EXTREME ENVIRONMENTS: COLD MEDICINE GUIDE



WORLD EXTREME MEDICINE
PUSHING BOUNDARIES

CONTENTS

Cold Medicine

Heat Loss

Risk Factors for Cold Injury

Hypothermia Management

Other Cold Related Conditions

Cold Water Immersion

Freezing Cold Injuries Treatment

Cold Medicine Courses

References



WELCOME

Welcome to our e-book on preventing and treating cold illnesses and injuries in extreme environments. As physicians, explorers, and outdoor enthusiasts operating in harsh cold conditions, we need specialised knowledge to avoid and respond to unique medical risks.

In this comprehensive guide we will equip you with advanced insights on:

- Sources of dangerous heat loss in extreme cold and risk factors for injuries.
- Progression, field management, and treatment of cold injuries under extreme conditions.
- Improvised rewarming methods.
- Coverage of cold water immersion, frostbite and non-freezing cold injuries.

Our aim is to provide you with practical know-how to avoid risks and respond decisively when cold threatens health or lives.

Let's begin building your extreme cold medicine skills...



COLD MEDICINE

Maintenance of core temperature is essential for organs to operate proficiently on a cellular level. In an ambient air temperature window of 20°C to 25°C, an otherwise healthy, unclothed individual is able to easily maintain a core temperature of approximately 37°C without expending additional energy.[1] In more extreme non-thermoneutral environments, human can thermoregulate within certain parameters (approximately 12°C - 54°C) for variable periods. These time periods can be extended through equipment and clothing (down jackets, shelter, heat-generating devices).[2]

HEAT LOSS

Heat loss occurs through 5 mechanisms;[3]

1. Radiation (heat loss to the surrounding environment)
2. Convection (loss to wind chill)
3. Conduction (direct contact with objects such as metal)
4. Evaporation (heat loss through perspiration and wet kit)
5. Respiration (heat and vapour loss when breathing)

A high risk environment is one that exposes humans to low ambient air temperature, high winds, or altitude (air temperature decreases by approximately 6.5°C every 1000 metres height gain).[4]

To counterbalance heat loss the body evokes two responses;

1. Peripheral vasoconstriction to inhibit heat loss, and
2. Shivering to replace lost heat through thermogenesis. [5]

If heat loss exceeds heat retention cold injury may occur.

WHOLE BODY COOLING (HYPOTHERMIA)

Occurs when the core temperature drops below approximately 35°C.

PART BODY COOLING (FREEZING COLD & NON-FREEZING COLD INJURY)

Mainly impacts the peripherals.

FREEZING COLD INJURY (FCI)

Includes Frostnip and Frostbite and is defined as damage sustained by tissue exposed to temperatures below their freezing point (-0.55°C).

NON-FREEZING COLD INJURY (NFCI)

Includes Chilblains and Trench Foot, is defined as tissue exposed to low temperatures between 0°C - 15°C for hours or days. [6] [7]

RISK FACTORS FOR COLD INJURY [8]

ENVIRONMENTAL FACTORS:

- Low ambient air temperature, high wind chill, damp or inadequate clothing [9]
- Static casualty (i.e. injured and unable to move, not generating body heat)

PATIENT FACTORS:

- Poor nutrition
- Dehydration
- Alcohol
- Medical conditions (i.e. Raynauds)

Treatment of cold injury may be delayed due to the nature of an expedition, environment, activity or participant.

EXAMPLE CASE

During the 2022 Winter Olympics, the men's 50km mass start cross country race was shortened to 30km due to the still air temperature of -25°C (-32°C with wind chill). In spite of this mitigation measure the athlete placing 28th suffered frostbite to his penis. He had suffered the same injury in a previous race and was therefore more susceptible to re-injury.



HYPOTHERMIA

Arbitrarily defined as a drop in core temperature of at least 2°C (or below 35 °C) [10], hypothermia can be both the presenting problem and also a complicating factor in other conditions such as trauma in a wilderness setting. In mild hypothermia, shivering is a key mechanism that raises core temperature. However, as hypothermia deepens, mechanisms for thermogenesis start to fail. Once overwhelmed, patients will ultimately assume the temperature of their surroundings, unless they are treated promptly.

There are two main scoring systems in widespread use that commonly result in confusion. The Swiss method categorises hypothermia in stages 1 – 5, whereas the WMS system prefers mild/mod/severe/profound. Whilst the core temperature ranges correspond between system the clinical features at each stage do not.

CORE TEMP°C	Swiss System [9]	WMS System
35 - 32	Stage 1	Mild
32 - 28	Stage 2	Moderate
<28	Stage 3	Severe/Profound
<13.7	Stage 4	

DIAGNOSIS IN THE FIELD

Behaviour is a key early indicator of hypothermia in a pre-hospital setting. The well described behavioural changes below are colloquially referred to as the 5 ‘umbles’: [11]

GRUMBLES	change in behaviour, negative attitude and complaints.
FUMBLES	Reduced fine motor skills, difficulty operating buttons/zips due to cold peripheries.
MUMBLES	quiet, slowed or slurred speech
STUMBLES	Off balance, falling behind, tripping over.
CRUMBLES	Implies moderate to severe hypothermia – disorientation, patient combative, reduced conscious level or in rare cases paradoxical undressing.

Whilst the stages of hypothermia are commonly classified according to the fall in core body temperature, this is more applicable to the worlds of research and hospital treatment than wilderness environments as it is not an easy thing to measure. Tympanic, oral or axillary thermometers are do not measure core temperature. This requires a specialist low reading rectal thermometer which are rarely carried on expeditions. In clinical practice a pragmatic broad-brush classification is as follows, incorporating elements from both the Swiss and WMS systems: [12]

Cold stressed but not hypothermic = Shivering but normal function.

Mild = Shivering but mentally alert with impaired function and movement. May be Dysarthric, ataxic, tachycardic.

Moderate = reduced movements and reduced shivering. Bradycardic, hypotensive.

Severe = reduced conscious level, not shivering, not moving. Profoundly deranged vital signs.

NB if a casualty is found cold and unconscious then assume severe hypothermia until proven otherwise.

A note on clinical categorisation:

- Musi et al (2021) argue that shivering should not be a ‘stage defining’ sign in hypothermia[i]
- They propose a modified Swiss system that attaches more importance to the AVPU (conscious level) as follows:

o Stage 1 hypothermia -Alert
o Stage 2 hypothermia – Responds to Voice
o Stage 3 hypothermia – Responds ot Pain
o Stage 4 hypothermia – Unresponsive

In the absence of a rectal thermometer, there is no definitive clinical gold standard for categorising hypothermia.

HYPOTHERMIA MANAGEMENT [13]

COLD STRESS OR AT RISK OF HYPOTHERMIA

Mentally alert and shivering = mild hypothermia

- Layer up
- Swap out wet layers for dry ones
- Get under shelter (such as a Bothy bag) to warm up)
- Get moving – exercise generates heat

MILD HYPOTHERMIA

- Remove from the cold environment
- Add a vapour barrier
- Consider the Burrito wrap technique (see section below)
- Insulate from the ground (roll mats, rucksacks)

Other steps:

- Sugar – refuel that ‘inner furnace’ of thermogenesis
- Warm drink, hydrate – due to cold diuresis (see section below) patients are often dehydrated
- Reassess after 30 minutes. If worsening or no improvement, consider early evacuation

Avoid:

- Alcohol = vasodilator
- Caffeine = Diuretic
- Nicotine = Vasoconstrictor

Leave wet clothes on or remove them?

- Expert consensus is to removed clothes if a warm shelter is more than 30 minutes away (anticipating more prolonged field care).
- If warm shelter is less than 30 minutes away then leave wet clothes on, wrap the patient up, scoop and run.

Body-to-body rewarming:

- The rescuer uses their own body heat for active rewarming of the casualty by lying next to them
- Can be used to increase patient comfort in mild hypothermia BUT there is evidence to show that it can blunt thermogenesis from the shivering response which may paradoxically slow rewarming.
- This must not delay evacuation

Passive vs active rewarming:

- Passive rewarming is reducing further heat loss and allowing the body's own mechanisms for thermogenesis to generate heat.
- Active rewarming is the application of heat and can be external (heat packs) or internal (warm IV fluids).
- Traditionally, in the literature, passive rewarming is the preferred treatment method for mild hypothermia whilst moderate and severe hypothermia normal necessitate additional active methods.
- In clinical practice it may not be this clear cut. Consider active rewarming in mild hypothermia patients who are more vulnerable (elderly, medical co-morbidities, trauma) or are at risk of deterioration (see the section on 'afterdrop' below).

MODERATE HYPOTHERMIA

- Passive rewarming steps as per mild hypothermia BUT ALSO
- Keep horizontal (vertical orientation can lead to cardiovascular collapse).
- Do not give drink or food.

Additional active external rewarming

- Provide heat to upper trunk
- Bear hugger
- Heat packs or hot water bottles (apply to chest/axillae)
- Lamps
- Consider volume replacement with warm IV fluid (40-42degC)
- Intensive, continuous monitoring
- Plan evacuation

A note on warm showers or baths for rewarming:

- The 2019 WMS guidance advises against this even in mild hypothermia, due to the risk of increasing peripheral blood flow and hypotension, increasing the risk of cardiovascular collapse and increased risk of afterdrop (see section below).

SEVERE HYPOTHERMIA

General Measures:

- Aggressive passive and active rewarming as above
- Supplemental oxygen
- Early IV access (remember, this may be challenging in a shut-down patient)
- Continuous monitoring of pulse, sats, BP, urine output (catheterise).
- Consider advanced airway (RSI) plus NG tube if resources/skills allow.
- ECG if able. (Look for slow AF and J waves)
- Evacuate promptly and carefully

Advanced Active Core Rewarming:

- Warm IV Fluids and Oxygen (44°C)
- Cavity lavage (reserved for cardiac arrest, frozen limb or failed conservative)
- ECMO. Assess suitability in secondary care settings using the HOPE (Hypothermia Outcome Prediction after Extracorporeal Life support) Score

Advanced Life Support:

- Prolonged 1 minute pulse and respiratory effort check (instead of 10 seconds). If in doubt, start CPR.
- CPR can be considered futile if the chest is non-compressible (due to frozen tissues) or prolonged avalanche burial with snow in airways.
- Consider mechanical chest compression to overcome chest wall stiffness, particularly if limited personnel available to provide continuous CPR during transfer (such as a LUCAS 3 or Michigan device).
- Use a low reading thermometer for core temperature monitoring. Consider an oesophageal device for intubated patients.
- If patient remains in VF after 3 shocks, delay any further shocks until core temperature has risen >30°C
- Wait until temp >30°C before administering adrenaline. In the temperature range 30-34°C, administer adrenaline less frequently (every 6-10 minutes instead of every 3-5 minutes)
- Chest compressions may convert PEA to VF during CPR.
- Do not treat hypothermia induced bradycardia with atropine [20].

Patients with hypothermia are not dead until they are warm and dead.

Patients may appear dead: Pulseless at radials, HR = 3, RR = 1, Pupils dilated, no corneal reflex. However, Oxygen consumption is significantly reduced and hypothermia is neuroprotective. There are numerous case reports of extreme survival, including a case of neurologically intact survival 2 year old boy presenting with a core body temperature of 11.8 °C[14].



THE ‘BURRITO’ WRAP

This is a technique we teach on our Expedition & Wilderness Medicine and Polar Medicine courses. It is a layering and wrapping method that optimizes rewarming in a wilderness setting. The layers include (working inside to out) a plastic or foil wrap, a hooded sleeping bag, a sleeping pad and finally a tarpaulin, leaving only the patients face exposed. In this method there are two vapour barriers, one directly against the patient and the other on the outside with the insulation layers sandwiched in between.

PITFALLS TO AVOID

1.Ventricular arrythmias and **VF arrest can be triggered by patient movement**. It is important to handle unconscious and not shivering patients with care. Handle like porcelain. Any action that increases cooler peripheral blood returning to the heart can lead to cardiac stress and myocardial irritability leading to arrythmias.

2. **Afterdrop:** This refers to a continued drop in core temperature that continues after treatment for hypothermia is started. It is linked to conductive heat loss into cooler peripheral tissues. Be wary of early patient deterioration including blood pressure collapse on rewarming and monitor carefully for signs of improvement.

3. **Cold diuresis:** Cold temperatures can result in urine overproduction (diuresis) to offset the raised blood pressure from the shunting of blood from peripheral to central circulation. This increases a patients fluid requirements and risk of dehydration, hypovolaemia and shock.

4. Tympanic, axillary, sublingual and forehead **thermometers are not useful for an accurate diagnosis of hypothermia** but they may be used as an adjunct to other clinical features in monitoring response to treatment.

5. Always **check glucose levels** as part of assessment and correct if needed. (Oral glucose for conscious patients, IV glucose for unconscious).

6. Consider **wider rescuer and group safety**. Avoid becoming too task focused on managing one casualty when other members of your party may also be at risk.

7. Hypothermia in the context of significant **trauma and/or hypovolaemia** is a particularly challenging scenario, hugely increasing the risk of rapid deterioration and poor outcomes.

8. **Avoid burning patients** with heat packs or hot water bottles, particularly if these are buried within a burrito wrap – protect the skin with extra layers of material.

9. Patients with moderate to severe hypothermia commonly **also have frostbite** or other cold injuries. Always treat the hypothermia first.

Interesting fact: The 'hunting reaction' (or hunting response) is an evolutionary adaptation in which the body periodically vasodilates (every 5-10 mins) and constricts hands & feet to balance hypothermia & cold injury.[i] Subjects who work or are acclimatized to cold environments have been found to have a stronger response. [15]

OTHER COLD RELATED CONDITIONS

FROSTBITE

Hypothermia and frostbite often co-present. Moderate to severe hypothermia should be addressed first. Thereafter, the medical professional must make a decision to rewarm and thaw or leave the affected body part frozen. If there is a risk of refreezing after thawing, then it is generally considered better to delay rewarming. The severity of frostbite is determined by a 2-tier system; superficial (1st and 2nd degree) or deep (3rd or 4th degree). [16] Frostbite presents as numb & pale skin with a woody appearance (covering socks or gloves may themselves be frozen). Large areas may go purple from blood sludging. [17]

NON-FREEZING COLD INJURY (NFCI)

Chilblains are localised legions presenting mainly in susceptible individuals (e.g Raynauds) after prolonged exposure to cold then heat (e.g cold feet on hot radiator). [18] Trench foot is caused by sustained cold and non-freezing cold conditions (e.g skiing in damp socks). [19]

POLAR THIGH

Appears to present in polar regions due to mechanical abrasion coupled with cold and/or wind chill conditions. It most commonly presents on the anterior thigh but has also been reported on the medial/posterior thigh. [20]

IATROGENIC HYPOTHERMIA

Awareness of the cold environment is paramount when treating a casualty for other unrelated injuries or illness. Inflicting accidental hypothermia needs to be avoided. Beware of the risk of evolving hypothermia in the wider group once you are all standing still and no longer moving, this includes yourself.

A NOTE ON PEOPLE WITH AMPUTATIONS

Several polar expeditions have been undertaken by ex-military amputees in the past decade. A lack of sensation in the amputated area appears to inhibit acknowledgement of cold injury. Research around stump injury diagnosis and management is limited.

COLD WATER IMMERSION

WEM Conference Speaker Gordon Giesbrecht coined the 1-10-1 rule which describes the three phases of cold water immersion. Whilst widely used, please note this is conceptual only and has been criticized by some for a lack of scientific rigor. [21]

A casualty has :

1 MINUTE	to control their breathing – gasp response followed by hyperventilation causes aspiration and drowning.
10 MINUTES	to self rescue – either swim to shore or climb on top of the ice before the casualty loses effective use of their arms, legs and fingers and becomes incapacitated.
1 HOUR	before falling unconscious from hypothermia.

A flotation device (life jacket, PFD) improves survival at every stage and is a key component of water safety and prevention.

NON FREEZING COLD INJURIES

MANAGEMENT

- Warm slowly / passively (may get very painful, swollen & red)
- Amitryptilline 50mg to help night pain
- Evacuate (don’t walk on a NFCI - more likely to damage tissue not frozen solid) and don’t rub.

PREVENTION

- Periodic removal from cold and wet into dry and warm (sock changes). Beware vapor barrier footwear trapping moisture.
- Toe wiggling to maintain circulation.
- Loose boots.

FREEZING COLD INJURIES

FROST NIP MANAGEMENT

10 min re-warm in an armpit, groin or palm of hand, don't rub. Don't need to evacuate if a first episode. Clothing & Weather check. If sensation does not return in 30 mins, treat as frostbite. Prognosis: Resolves completely.

FROSTBITE MANAGEMENT

- Protect from cold and start hypothermia treatment first, hydrate
- Evacuate (can walk on frozen foot to evacuate if desperate).
- Only warm once certain can avoid re-freezing. Use a water bath and warm fast (42°C). Fire is too erratic as heat source.
- Once re-warmed, cannot use limb, don't put any pressure on the tissues (handle like porcelain and don't rub.)
- Loosely bandage with non-stick dressing (especially between fingers).
- Avoid bursting blisters
- Give oxygen if >4000m
- Start Aspirin 75mg OD, Ibuprofen 400mg TDS (Inhibit Plt & PG toxins)
- Analgesia for pain (IV if possible – or strongest alternative)
- Give Abx if suspicion of infection
- Tetanus booster if required
- DELAY AMPUTATION
- Staging & prognostication of frostbite is difficult in the field
- Evacuate to specialist center for angiography & Iloprost (PGI2) infusion
- <24h but even 5 days delay can still be worth it!
- Hyperbaric 02 may also be useful & Thrombolysis
- Take daily photos
- Email chrisimray@aol.com BMC Frostbite Advisory Service

OTHER CONSIDERATIONS

- Eyelids frozen shut (Cover with a hand until thaws and re-open eye)
- Cornea frozen (Cover with a hand until thaws and cover for 48h - Evacuate – risk for wind or arctic marathon runner)
- Polar thigh & polar penis (Evacuate)

THANK YOU FOR READING

Now that we have provided a concise overview of the signs, symptoms, and treatments associated with cold medicine, it's time for you to delve into the practical learning opportunities that will empower medical professionals and aspiring adventurers to excel in such challenging environments.

You can join us for practical cold medicine learning at the following courses:



ALPINE MEDICINE, CHAMONIX

FULL DETAILS



ALPINE MEDICINE, SLOVENIA

FULL DETAILS



POLAR MEDICINE, NORWAY

FULL DETAILS



WINTER MEDICINE, USA

FULL DETAILS

QUESTIONS? COMMENTS?

CONTACT US

WORLDEXTREMEMEDICINE.COM

OPERATIONS@EXTREME-MEDICINE.COM

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