

# Accidental Hypothermia and intermittent CPR

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# Pathophysiology Diagnosis Therapy

# Defintion

Accidental hypothermia core temperature  
unintentionally  $<35^{\circ}$  C ( $95^{\circ}$  F)

Brown D, et al. *N Engl J Med*. 2012 Nov 15;367(20):1930-8. doi: 10.1056/NEJMra1114208.

Hislop LJ, et al. *BMJ* 1995, 311, 725.

Darocha T, et al. *J Cardiothorac Vasc Anesth* 2019 in press, <https://doi.org/10.1053/j.jvca.2019.07.152>





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<https://humanorigins.si.edu/evidence/human-fossils/species/homo-sapiens>



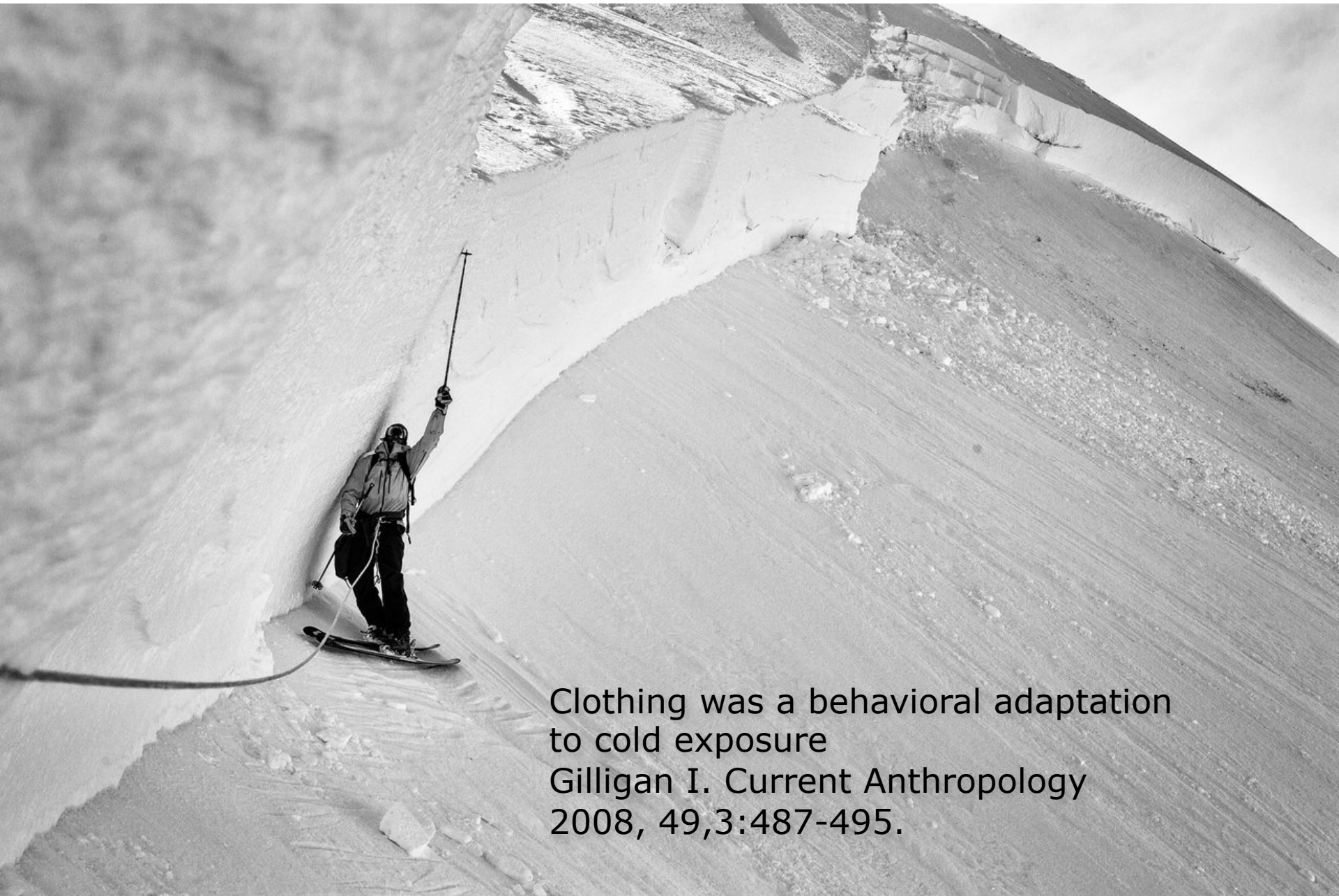
# Cheddar Man



10.000 BC

<http://www.independent.co.uk>





Clothing was a behavioral adaptation  
to cold exposure  
Gilligan I. Current Anthropology  
2008, 49,3:487-495.



# Lowest AH core temperature

- 2-year-old boy
- Lowest core temperature 11.8° C
- Unwitnessed asystolic cardiac arrest
- CPR 135min
- 22hrs ECMO
- At hospital discharge CPC 1
- No mental impairment after five years

# Longest submersion

- 2.5-year-old, submersion in cold water for at least **66 min**, **19° C**, **ECLS** rewarming, **full recovery**

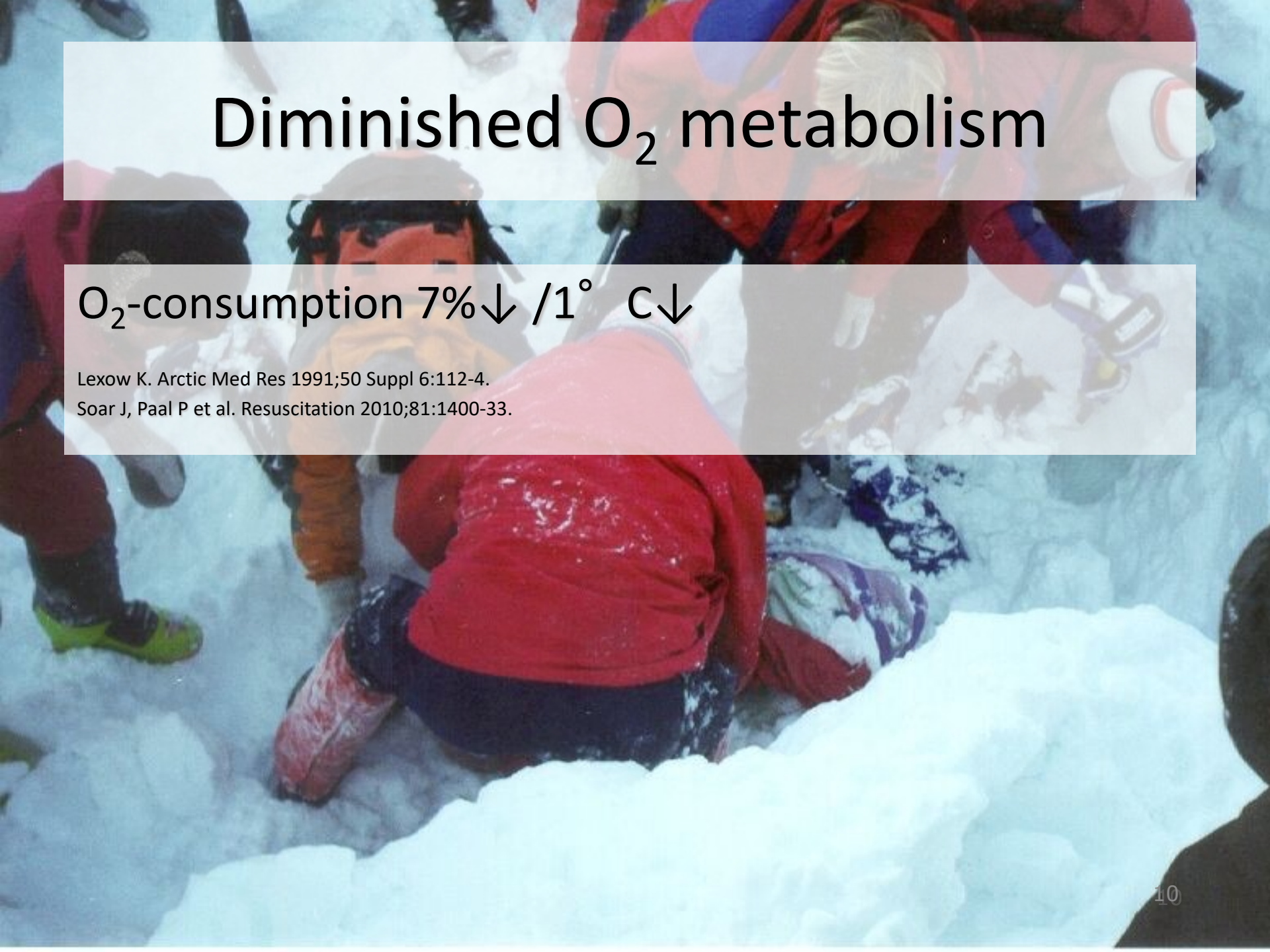
Bolte RG, et al. JAMA 1988;260(3):377–9

- 7-year-old child, submersion in icy water for at least **83 min**, CPR for 64 min, **13.8° C**, **K<sup>+</sup> 11.3 mmol L<sup>-1</sup>**, **ECLS** rewarming, **full recovery**

Romlin BS, et al. Crit Care Med 2015;43:e521–5.



# Diminished O<sub>2</sub> metabolism



O<sub>2</sub>-consumption 7%↓ /1° C↓

Lexow K. Arctic Med Res 1991;50 Suppl 6:112-4.

Soar J, Paal P et al. Resuscitation 2010;81:1400-33.

# Hypothermic cardiac arrest can be survived exceptionally long

Severe accidental hypothermia: survival after 6 hours 30 minutes of cardiopulmonary resuscitation.

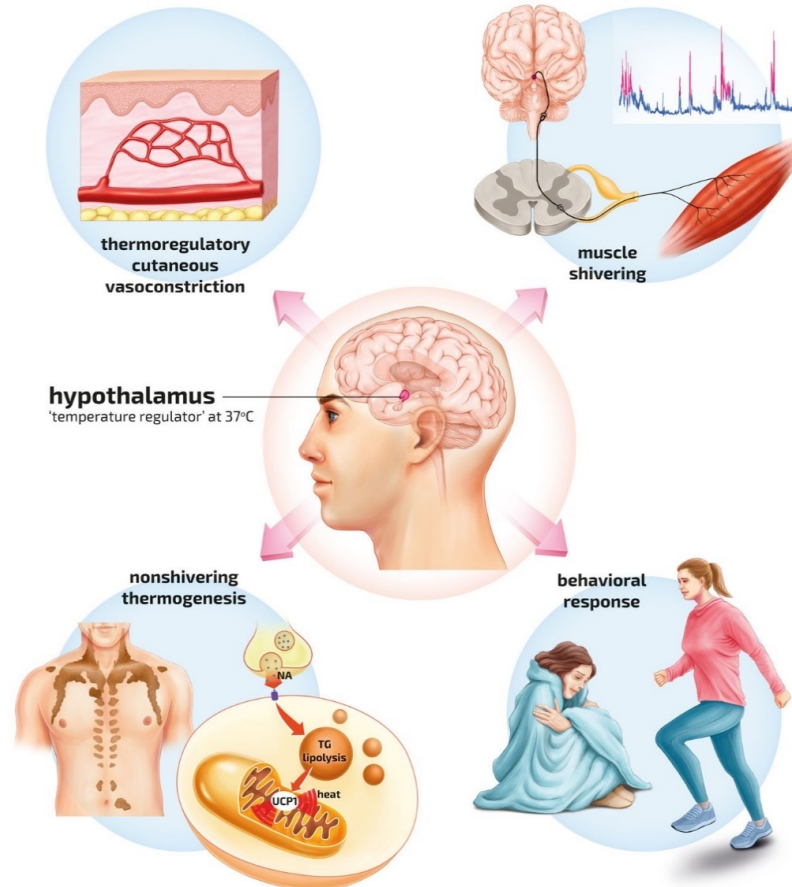
Lexow K. Arctic Med Res 1991;  
50 Suppl 6:112-4.

**Hypothermia before  
Hypoxia**





# Thermoregulation



Paal P, et al. IJERPH 2021, in press.

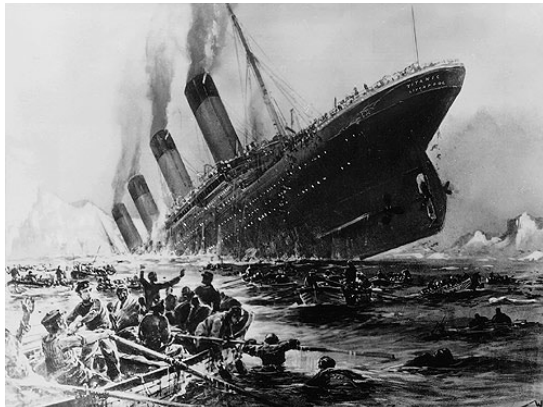
# Acute hypothermia

## Setting

- Hypothermia induced cardiac arrest

## Pathophysiology

- Water immersion/snow burial
- Cold overwhelms heat production
- Cooling before glucose depletion → catecholamines/corticosteroids grossly stimulated, CPR
- **Glucose level supranormal**



Beiser DG et al. Resuscitation. 2009 Jun;80(6):624-30.  
van den Berghe G et al. N Engl J Med. 2001 Nov 8;345(19):1359-67.  
Skrifvars MB et al. Resuscitation. 2003 Dec;59(3):319-28.



# Subacute hypothermia

## Setting

- Exhaustion, exposure to moderate cold
- Immersion in relatively warm water

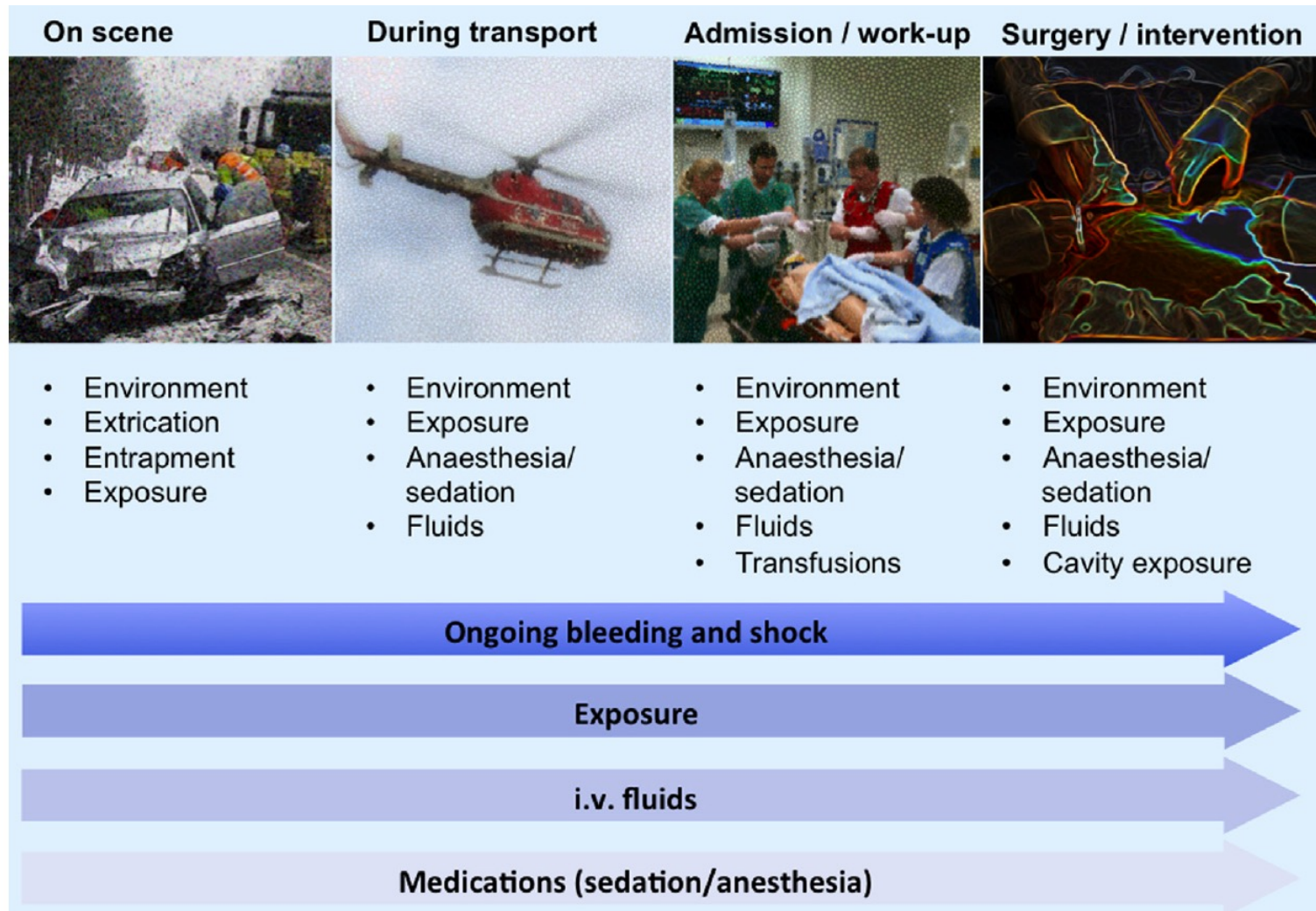
## Pathophysiology

- Moderate cold
- Cooling when glucose is depleted
- No spontaneous rewarming
- **Glucose level low**



Young A et al. Appl Physiol Nutr Metab 2007 Aug;32(4):793-8.

# Involuntary cooling



# Staging hypothermia

Stage	Clinical Findings	Core temperature (°C) (if available)
<b>Hypothermia I (mild)</b>	Conscious, shivering*	35-32°C
<b>Hypothermia II (moderate)</b>	Impaired consciousness*; may or may not be shivering	<32-28°C
<b>Hypothermia III (severe)</b>	Unconscious*; vital signs present	<28°C
<b>Hypothermia IV (severe)</b>	Apparent death; Vital signs absent	Variable**

Adapted from Paal 2016.

\*Shivering or consciousness may be impaired by comorbid illness (e.g. trauma, brain disorders, toxins) or drugs (e.g. sedatives, opioids, muscle relaxants) independent of core temperature.

\*\*Cardiac arrest can occur at earlier or later stages of hypothermia and some patients may still have vital signs at <24 °C



# Revised Swiss Staging

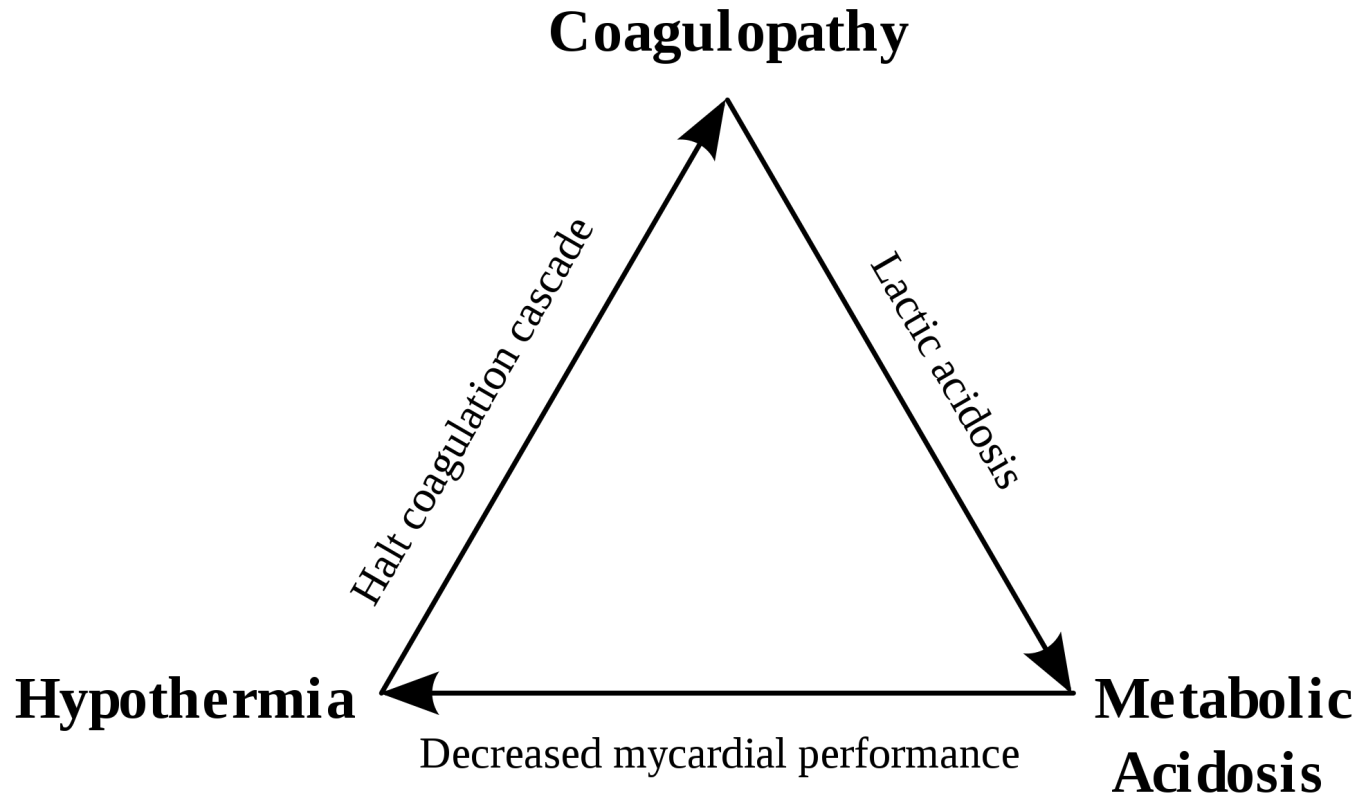
	Stage 1	Stage 2	Stage 3	Stage 4
<b>Clinical findings<sup>1</sup></b>	“Alert” from AVPU	“Verbal” from AVPU	“Painful” or “Unconscious” from AVPU Vital signs present	“Unconscious” from AVPU <b>AND</b> No detectable vital signs <sup>2</sup>
<b>Risk of cardiac arrest<sup>3</sup></b>	<b>Low</b>	<b>Moderate</b>	<b>High</b>	<b>Hypothermic cardiac arrest</b>
<b>Oxygen</b>	According to good clinical practice, (goal: SpO <sub>2</sub> > 94%) <sup>4</sup>			
<b>Carbohydrats</b>	Warm sweet tea, sweet bars	Glucose i.v. / i.o. <sup>5</sup>	Glucose i.v. / i.o. <sup>5</sup>	-
<b>Active movement</b>	+	- <sup>6</sup>	-	-
<b>Passive rewarming</b>	+	+	+	+
<b>Active rewarming</b>	(+)	+	+	+
<b>Cautious mobilization / horizontal transport if possible</b>	-	+	+	-
<b>Defibrillation pads</b>		+	+	+
<b>Intubation</b>			to be considered	+
<b>Hypothermia CPR</b>				+
<b>Defibrillation</b>				+ <sup>7</sup>

# THE RESCUE DEATH



CARDIAC / RESPIRATORY ARREST  
DURING REMOVAL AND TRANSPORT

# Deadly triad in trauma





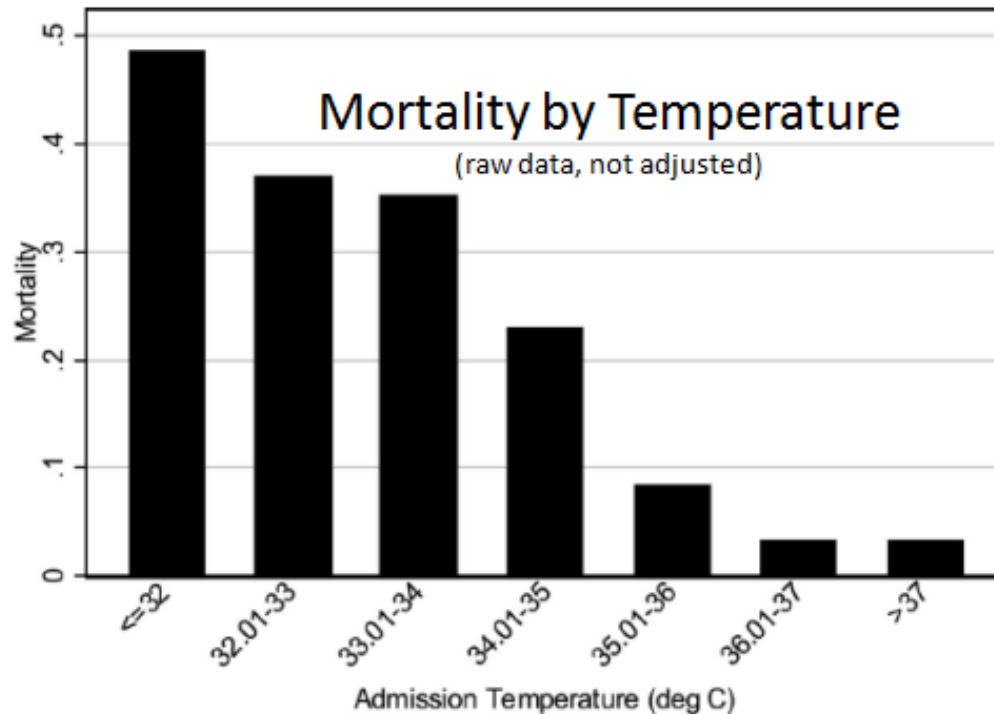
# Blood loss

1° C cooling

- intraoperative bleeding 10-15%↑
- packed red blood cells transfusion 12%↑

Rajagopalan S et al. Anesthesiology 2008;108(1):71-7.

# Admission hypothermia and outcome after major trauma



**Adjusted Odds of Death: 2.4** (all comers)  
temperature  $< 35^{\circ}\text{C}$   
adjusted for: age, ISS, mechanism

**1.5** (isolated head injury)




REVIEW

Open Access

# Multiple trauma management in mountain environments - a scoping review



Evidence based guidelines of the International Commission for Mountain Emergency Medicine (ICAR MedCom). Intended for physicians and other advanced life support personnel

G. Sumann<sup>1</sup>, D. Moens<sup>2</sup>, B. Brink<sup>3</sup>, M. Brodmann Maeder<sup>4</sup>, M. Greene<sup>5</sup>, M. Jacob<sup>6</sup>, P. Koirala<sup>7</sup>, K. Zafren<sup>8,9</sup>, M. Ayala<sup>10</sup>, M. Musi<sup>11</sup>, K. Oshiro<sup>12</sup>, A. Sheets<sup>13</sup>, G. Strapazon<sup>14,15</sup>, D. Macias<sup>16</sup> and P. Paal<sup>17\*</sup> 



# Pre-hospital therapy



Splinting and immobilization → bleeding ↓

Ellerton J, Paal P et al. High Alt Med Biol. 2009 Winter;10(4):337-42.

## Insulation and heating

- Avoid wind and wetness
- Warming pack
- Warm transport vehicle





## No faster rewarming with large chemical heat pads

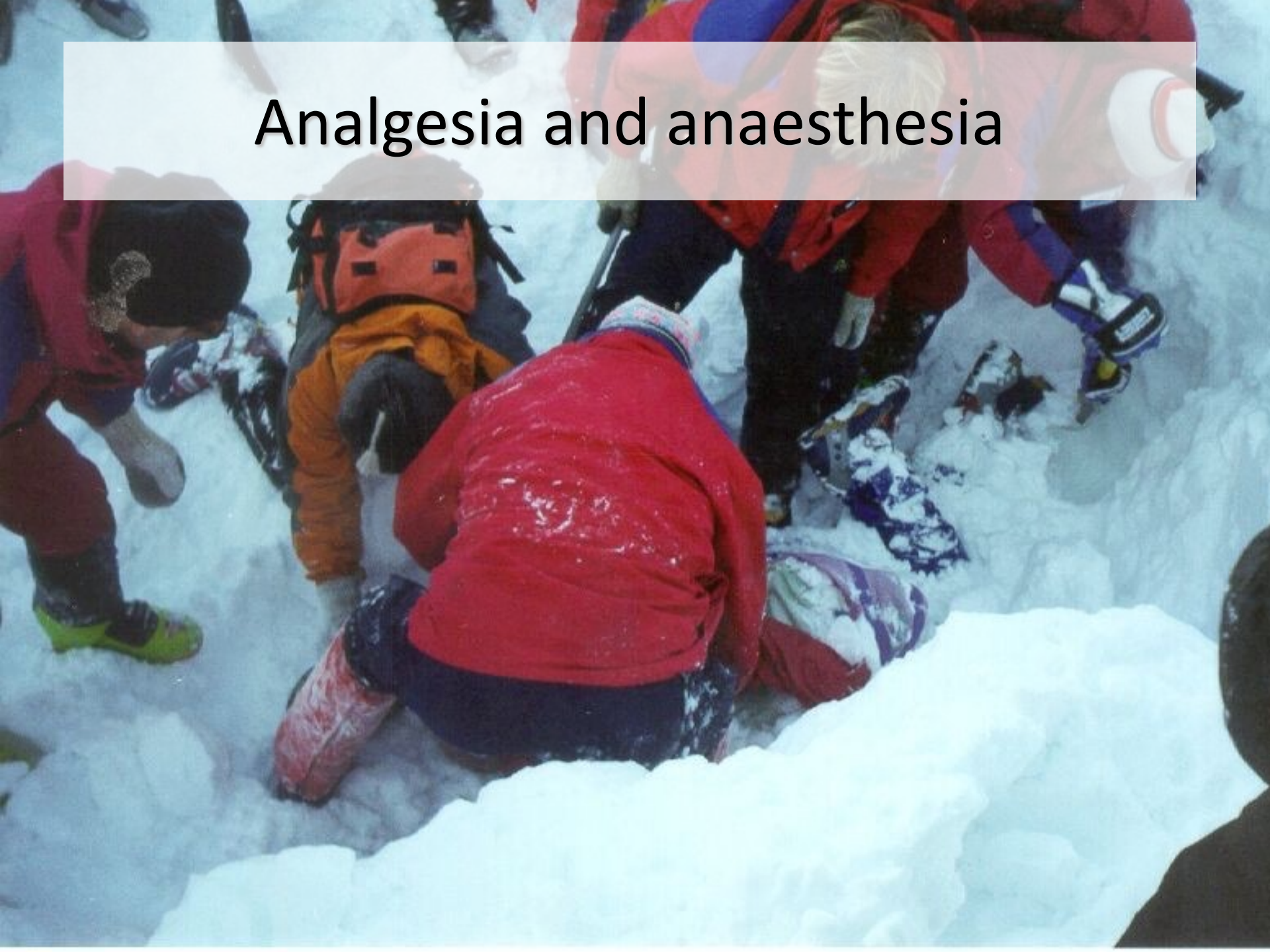
Lundgren P, Henriksson O, Naredi P, Björnstig U. Scand J Trauma Resusc Emerg Med. 2011 Oct 21;19:59.

## No difference whether wet clothes are removed or waterproof vapour barrier is provided

Henriksson O, Lundgren P, Kuklane K, Holmér I, Naredi P, Björnstig U. Prehosp Disaster Med 2012 Feb;27(1):53-8.



# Analgesia and anaesthesia





# Analgesia decreases thermoregulation

Analgesia & anaesthesia → vasodilatation & thermoregulation ↓

Ketamine may be the least detrimental analgesic

Marland S, et al. CNS Neurosci Ther. 2013 Jun;19(6):381-9. doi: 10.1111/cns.12072.

Methoxyflurane, fentanyl lozenges

Prehosp Emerg Care. 2023;27(8):987-992. doi: 10.1080/10903127.2022.2107125. Epub 2022 Aug 12..



# Accidental Hypothermia Clinical Practice Guideline for British Columbia

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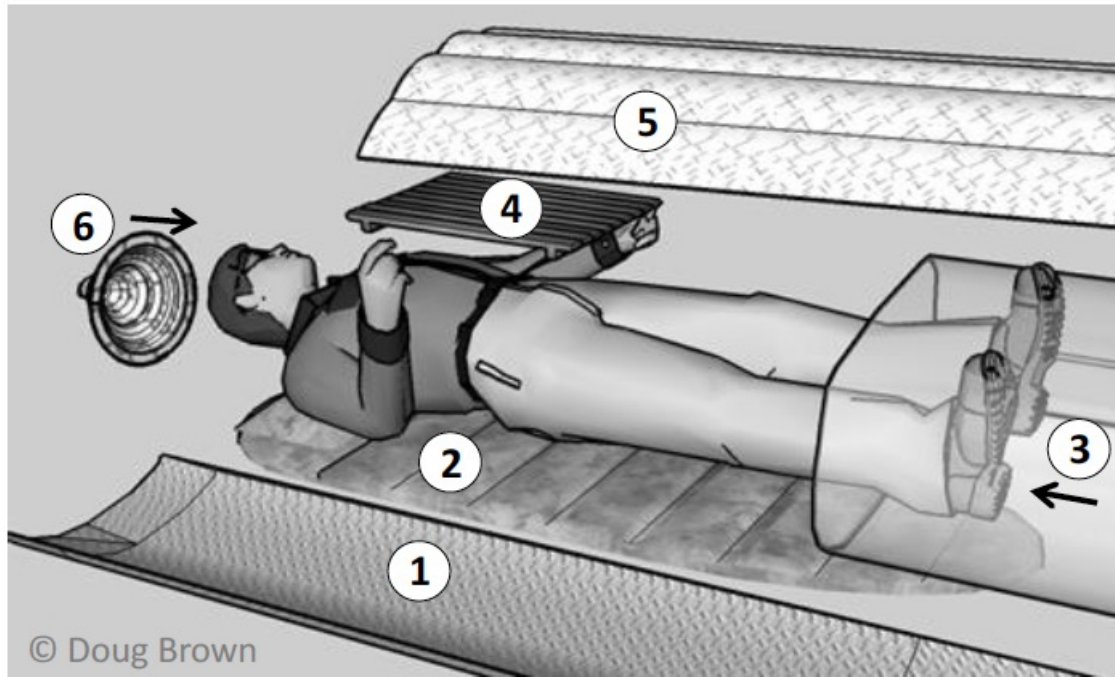
## **Accidental Hypothermia – Evaluation, Triage & Management**

Version 1.02: April 4, 2016

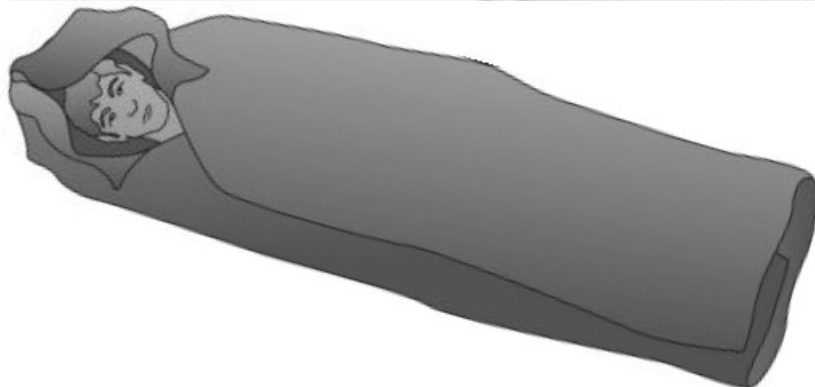
Written by: Dr. Doug Brown & BC Accidental Hypothermia Working Group



# Minimally Invasive Rewarming- Hypothermia burrito



- ① Outer wind & waterproof +/- reflective tarp (prehospital only)
- ② Insulation or heating pad\*
- ③ Replace wet clothes if practical, otherwise wrap patient in plastic
- ④ Forced air, chemical or electrical heating device(s)\*
- ⑤ Insulating blanket
- ⑥ Insulate the head\*\*

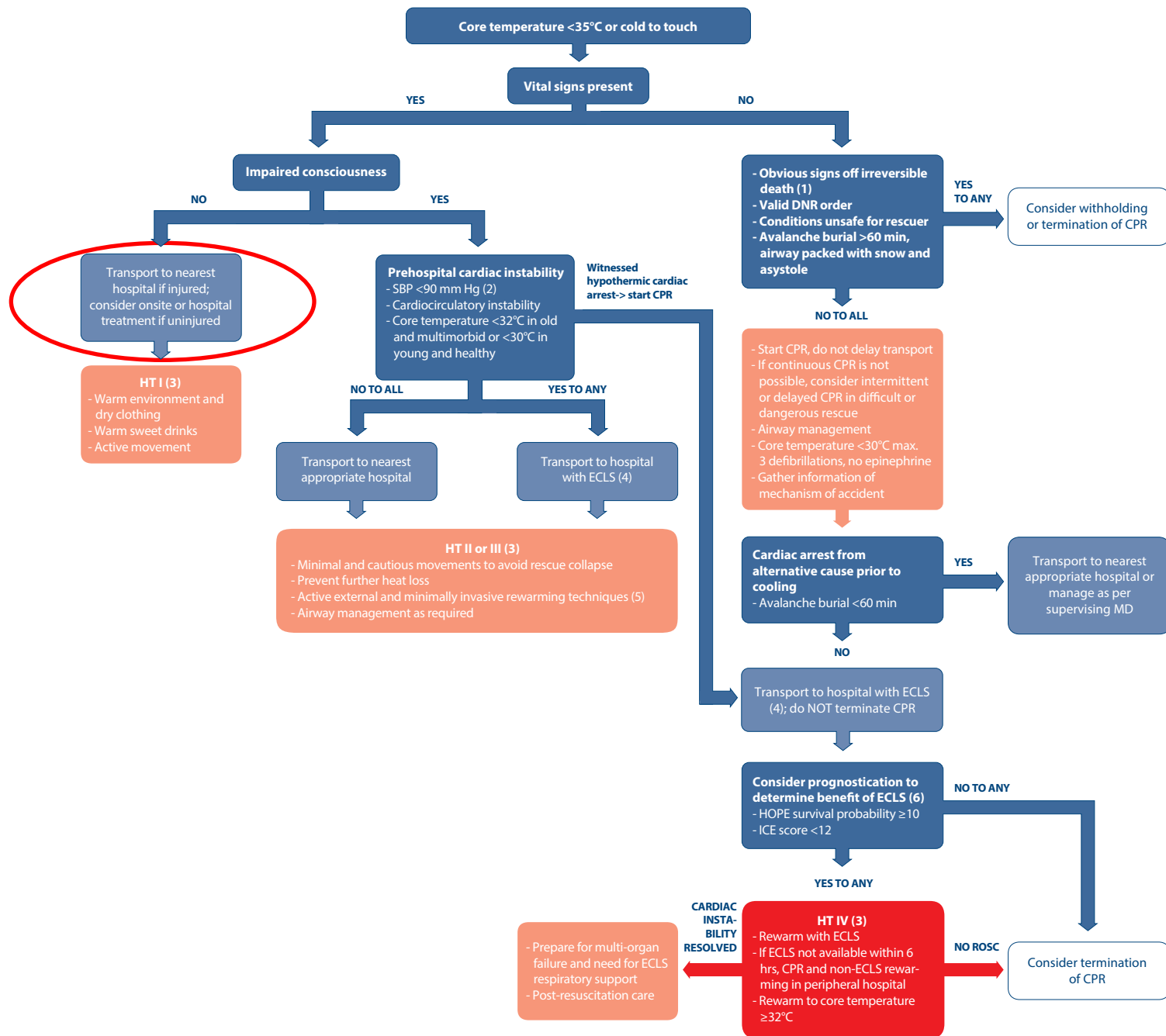


\* To avoid burns, keep heating device temperatures  $< \sim 40^{\circ}\text{C}$ .

\*\*If in cardiac arrest, do not apply heat to the head (allow warm oxygenated blood to rewarm the brain centrally).

# Cold Patient, Conscious

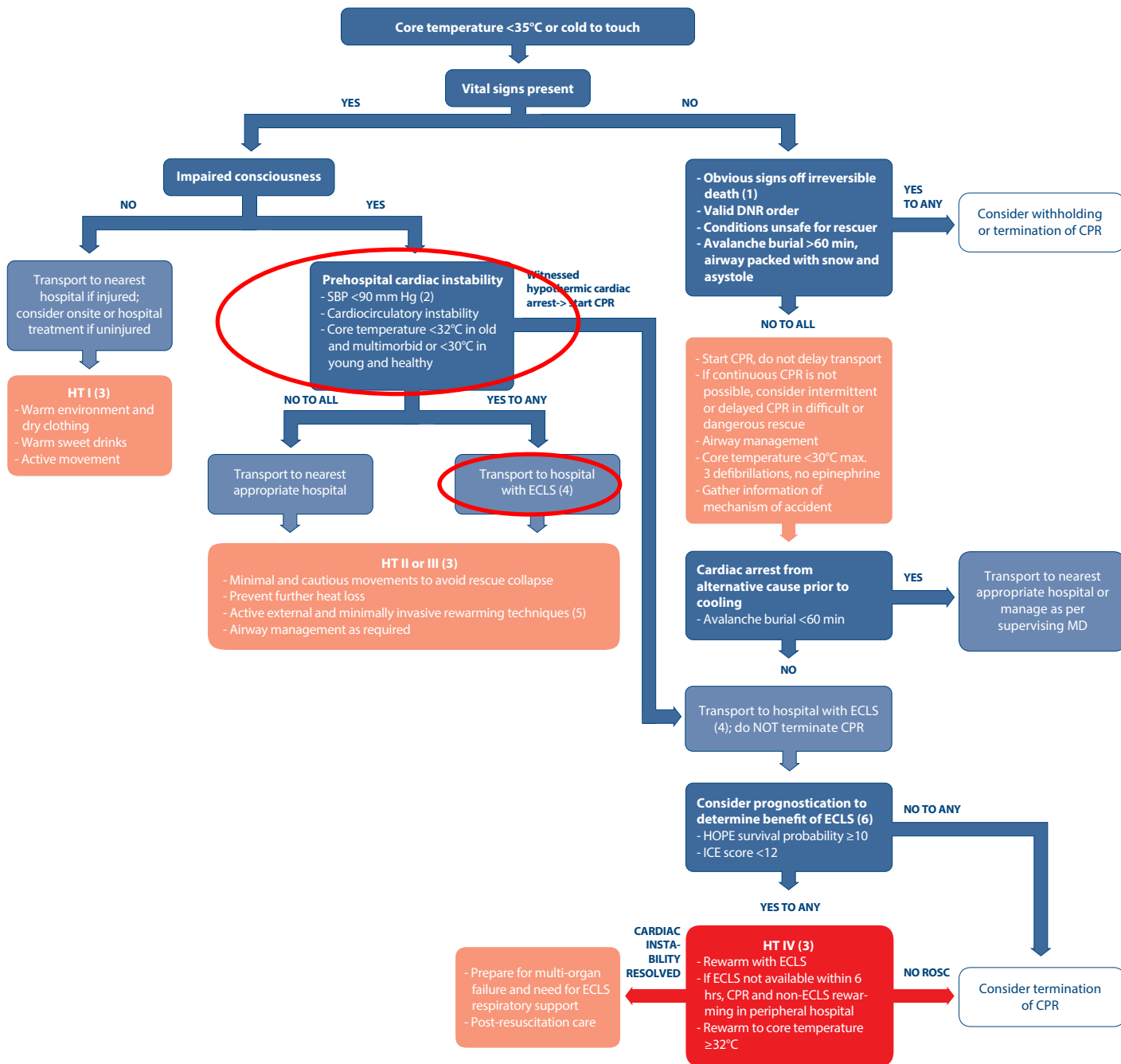






# Cold Patient, Unconscious with Vital Signs



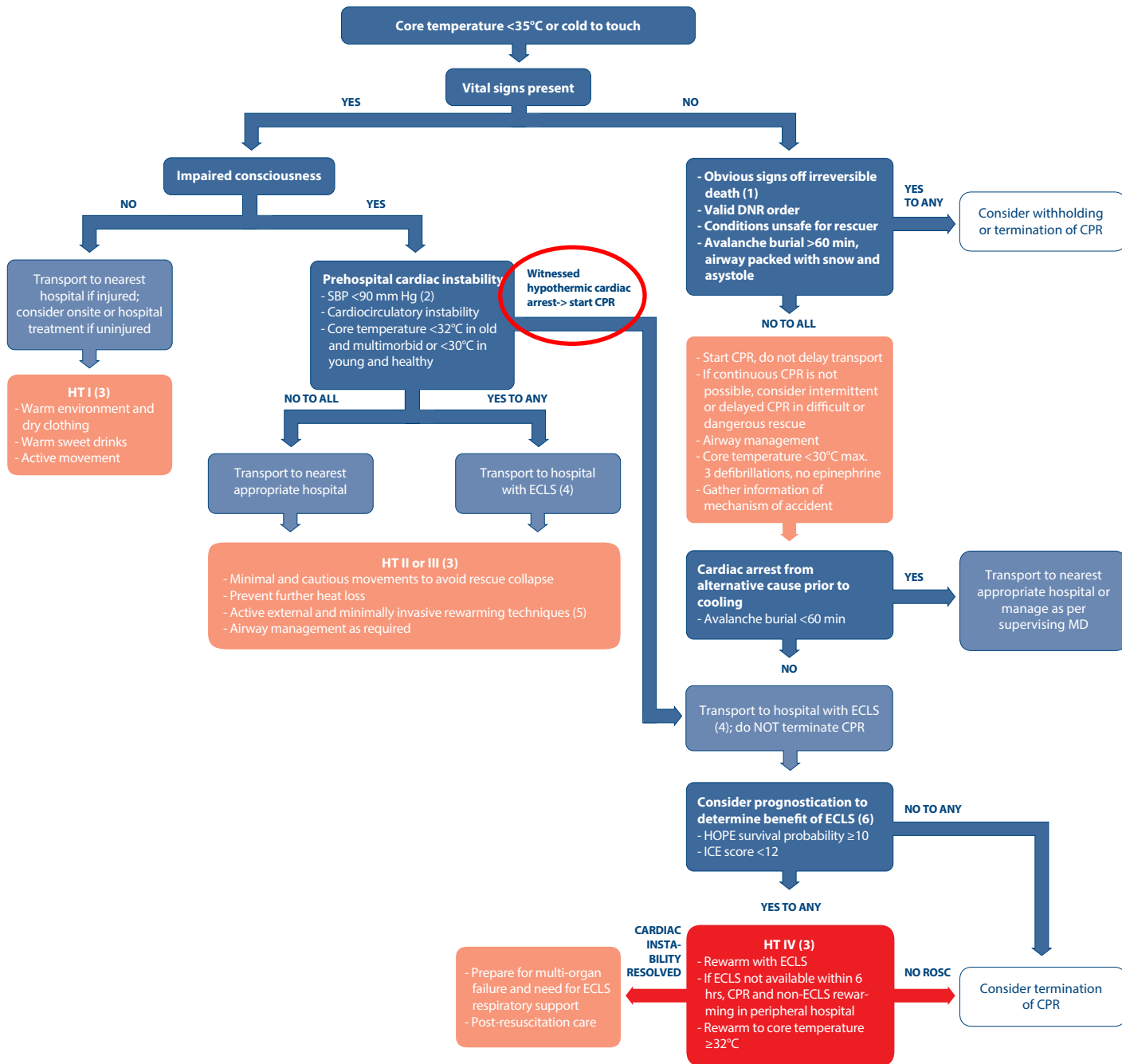


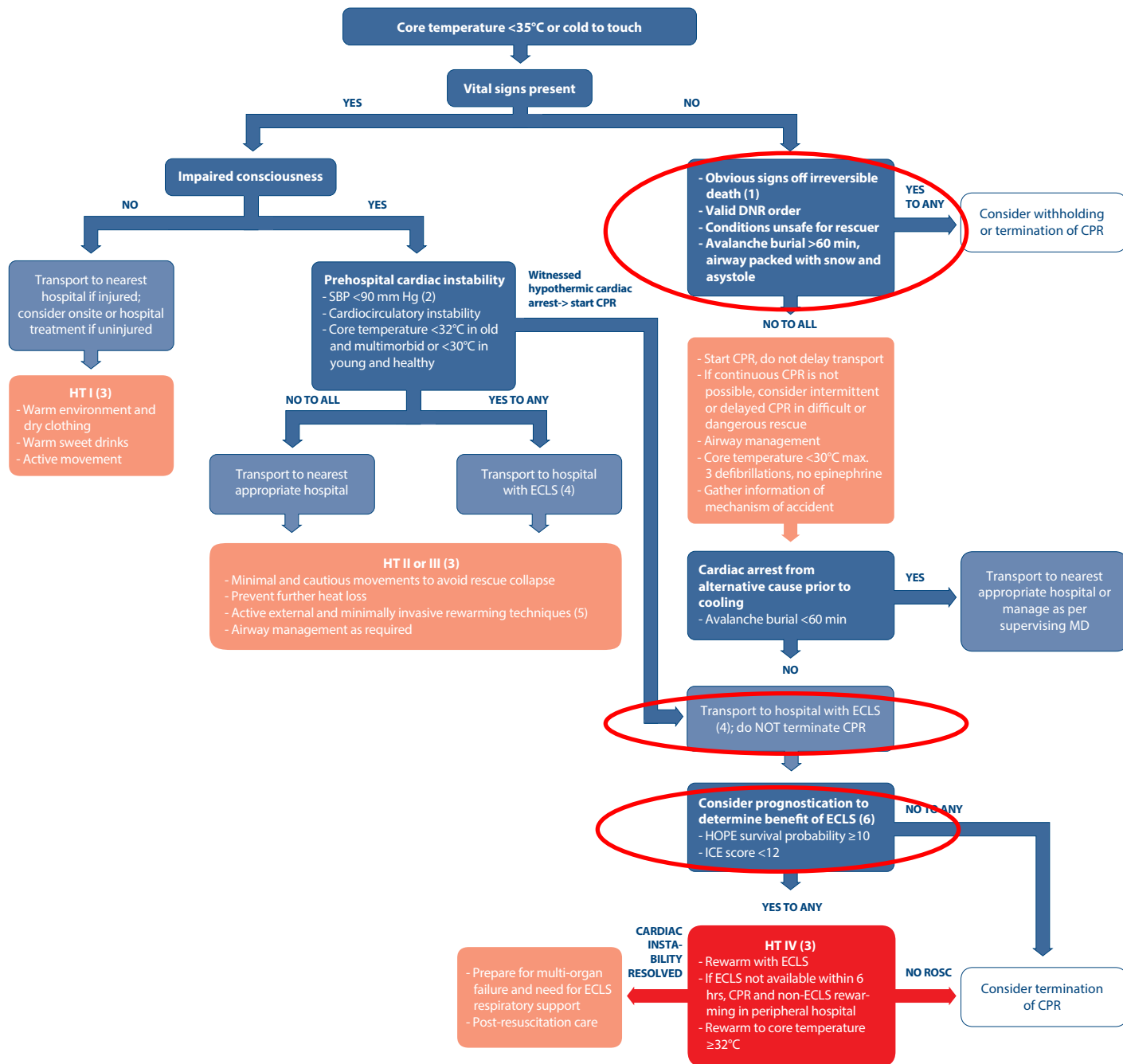


# Cold Patient, No Signs of Life









# How to perform CPR?

1. Higher chest compression: ventilation ratio ( $>30:2$ )
2. Slower chest compression frequency ( $\text{min}^{-1}$ )
3. Slower ventilation rate
4. This doesn't convince me at all, I stick to the normothermic CPR rules



## Præstø Fjord, February 11, 2011

- 13 students and 2 teachers,
- Capsized approx. 11:22
- In 2° C cold salt water
- Depth 2-5 m
- Air temperature 4° C
- Wind speed 7 m/s and increasing
- A student reaches shore
  - swimming 500 m.
- Walks 2.1 km to nearest town
- Calls EMS at 12:43





## Emergency Medical Service Assessment/Management



	Patient	1	2	3	4	5	6	7
Arrival EMS (min)		13:20	13:20	14:14	14:14	14:14	14:19	13:10
GCS		3	3	3	3	3	3	3



## Emergency Medical Service Assessment/Management



	Patient	1	2	3	4	5	6	7
<b>Arrival EMS (min)</b>		13:20	13:20	14:14	14:14	14:14	14:19	13:10
GCS		3	3	3	3	3	3	3
Intubation/ventilation (y/n)		n	n	y	y	y	y	y
CPR (y/n)		y	y	y	y	y	y	y
Helicopter		y	y	y	y			
Rescue boat and Helicopter						y	y	
Rescue boat and ambulance								y

Wanscher M, et al. Resuscitation. 2012 Sep;83(9):1078-84.



# Outcome

All 7 survive

Hospital LOS :10 – 17 days

All 7 transferred to Hammel Neuro Rehabilitation Centre with various signs of damage to central and peripheral nerve functions

CPC at discharge:

CPC 1-2: 4 patients (2 males, 2 females)

CPC 3-4: 3 patients (3 males)

## Cerebral Performance Category (CPC)

CPC 1 – conscious, no neurologic disability

CPC 2 – conscious, moderate neurologic disability, can work

CPC 3 – conscious, severe neurologic disability, dependent

CPC 4 – coma

(CPC 5 – dead)



Wanscher M, et al. Resuscitation. 2012 Sep;83(9):1078-84.

# Quality of manual CPR?

1. 5-20% of normal blood flow?
2. 30-40%
3. 50-70%
4. We have strong team: 80-100%

# CPR

## Mechanical



Dembeck A et al. Notfall und Rettungsmed 2011



# CPR

57-yr old woman, 16.9° C,  
HR 6min-1. Rescue collapse.  
Extrication from above 2000m,  
Down over a rock face



# To resuscitate or not resuscitate?

1. Everything comes to an end, the sooner the better
2. We start as soon as we can perform continuous CPR
3. Do CPR whenever you can

# CPR

Intermittent manual CPR  
VA ECMO  
Good neurologic recovery



Boue Y, et al. Crit Care Med 2014 Feb;42(2):e167-70.





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Contents lists available at [ScienceDirect](#)

# Resuscitation

journal homepage: [www.elsevier.com/locate/resuscitation](http://www.elsevier.com/locate/resuscitation)



EUROPEAN  
RESUSCITATION  
COUNCIL



CrossMark

Commentary and concepts

## Delayed and intermittent CPR for severe accidental hypothermia<sup>☆</sup>

Les Gordon<sup>a,b</sup>, Peter Paal<sup>c,d,\*</sup>, John A. Ellerton<sup>e,d</sup>, Hermann Brugger<sup>f,g,d</sup>,  
Giles J. Peek<sup>h,i,j</sup>, Ken Zafren<sup>k,l,d</sup>

<sup>a</sup> University Hospitals of Morecambe Bay Trust, Royal Lancaster Infirmary, LA1 4RP, United Kingdom

<sup>b</sup> Langdale Ambleside Mountain Rescue Team, United Kingdom

<sup>c</sup> Department of Anaesthesiology and Critical Care Medicine, University Hospital Innsbruck, Austria

<sup>d</sup> International Commission for Mountain Emergency Medicine (ICAR MEDCOM), Austria

<sup>e</sup> Birbeck Medical Group, Penrith, Cumbria, United Kingdom

<sup>f</sup> Institute of Mountain Emergency Medicine, EURAC Research, Bolzano, Italy

<sup>g</sup> Medical University Innsbruck, Austria

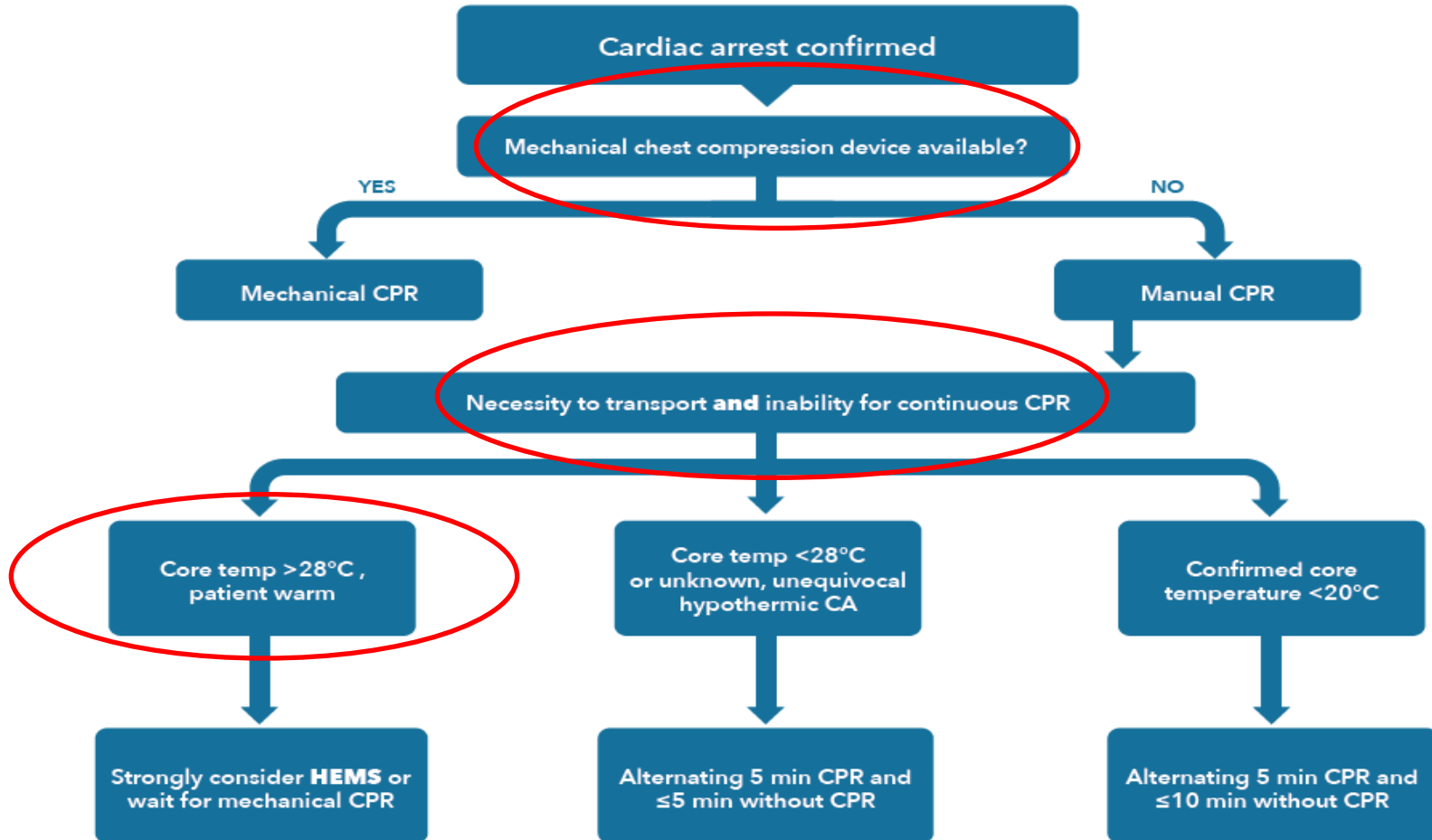
<sup>h</sup> East Midlands Congenital Heart Centre, United Kingdom

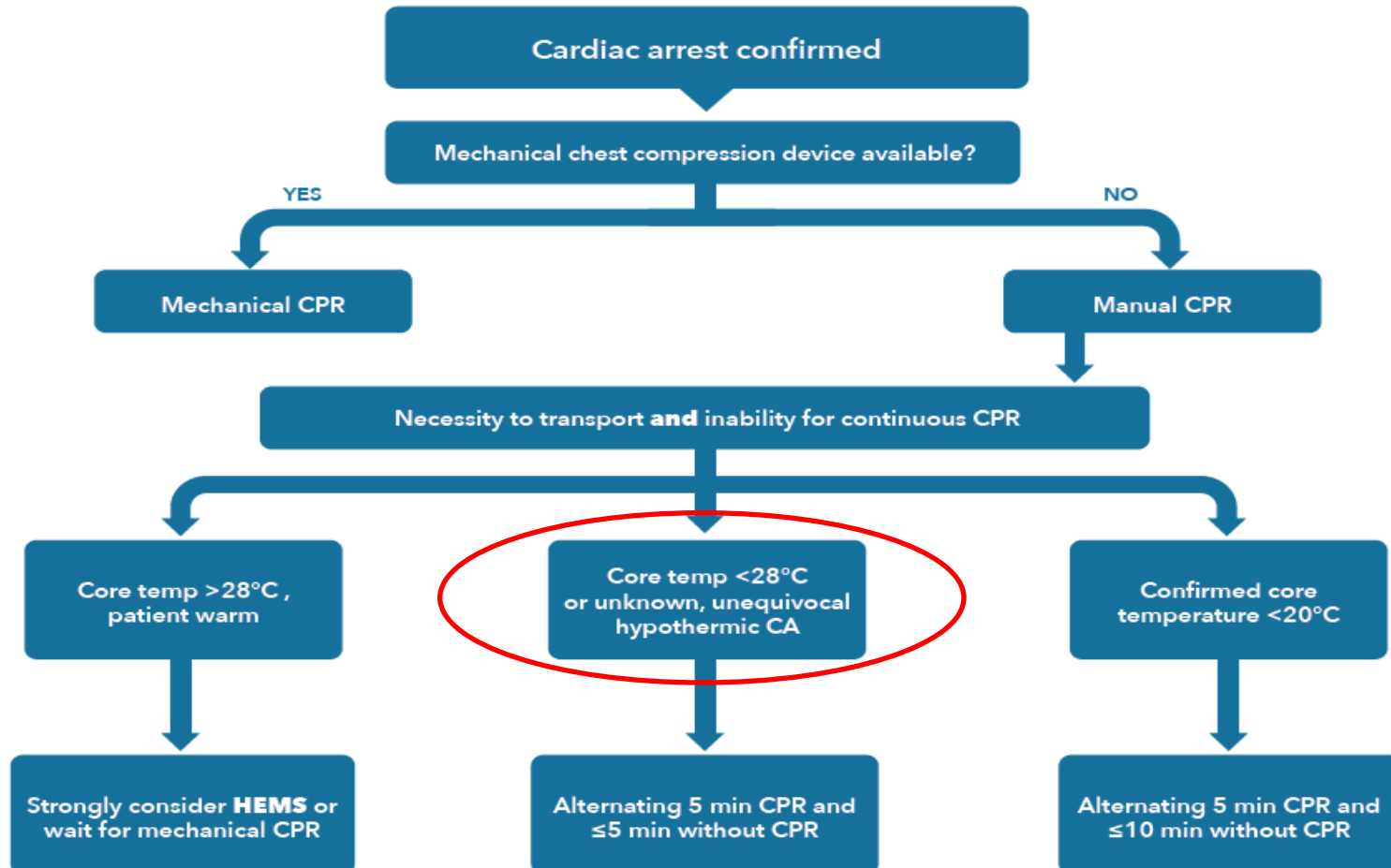
<sup>i</sup> Glenfield Hospital, Leicester LE3 9QP, United Kingdom

<sup>j</sup> EuroELSO Steering Committee, United Kingdom

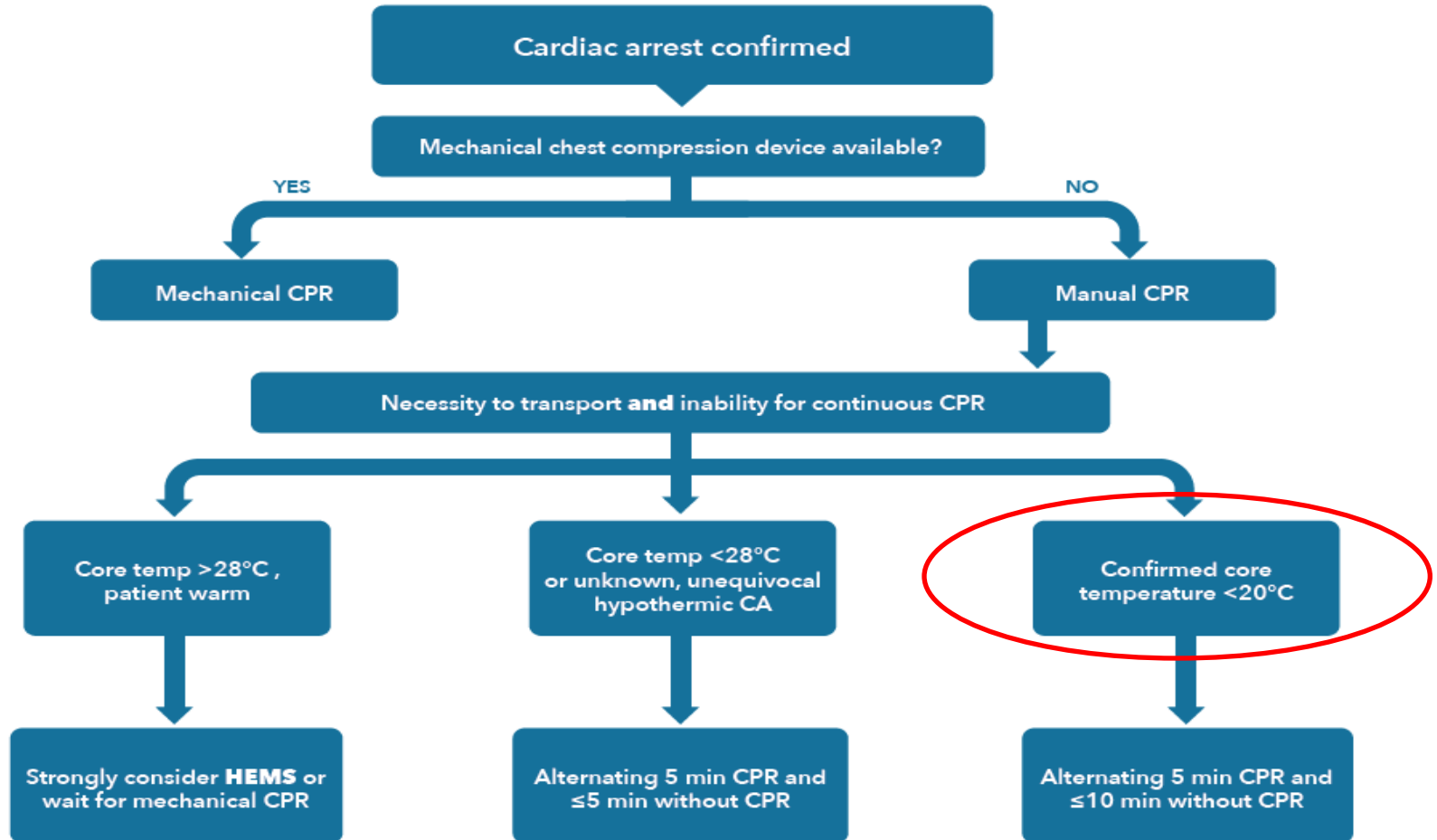
<sup>k</sup> Division of Emergency Medicine, Department of Surgery, Stanford University School of Medicine, Stanford, CA, USA

<sup>l</sup> Medical Director, Alaska Mountain Rescue Group, USA









Hermann Brugger  
Ken Zafren  
Luigi Festi

Peter Paal  
Giacomo Strapazzon

The title 'MOUNTAIN EMERGENCY MEDICINE' is displayed in large, bold, sans-serif letters. 'MOUNTAIN' is in green, while 'EMERGENCY' and 'MEDICINE' are in blue. The text is overlaid on a background of a snowy mountain peak under a clear blue sky.

# MOUNTAIN EMERGENCY MEDICINE

*"In **Mountain Emergency Medicine** is found the sum of all important research and experience in mountain medicine. Indispensable for all mountaineers, health care providers and mountain rescue doctors."*

**Reinhold Messner**



# Hypothermic CA patients

- Hypothermic CA before hypoxia
- Good chances of survival with unwitnessed asystolic CA
- Standard high quality CPR
- Consider delayed or intermittent CPR
- No epinephrine  $<30^{\circ}$  C,  
6-10min intervals  $\geq 30^{\circ}$  C
- ECMO/CPB centre
- Prognostication with HOPE







Thank you

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