin color
- Bullae with clear fluid
- Malleable skin

Unfavorable

- Hemorrhagic Bullae
- Non-blanching cyanosis
  - "Dipped in grape juice look"
- Hard, non-malleable skin

Contributing Factors

- Alcohol a factor in >60% of all reported cases nationwide
- YK Delta >90% involve alcohol
- Equipment Failure
- Sudden weather changes
- Inadequate clothing & gear
- Contributing Medical conditions

Contributing factors cont.

- Wind chill factor
- Duration of Exposure
- Wet Clothing
- Warm/re-freeze/re-warm cycle
  - Increased damage

Wind Chill Chart

The wind chill temperature is how cold people and animals feel when outside. Windchill is based on the rate of heat loss from exposed skin caused by wind and cold. As the wind increases, it draws heat from the body, driving down skin temperature and eventually the internal body temperature. Therefore, the wind makes it FEEL much colder.

Wind (mph)	°F	40	38	36	34	32	30	28	26	24	22	20	18	16	14	12	10	8	6	4	2	0	-2	-4	-6	-8	-10	-12	-14	-16	-18	-20	-22	-24	-26	-28	-30	-32	-34	-36	-38	-40	-45	-50	-55	-60	°F
	0	40	38	36	34	32	30	28	26	24	22	20	18	16	14	12	10	8	6	4	2	0	-2	-4	-6	-8	-10	-12	-14	-16	-18	-20	-22	-24	-26	-28	-30	-32	-34	-36	-38	-40	-45	-50	-55	-60	0
	2	40	38	35	33	31	29	27	24	22	20	18	16	13	11	9	7	5	2	0	-2	-4	-6	-9	-11	-13	-15	-17	-20	-22	-24	-26	-28	-31	-33	-35	-37	-39	-42	-44	-46	-48	-54	-59	-65	-70	2
	4	37	35	33	30	28	26	23	21	19	17	14	12	10	7	5	3	0	-2	-4	-7	-9	-11	-14	-16	-18	-20	-23	-25	-27	-30	-32	-34	-37	-39	-41	-44	-46	-48	-50	-53	-55	-61	-67	-72	-78	4
	6	36	33	31	29	26	24	21	19	17	14	12	10	7	5	2	0	-2	-5	-7	-9	-12	-14	-17	-19	-21	-24	-26	-29	-31	-33	-36	-38	-40	-43	-45	-48	-50	-52	-55	-57	-60	-65	-71	-77	-83	6
	8	35	32	30	27	25	22	20	18	15	13	10	8	5	3	0	-2	-4	-7	-9	-12	-14	-17	-19	-21	-24	-26	-29	-31	-34	-36	-38	-41	-43	-46	-48	-51	-53	-56	-58	-60	-63	-69	-75	-81	-87	8
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	°F	40	38	36	34	32	30	28	26	24	22	20	18	16	14	12	10	8	6	4	2	0	-2	-4	-6	-8	-10	-12	-14	-16	-18	-20	-22	-24	-26	-28	-30	-32	-34	-36	-38	-40	-45	-50	-55	-60	°F

40°F to 21°F	COLD. Unpleasant
20°F to 1°F	VERY COLD. Very unpleasant.
0°F to -19°F	BITTER COLD. Frostbit possible. Exposed skin can freeze within 5 minutes
-20°F to -69°F	EXTREMELY COLD. Frostbite likely. Exposed skin can freeze within 1 minute. Outdoor activity become dangerous.
-70°F and lower	FRIGIDLY COLD. Exposed skin can freeze in 30 seconds.

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Examination & Staging

Superficial injury

- **1˚** Insensate central white plaque surrounded by ring of hyperemia
- **2˚** Clear/milky within 24 hours surrounded with erythema and edema

Deep Injury

- **3˚** Hemorrhagic blisters usually followed by eschar formation around 2 weeks post injury
- **4˚** Complete necrosis with visible tissue loss

Three phases of Treatment

- 1. Pre-thaw phase—field care
- 2. Re-warming phase—ED care
- 3. Post-Thaw phase—IP and OP care

Pre-thaw phase: Field Care

- Protect, Pad and splint
- DO NOT RUB
- Slow re-warming (not supported by literature)
- Do not attempt to thaw if refreezing is possible

Re-warming phase: ED care

- Rapid re-warming 98.6˚ – 102.2˚ F
  - Water temperature must remain constant
- Surgical antimicrobial agent in water bath
- 30-60 min until thaw complete
  - Red color, pliable skin
- Active movement of joint(s) helpful
- NO MASSAGE/ No PROM
- See Protocol

Reperfusion Medications

Strong recommendation

- Thrombolytics
  - tPA (tissue plasminogen activator)
    - Risk of bleeding
    - Use in conjunction with Heparin (usually)
- Vasodilators
  - Iloprost (synthetic prostacyclin)

Reperfusion Medications continued:

Weak Recommendation

- Low molecular weight dextran (LMWD)
- Ibuprofen
- Topical Aloe Vera

Re-warming Phase Goals

- Thaw tissue and halt direct cell damage
- Suppress local & systemic thromboxane production
- Provide adequate analgesia
- Prevent infection
- Maximize tissue retention

Post-thaw Phase: Wound Care

- To Debride or Not Debride
  - White or clear blisters = debride
    (supported by literature)
  - Hemorrhagic blisters = debated ???
    - Newer protocols suggest debridement of all blisters

Frostbite Wound Care Goals

- Promote optimal tissue circulation
- Control odor
- Prevent Infection
- Psychological Support
- Waiting game for amputation in severe cases
  - 22-45 days until clear demarcation
  - ANMC ortho average ~2 months

Standard Frostbite Wound Care

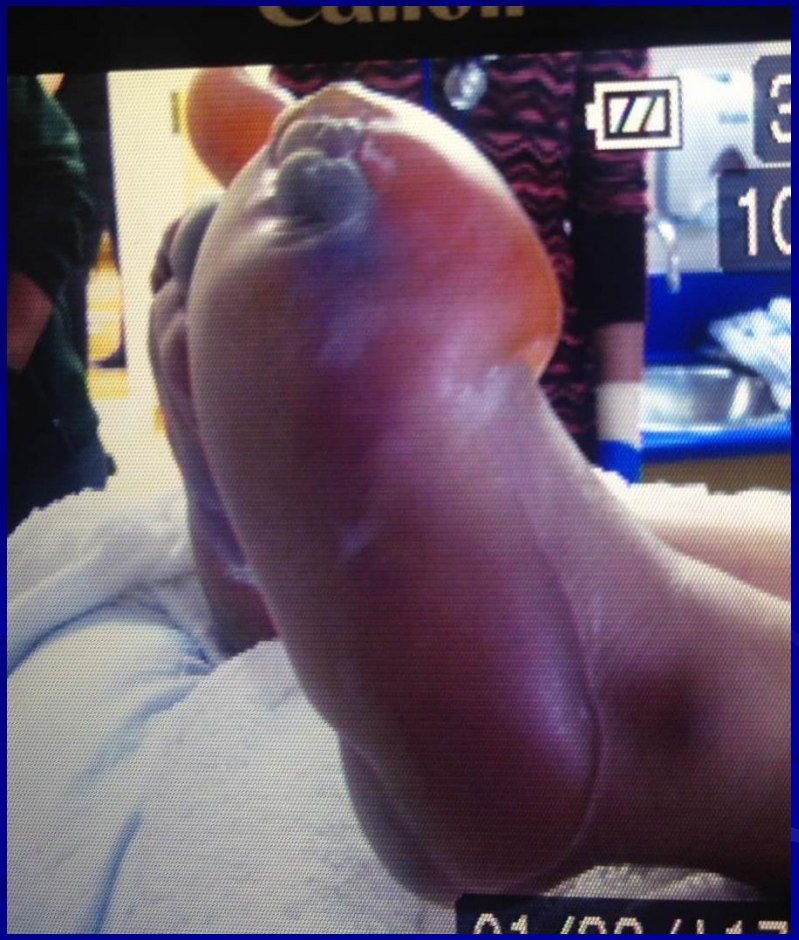
- Sharp debridement
  - Frequency
    - Daily if non-viable tissue present and if patient tolerates
- Whirlpool (2x/day first 72 hours; 1x/day after that)
- Topicals: Dermaide, Aloe Vera, Bacitrin or Saf-gel *
- Typical Dressings
  - Adaptic
  - Topical
  - Gauze & gauze rolls
- Patient Education
  - NO Nicotine
  - Protect injured area

Mobility???

- Ambulation/Functional mobility
  - Only if wound is not compromised
  - Decreased negative effects of immobility
  - Improved psychological well being

*Increased edema, exudate, or pain = no weight bearing

Patient One
Injury date: 1/22/17
Surgery: 3/28/17



Jan 27

Feb 3

Feb 15


I.D.
Date
2/21/17
MÖLNLYCKE HEALTH CARE


2/21/17
MÖLNLYCKE HEALTH CARE

Feb 21


2/21/17
MÖLNLYCKE HEALTH CARE


2/21/17
MÖLNLYCKE HEALTH CARE

Patient Two
Injury Date: 2/10/17
Surgery: 5/6, 5/8, 5/11, 5/15

Feb 15

Post-debridement
Feb 16

Feb 27

March 13

March 23

April 18

R transmetatarsal Amputation
L BKA

Patient Three
Date of Injury: 11/20
Ortho eval: 1/23/18

November 21

November 27th
Pre and Post Debridement

Dec 4th

Jan 18th

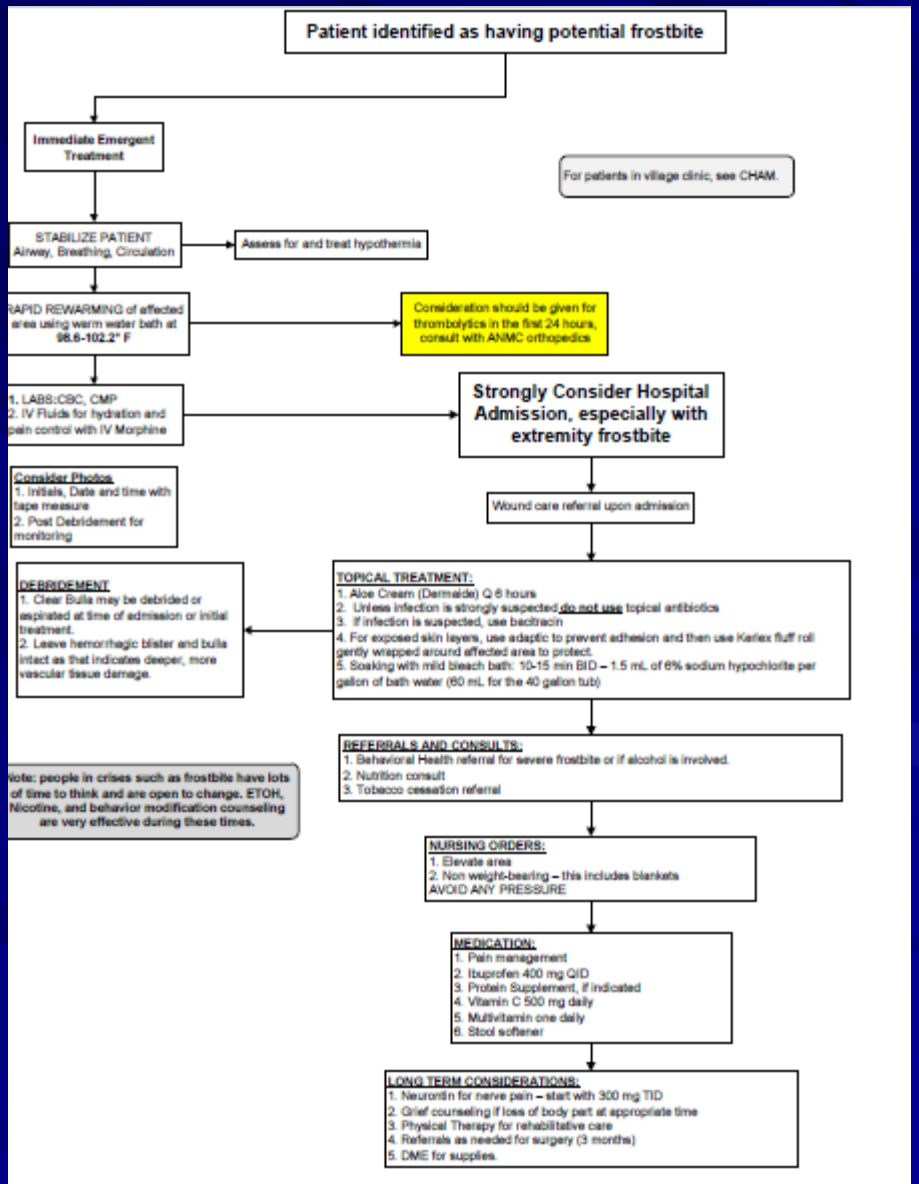
References

1. Wilderness Medical Society Practice Guidelines for the Prevention and Treatment of Frostbite. WILDERNESS & ENVIRONMENTAL MEDICINE, 22, 156–166 (2011).
2. Treatment of severe frostbite with Iloprost in Northern Canada. Whitehorse General Hospital. 2016.
3. The evolution of the Helsinki frostbite management protocol.Burns 43 (2017) 1455-1463.
4. Frostbite. Emerg Med Clin N Am 35 (2017) 281-299.

- Many more available upon request

Appendix 1

YKHC
2017



Appendix 1

Wilderness Medical Society Frostbite Protocol (2011)

Table 2. Summary of field treatment of frostbite (over 2 hrs from definitive care)

1. Treat hypothermia or serious trauma
2. Remove jewelry or other extraneous material from the body part
3. Rapidly rewarm in water heated and maintained between 37-39°C (98.6-102.2°F) until area becomes soft and pliable to the touch (approximately 30 minutes). Allow spontaneous/passive thawing if rapid rewarming is not possible
4. Ibuprofen (12 mg/kg per day divided twice daily) if available
5. Pain medication (eg, opiate) as needed
6. Air dry (ie, do not rub at any point)
7. Protect from refreezing and direct trauma
8. Apply topical aloe vera cream or gel if available
9. Dry, bulky dressings
10. Elevate the affected body part if possible
11. Systemic hydration
12. Avoid ambulation on thawed lower extremity (unless only distal toes are affected)

Table 3. Summary of initial hospital management of frostbite

1. Treat hypothermia or serious trauma
2. Rapidly rewarm in water heated and maintained between 37-39°C (98.6-102.2°F) until area becomes soft and pliable to the touch (approximately 30 minutes)
3. Ibuprofen (12 mg/kg per day divided twice daily)
4. Pain medication (eg, opiate) as needed
5. Tetanus prophylaxis
6. Air dry (ie, do not rub at any point)
7. Debridement: selectively drain (eg, by needle aspiration) clear blisters and leave hemorrhagic blisters intact
8. Topical aloe vera every 6 hrs with dressing changes
9. Dry, bulky dressings
10. Elevate the affected body part if possible
11. Systemic hydration
12. Thrombolytic therapy: consider for deep frostbite with potential significant morbidity if less than 24 hours after thawing; use angiography for pre-thrombolytic intervention and monitoring of progress
13. Clinical examination (plus angiography and/or technetium-99 bone scan if necessary) to assist determination of surgical margins
14. Evaluation by an experienced surgeon for possible intervention

Appendix 2

Whitehorse General Hospital Protocol (2016)

Box 2: Summary of the Whitehorse General Hospital (Yukon Hospital Corporation) frostbite protocol*

- Surgical consultation
- Rapid rewarming of the affected digits in hot water (39°C) with chlorhexidine and isopropyl alcohol
- Immersion of affected parts in hot water (39°C) in a hydrotherapy whirlpool daily (starting the day after rewarming)
- Débridement and aspiration of clear blisters
- Application of aloe vera protective ointment and porous low-adherent wound dressings
- Elevation of affected parts
- Avoidance of tobacco and alcohol
- Tetanus–diphtheria immunization
- Oral ibuprofen every 6 hours

For grade 3 or higher frostbite:

- Intravenous infusion of iloprost 2 ng/kg per min, 6 h/d, for 5 days

For grade 4 frostbite:

- After administration of iloprost, concurrent intravenous infusion of alteplase (for one day; weight-based dosage, progressively increased to a maximum total dose of 100 mg) and heparin (for 72 hours; dosage based on weight and prothrombin time)

*The complete protocol and dosing information are available in Appendix 1 (www.cmaj.ca/lookup/suppl/doi:10.1503/cmaj.151252/-/DC1).