Accidental Hypothermia

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Objectives

45min lecture, 15min discussion & questions:

- Inspirational case & overview
- Who is cold and dead
- Special circumstances (trauma, drowning, avalanche)
- Step by step resuscitation of severe hypothermia
- Transport issues
- Building the BC chain of survival

Disclosures

- No financial conflicts of interest
- Overzealous desire to build a chain of survival for a rare condition
- At risk for recreational hypothermia

IKAR CISA

fraserhealth

IRIDIA MEDICAL

UBC a place of mind THE UNIVERSITY OF BRITISH COLUMBIA

SEARCH & RESCUE LIONS BAY

WHISTLER BLACKCOMB

THE CANADIAN SOCIETY OF MOUNTAIN MEDICINE

Hypothermia with Apparent Death

- 29y/o F, falls into a frozen creek while skiing
- Trapped under the ice, immersed in flowing water, has an air pocket
- Becomes unconscious after 40 minutes
- Extricated after 80 minutes: lifeless, asystolic, CPR started
- 1 hour flight to hospital
- Arrive in hospital after 130 min downtime after 90min of CPR

Hypothermia with Apparent Death

- On Arrival: K 4.3, pH 6.6, PaO_2 65, $PaCO_2$ 77, Temp 14.4^oC, asystole
- Femoral AV Cardiopulmonary Bypass (CPB) started 40 min after arrival (130 min CPR)
- 13.7^oC lowest core temp measured (2 min after starting CPB)
- Vfib 10 min after starting CPB

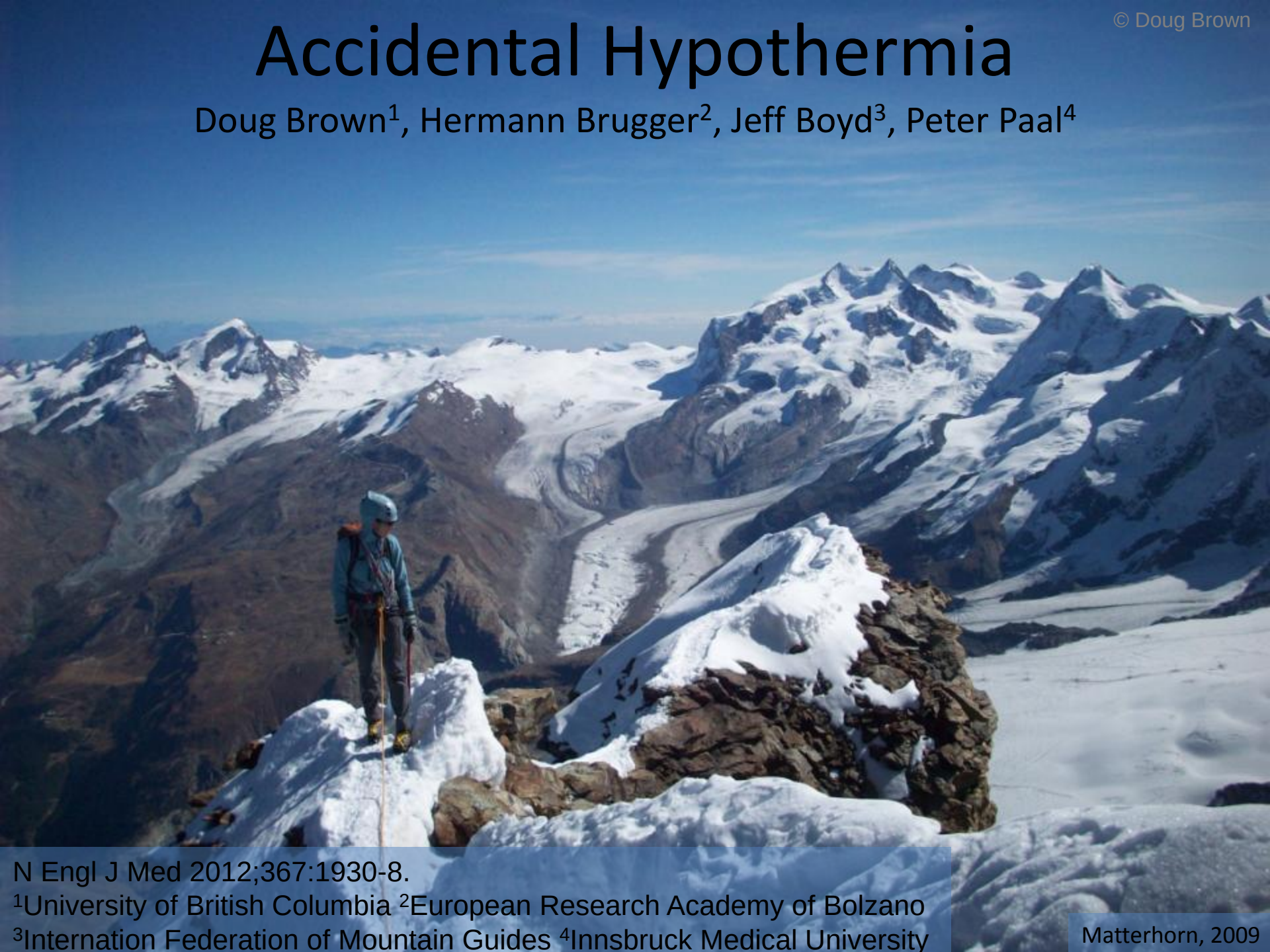
Successful Resuscitation From Apparent Death

- Spont conversion to pulsatile rhythm 15 min after CPB
- CPB stopped after 179 minutes, Temp 36 ^{o}C
- ECMO started 4hrs later and cont for 5 days
- 28 day ICU stay complicated by:
  - Renal failure requiring dialysis
  - Coagulopathy
  - Ischemic colitis
  - ICU Polyneuropathy
- Slow return to work as a radiology resident ~6 months later (prev orthopedic resident)

Gilbert M, Busund R, Skagseth A, Nilsen PÅ, Solbø JP. Resuscitation from accidental hypothermia of 13·7°C with circulatory arrest. The Lancet. 2000 1/29;355(9201):375-6

Accidental Hypothermia

Doug Brown[1], Hermann Brugger[2], Jeff Boyd[3], Peter Paal[4]



N Engl J Med 2012;367:1930-8.

[1]University of British Columbia [2]European Research Academy of Bolzano
[3]Internation Federation of Mountain Guides [4]Innsbruck Medical University

Matterhorn, 2009

NEJM – New Recommendations

- Simplified clinical staging & decision making
  (conscious, decr LOC, unconscious, cardiac arrest)
- Insulate and attempt rewarming for all patients
  (rescue collapse is common but is not caused by rewarming)
- Hypothermic cardiac arrest or instability requires ECMO/CPB (long transport times are OK)
- Cardiac stability -> minimally invasive rewarming
  (insulation, external heat & warmed IV fluids)

N ENGL J MED 367;20 NEJM.ORG NOVEMBER 15, 2012

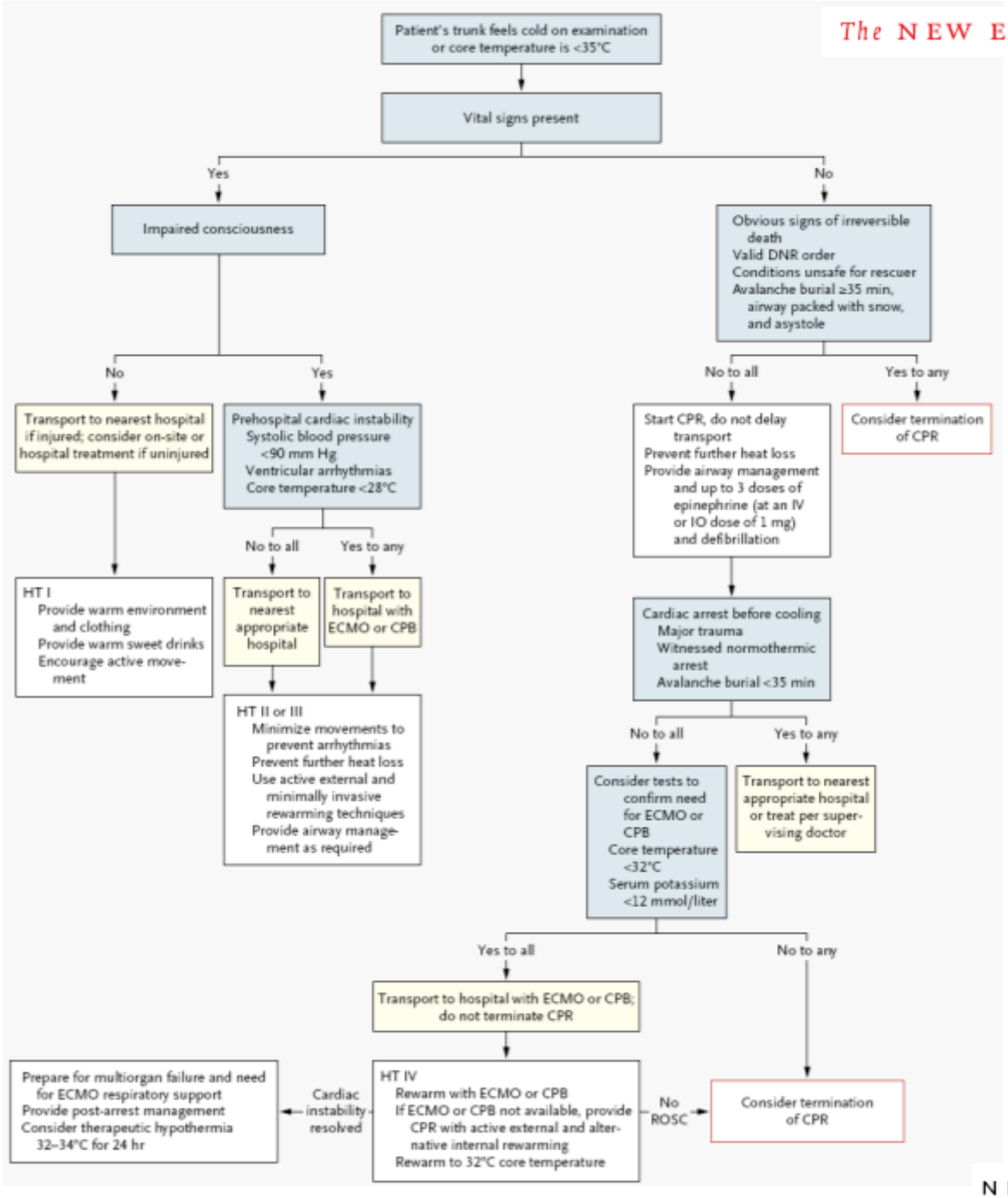


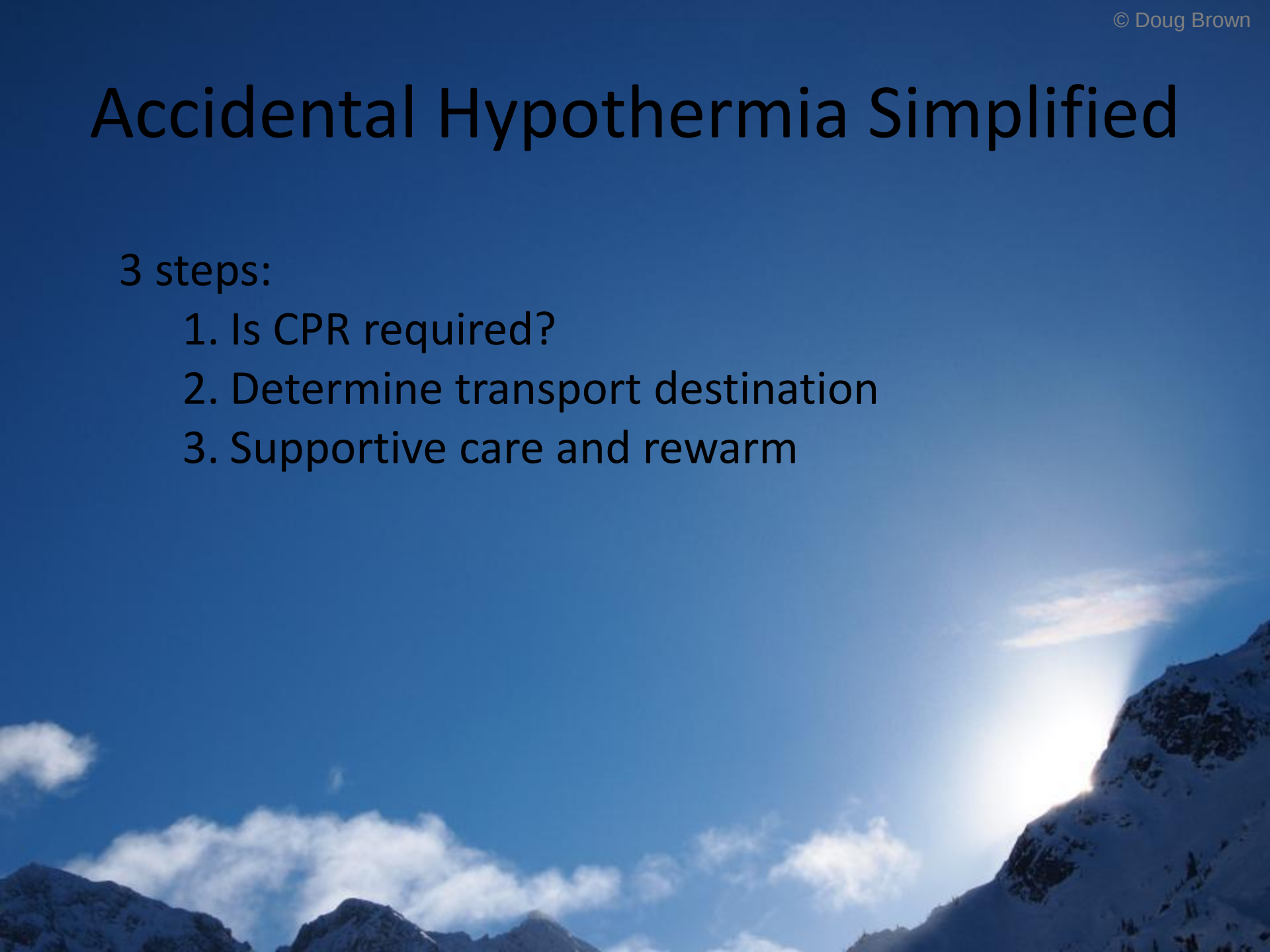
Figure 1 (facing page). Management and Transport in Accidental Hypothermia.

HT I, HT II, HT III, and HT IV refer to the four stages of hypothermia as defined by the Swiss staging system.[10] To convert values for temperature to degrees Fahrenheit, multiply by 9/5 and add 32. Obvious signs of irreversible death include decapitation, truncal transection, decomposition of the whole body, and a chest wall that is not compressible (i.e., the whole body is frozen solid). Rigor mortis as well as fixed and dilated pupils may be present in patients with reversible hypothermia. Active external and minimally invasive rewarming techniques include placement of the patient in a warm environment; use of chemical, electrical, or forced-air heating packs or blankets; and parenteral administration of warm fluids (38 to 42°C [100 to 108°F]). A systolic blood pressure of less than 90 mm Hg is a reasonable prehospital estimate of cardiac instability, but for in-hospital decisions, the minimum sufficient circulation for a patient with a core temperature of less than 28°C (82°F) has not been defined. Therefore, it is not known at what point a patient with refractory cardiac instability should be transitioned to extracorporeal membrane oxygenation (ECMO) or cardiopulmonary bypass (CPB). In remote areas, the transport adviser must balance the risk of increased transport time with the potential benefit of treatment in a center that can provide ECMO or CPB. For a patient with cardiac arrest in a remote area, the need for ECMO or CPB can be confirmed by measuring the serum potassium level at an intermediate hospital, ideally en route toward a center that can provide ECMO or CPB. When transfer to such a center is not feasible, active external and alternative internal rewarming techniques should be used. DNR denotes do not resuscitate, IO intraosseous, IV intravenous, and ROSC return of spontaneous circulation.

Accidental Hypothermia Simplified

3 steps:

1. Is CPR required?
2. Determine transport destination
3. Supportive care and rewarm



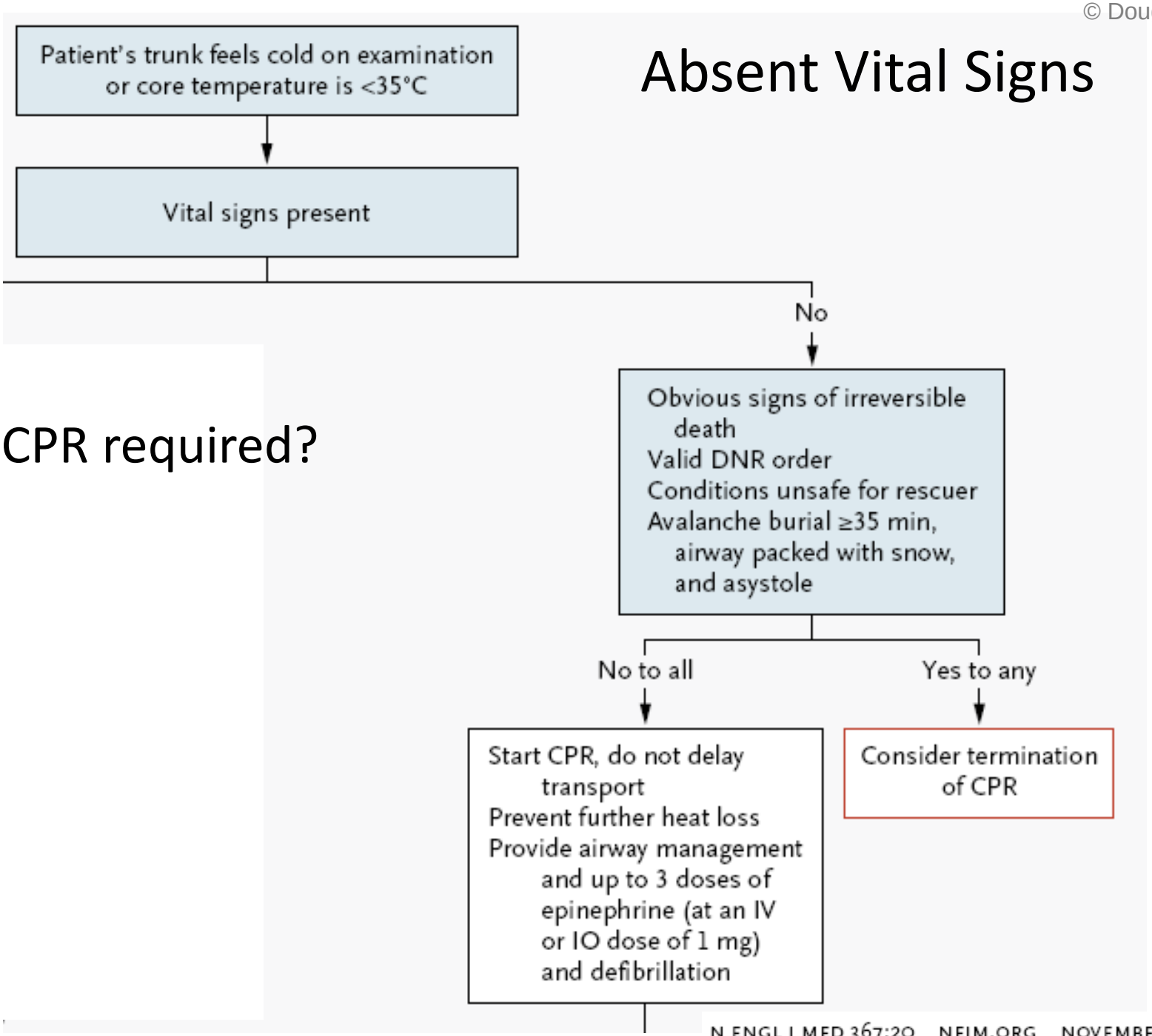
Cold Patient, No Signs of Life

Possible Causes of Cardiac Arrest:

- Trauma
- Asphyxia
- Hypothermia →
- Multi-factorial

Absent Vital Signs

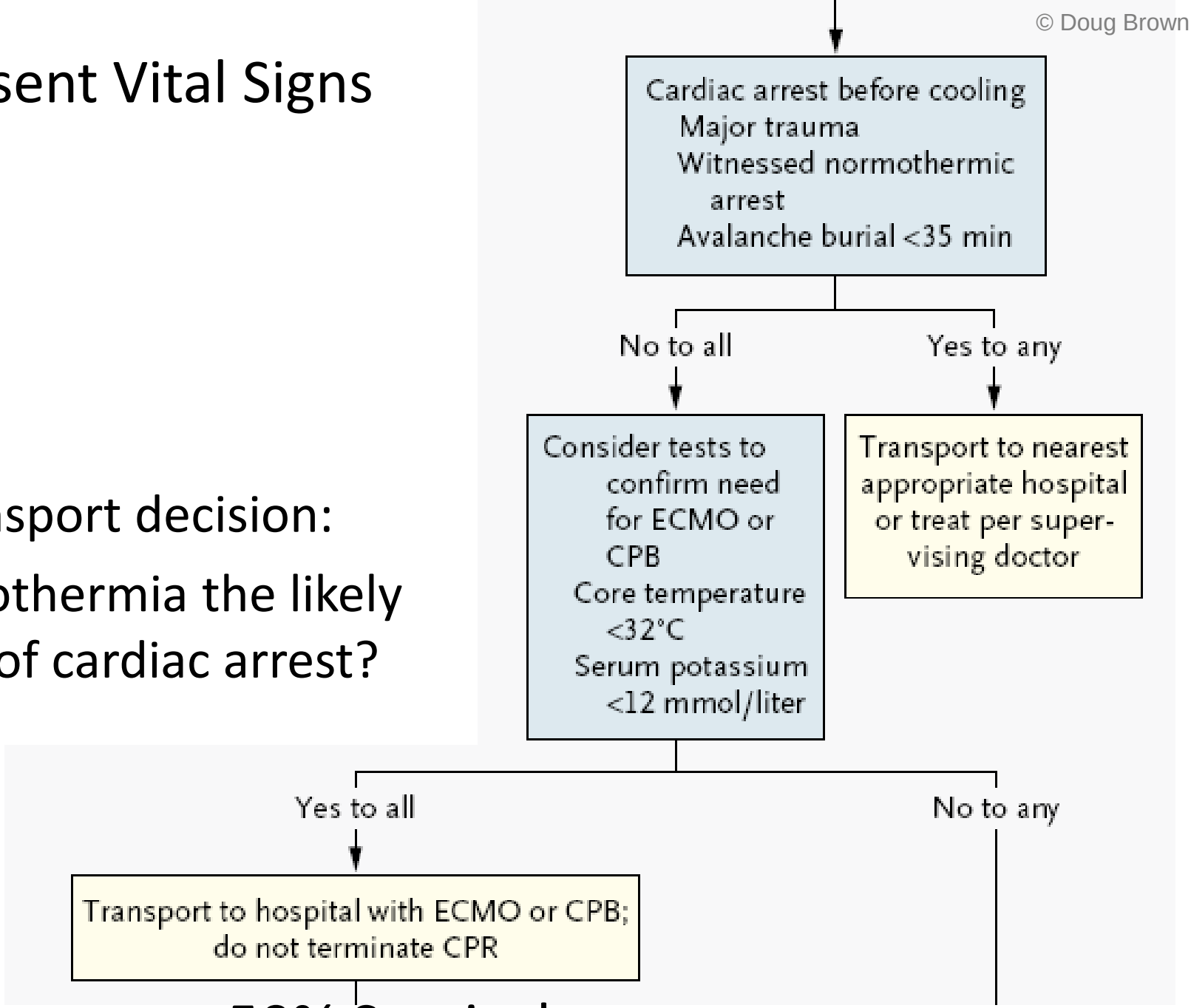
1. Is CPR required?



Absent Vital Signs

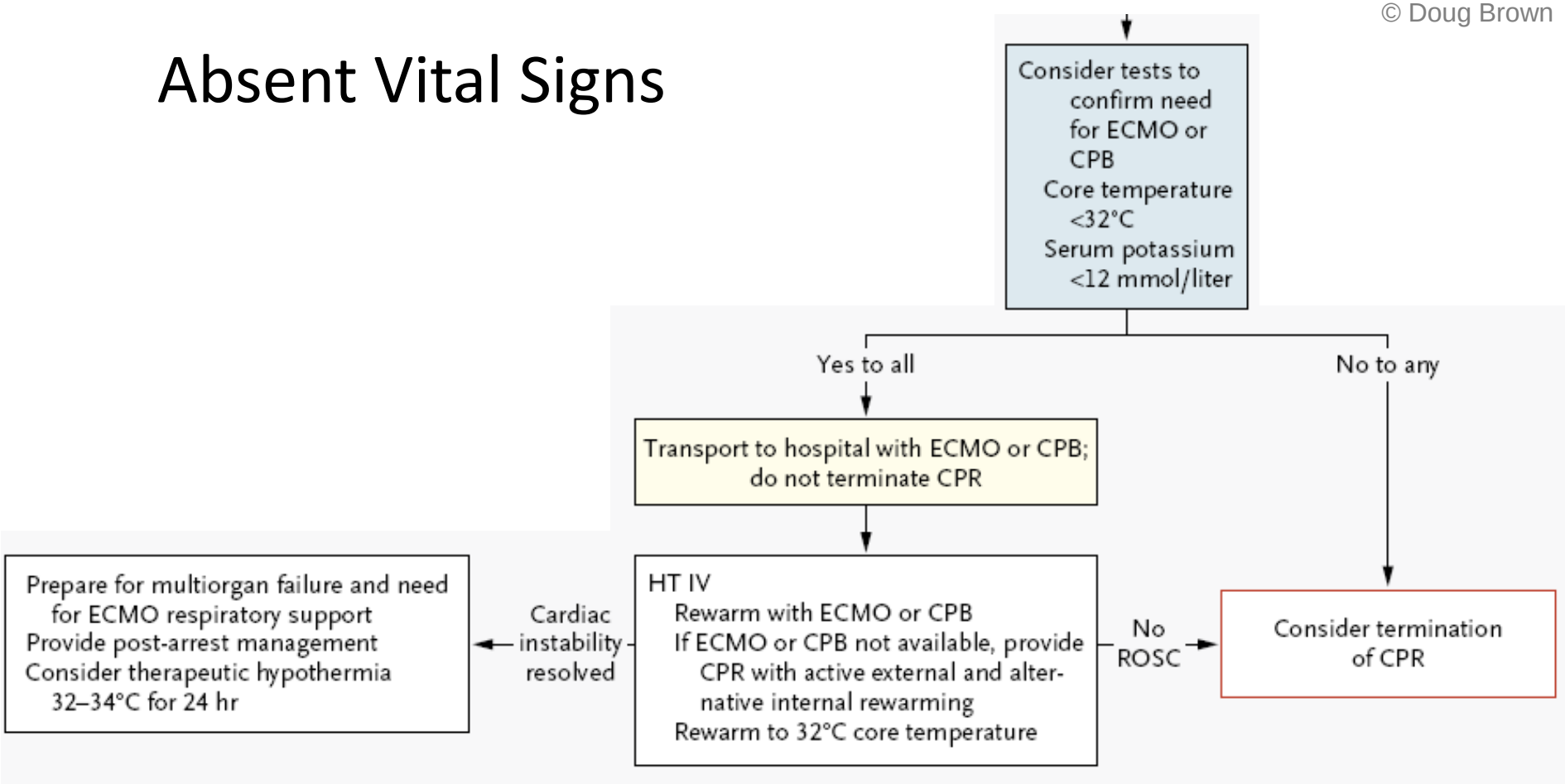
2. Transport decision:

Is hypothermia the likely cause of cardiac arrest?



~50% Survival

Absent Vital Signs

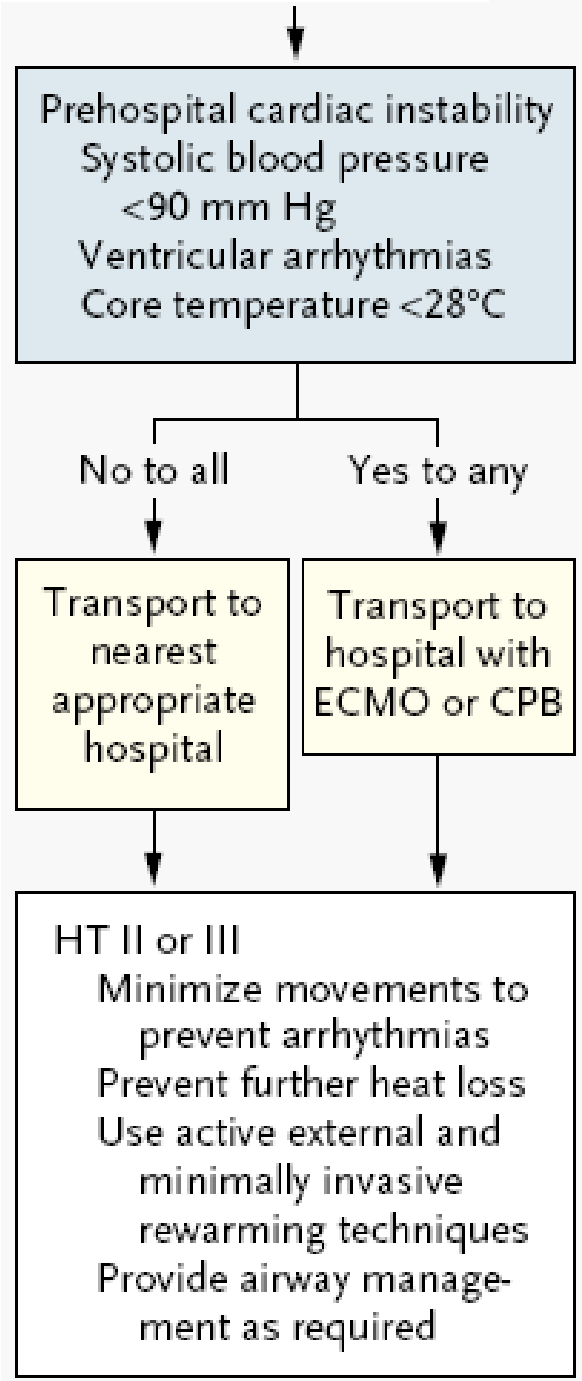


3. Supportive care & rewarm:
   - quality CPR
   - transport to ECMO
   - prevent heat loss

Cold Patient, Unconscious with Vital Signs

Unconscious with Vital Signs

1. No CPR required
2. Transport to ECMO if hypotension, ventricular arrhythmia or temp<28°C
3. Careful handling and rewarm



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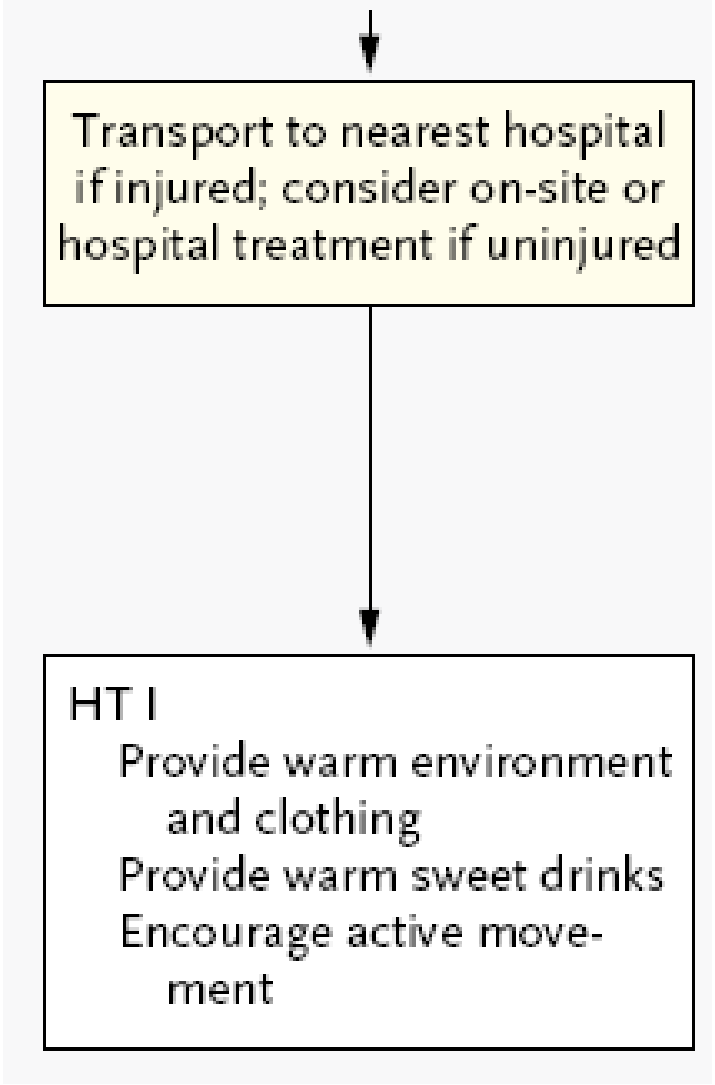
Cold Patient, Conscious

Normal LOC

1. No CPR required
2. Consider on-site rewarming if uninjured*
3. Rewarm



*Trauma & hypothermia are a deadly combination. Prevention & rewarming can be lifesaving for hypothermic trauma patients.

Classical Staging

Mild: <35

Moderate: <=32

Severe: <=28

Profound: <=25

TABLE 5-2 Characteristics of the Four Zones of Hypothermia

Stage	Core Temperature °C	Core Temperature °F	Characteristics
Mild	37.6	99.7 ± 1	Normal rectal temperature
	37.0	98.6 ± 1	Normal core temperature
	36.0	96.8	Increases in metabolic rate, blood pressure, and preshivering muscle tone
	35.0	95.0	Urine temperature 34.8°C (94.6°F); maximal shivering thermogenesis
	34.4	93.2	Development of amnesia, dysarthria, and poor judgment; maladaptive behavior; normal blood pressure; maximal respiratory stimulation; tachycardia, then progressive bradycardia
	33.30	91.4	Development of ataxia and apathy; linear depression of cerebral metabolism; tachypnea, then progressive decrease in respiratory minute volume; cold diuresis
Moderate	32.0	89.6	Stupor; 25% decrease in oxygen consumption
	31.0	87.8	Extinguished shivering thermogenesis
	30.0	86.0	Development of atrial fibrillation and other arrhythmias; poikilothermia; pupils dilated and cardiac output two-thirds of normal; insulin ineffective
	29.0	84.2	Progressive decrease in level of consciousness, pulse, and respiration; pupils dilated; paradoxical undressing
Severe	28.0	82.4	Decreased ventricular fibrillation threshold; 50% decrease in oxygen consumption and pulse; hypoventilation
	27.0	80.6	Loss of reflexes and voluntary motion
	26.0	78.8	Major acid–base disturbances; no reflexes or response to pain
	25.0	77.0	Cerebral blood flow one-third of normal; loss of cerebrovascular autoregulation; cardiac output 45% of normal; pulmonary edema may develop
	24.0	75.2	Significant hypotension and bradycardia
	23.0	73.4	No corneal or oculocephalic reflexes; areflexia
	22.0	71.6	Maximal risk of ventricular fibrillation; 75% decrease in oxygen consumption
Profound	20.0	68.0	Lowest resumption of cardiac electromechanical activity; pulse 20% of normal
	19.0	66.2	Electroencephalographic silencing
	18.0	64.4	Asystole
	13.7	56.7	Lowest adult accidental hypothermia survival[106]
	15.0	59.0	Lowest infant accidental hypothermia survival[264]
	10.0	50.0	92% decrease in oxygen consumption
	9.0	48.2	Lowest therapeutic hypothermia survival[258]

complicated

overlapping

core temperature required

Danzl DF. Accidental hypothermia. In: Auerbach PS, ed. Wilderness medicine. 6th ed. Philadelphia: Mosby, 2012:116-42.

Simplified Clinical Staging

Table 2. Staging and Management of Accidental Hypothermia.*

Stage	Clinical Symptoms	Typical Core Temperature†
HT I	Conscious, shivering	35 to 32°C
HT II	Impaired consciousness, not shivering	<32 to 28°C
HT III	Unconscious, not shivering, vital signs present	<28 to 24°C
HT IV	No vital signs	<24°C

Core Temperature Measurement

Problematic:

- Requires calibrated, low-reading thermistor
- Ideally esophageal (distal to carina)
- Rectal (~15cm depth, may lag during rewarming)
- Can't use oral or IR tympanic

Useful:

- Temp >32^{o}C then hypothermia unlikely the cause of cardiac arrest
- Prognosis: double edged sword*

*lower temperature increases ischemic protection but on average increases morbidity & mortality

Secondary Hypothermia

Table 1. Conditions Associated with Secondary Hypothermia.*

Impaired thermoregulation

Central failure
- Anorexia nervosa
- Cerebrovascular accident
- Central nervous system trauma
- Hypothalamic dysfunction
- Metabolic failure
- Neoplasm
- Parkinson's disease
- Pharmacologic effects
- Subarachnoid hemorrhage
- Toxins

Peripheral failure
- Acute spinal cord transection
- Decreased heat production
- Neuropathy

Endocrinologic failure
- Alcoholic or diabetic ketoacidosis
- Hypoadrenalism
- Hypopituitarism
- Lactic acidosis

Insufficient energy
- Extreme physical exertion
- Hypoglycemia
- Malnutrition

Neuromuscular compromise
- Recent birth and advanced age with inactivity
- Impaired shivering

Increased heat loss

Dermatologic disorder
- Burns
- Medications and toxins

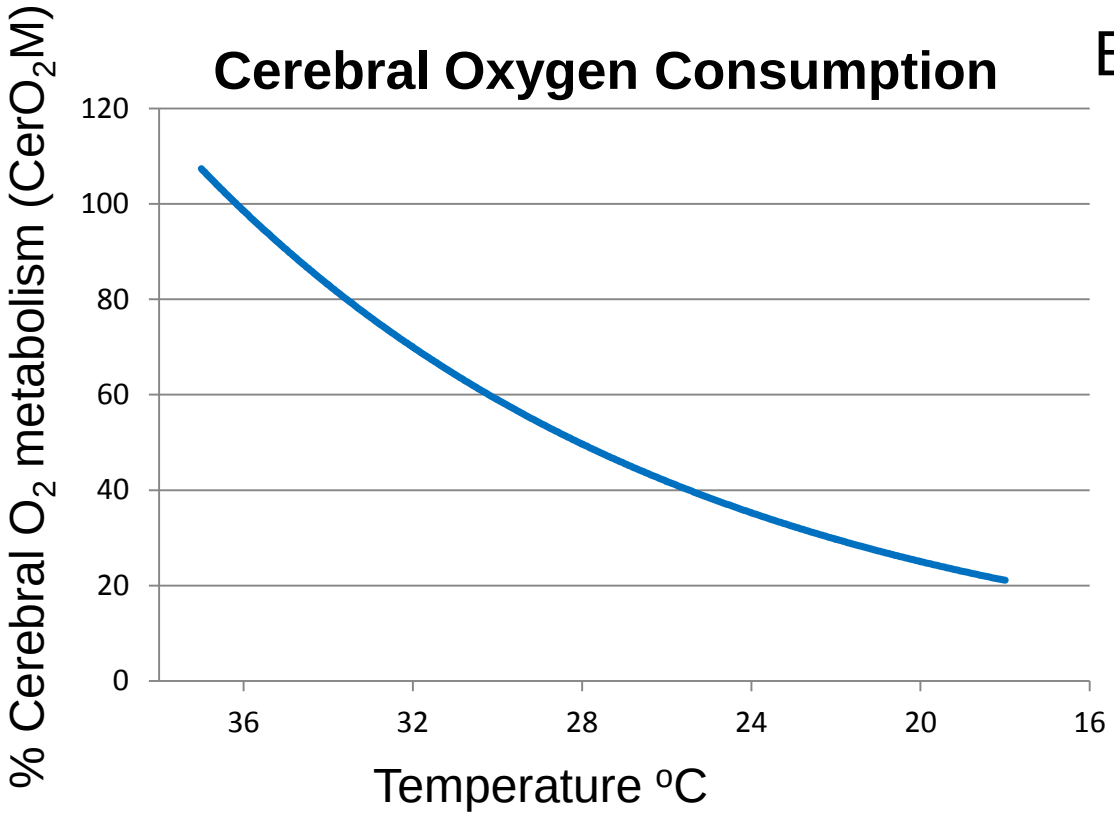
Iatrogenic cause
- Emergency childbirth
- Cold infusions
- Heat-stroke treatment

Other associated clinical states
- Carcinomatosis
- Cardiopulmonary disease
- Major infection (bacterial, viral, parasitic)
- Multisystem trauma
- Shock

* Adapted from Danzl.[9]

NEJM 2012:367:1930-8

Physiology Primer

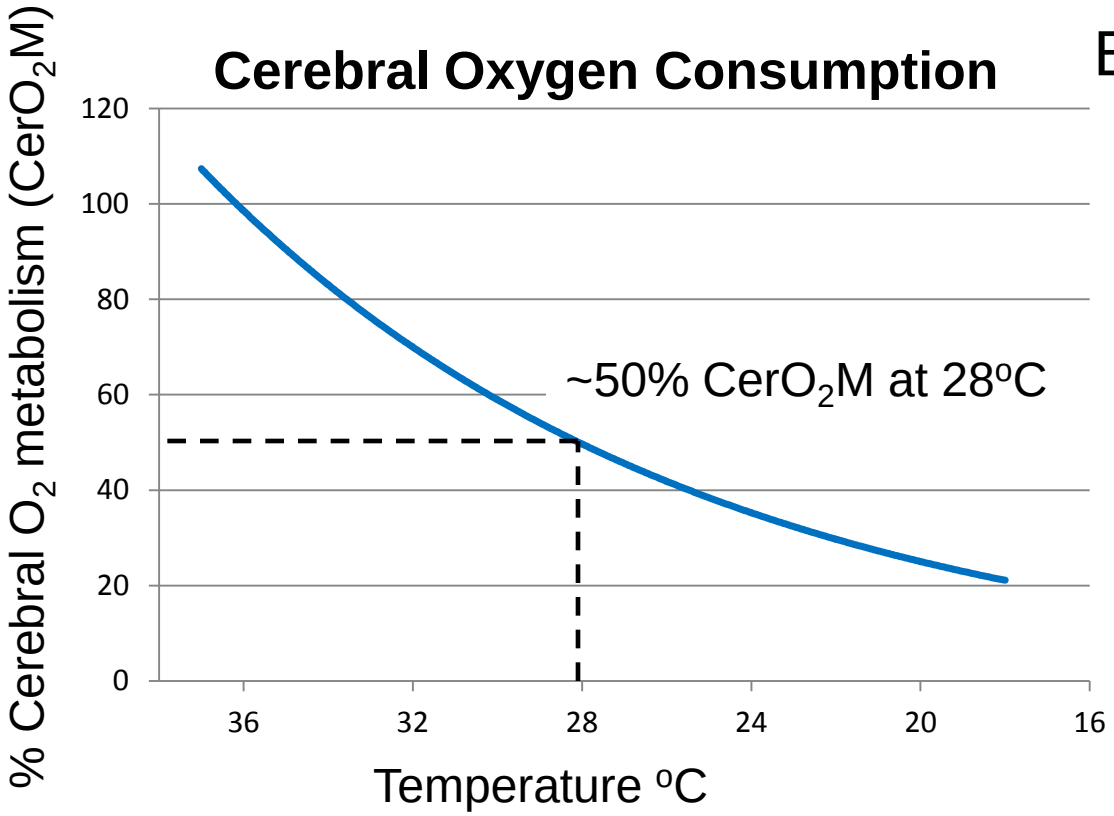


Benefit:

- ⇩ $Cer0_2M$ ~6%/°C

Wood SC. Annu Rev Physiol 1991;53:71-85
Ehrlich MP. Ann Thorac Surg. 2002 Jan;73(1):191-7

Physiology Primer



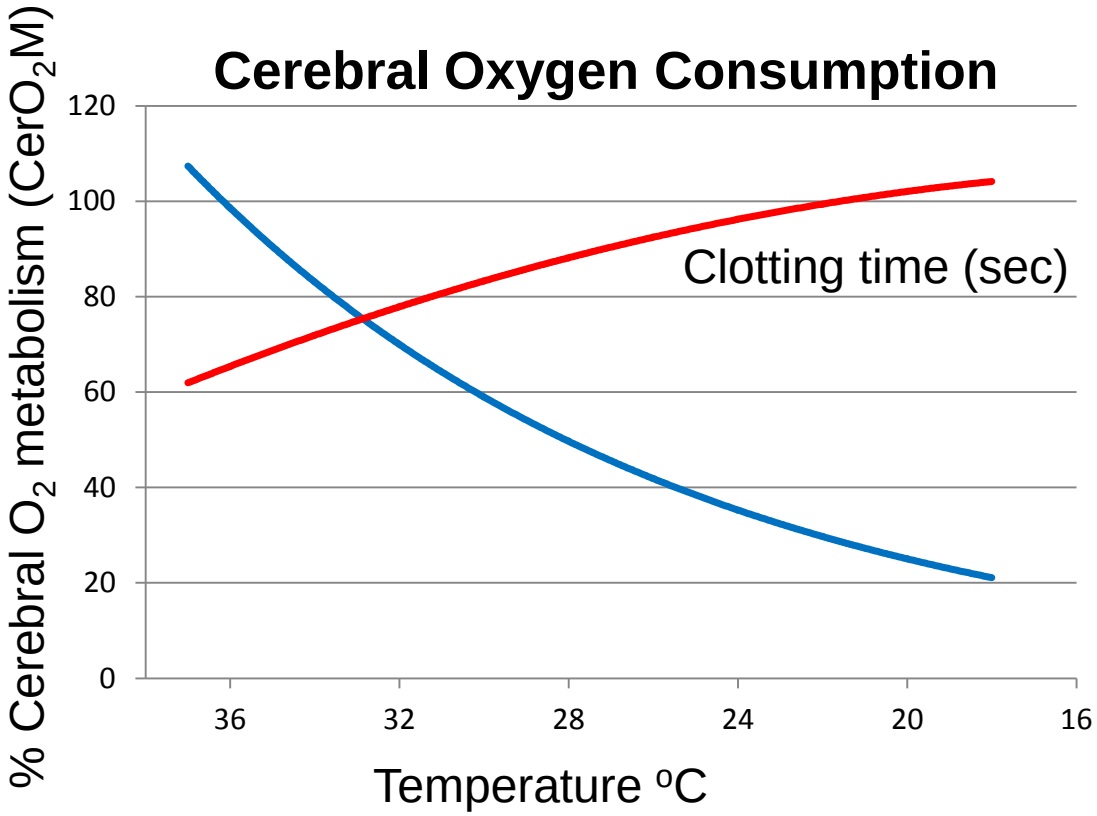
Benefit:

- ⇩ $Cer0_2M$ ~6%/ºC

1. CPR provides ~50% of normal cerebral blood flow
2. Below 28ºC, outcome may be completely independent of CPR duration

Wood SC. Annu Rev Physiol 1991;53:71-85
Ehrlich MP. Ann Thorac Surg. 2002 Jan;73(1):191-7
Rubertsson, Resuscitation 2005: 65 357-363

Physiology Primer



Benefit:

- ⇩ $Cer0_2M$ ~6%/ºC

Risks:

- ⇧ clotting time
- ⇧ bleeding ~16%*
- ⇧ transfusion ~22%*
- ⇧ mortality 2.4*

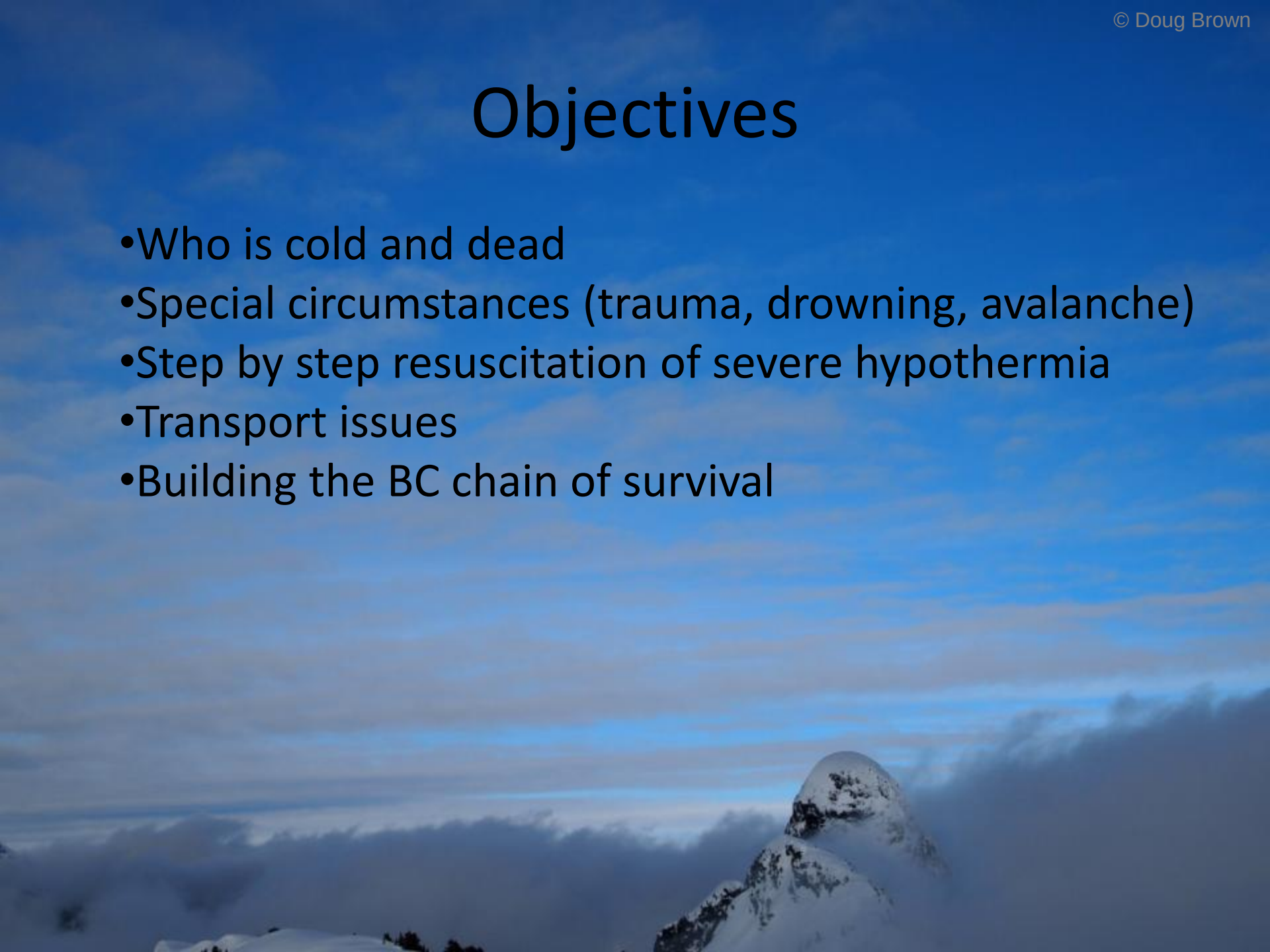
*in trauma patients

1. Trauma & hypothermia are a lethal combination

Wood SC. Annu Rev Physiol 1991;53:71-85
Ehrlich MP. Ann Thorac Surg. 2002 Jan;73(1):191-7
Dirkmann D, Hanke AA, Görlinger K, Peters J. Anesthesia & Analgesia 2008;106:1627-1632
Rajagopalan S et al. Anesthesiology 2008;108:71-77

Objectives

- Who is cold and dead
- Special circumstances (trauma, drowning, avalanche)
- Step by step resuscitation of severe hypothermia
- Transport issues
- Building the BC chain of survival



Hypothermia can mimic death

- Fixed & dilated pupils
- Stiffness that resembles rigor mortis
- Respiratory arrest
- Cardiac arrhythmias including asystole

Who is Cold & Dead?

- History of arrest prior to cooling
- Core temp >32^{o}C (hypothermia not the cause)
- Frozen solid (chest not compressible)
- K>12mmol L^{-1}
- Special circumstances

Serum Potassium

K<8 mmol/L:

- no prognostic value
- use history, not K to make decisions

K>?8, ?10, ?12

- possible marker of cell death prior to cooling
- Outliers / Survivors:
  - 2.5yr child K=11.8
  - 13yr child K=9.5
  - 34yr K=7.9

Objectives

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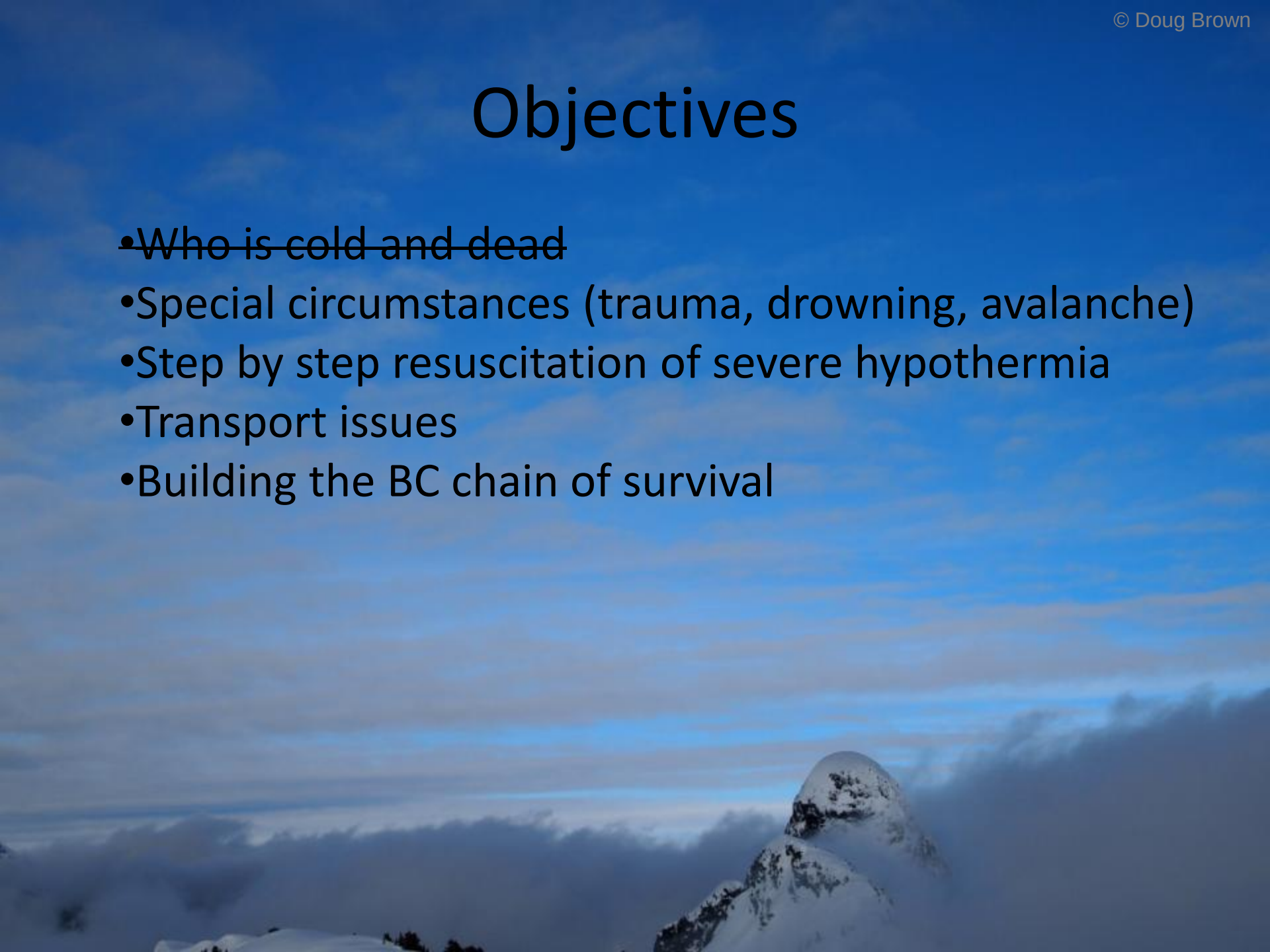

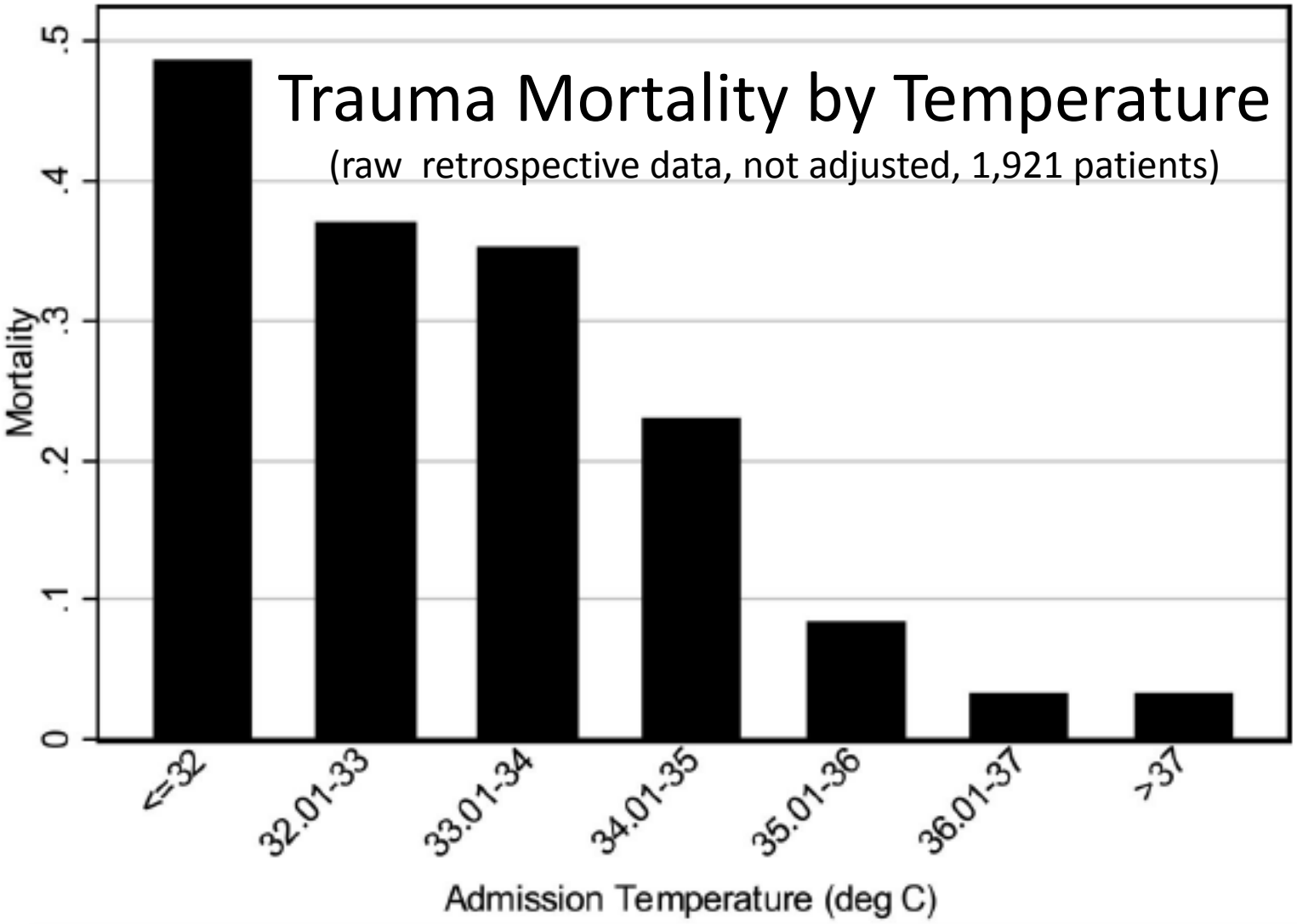

Adjusted Odds of Death: 2.4 (all comers)

temperature < 35C
adjusted for: age, ISS, mechanism

1.5 (isolated head injury)

Admission hypothermia and outcome after major trauma. Crit Care Med 2005 Vol. 33, No. 6

Hypothermia and Trauma

- Pathologic:
  - Coagulopathy undetected by lab (samples are heated)
  - 'Minor' bleeding can be catastrophic
  - Acidosis & arrhythmias
  - Fixed & dilated pupils: head injury, hypothermia or brain death?
  - Surgical cure is compromised….can't stop the bleeding
- What about Neuroprotection?
  - Shock state deplete ATP stores
  - Decreased hypothermic metabolism offset by traumatic hypermetabolic state & increased bleeding

Special Situations

Cold water drowning:

- **Submersion**: with hypoxic cardiac arrest has a dismal prognosis (exceptional pediatric cases possible)
- **Immersion**: with cooling and hypothermic cardiac arrest prior to submersion has a much better prognosis

Pediatric submersion outlier:

- 2.5yr fell into 5^{o}C creek and pinned underwater for 66minutes
- 19^{o}C , asystole, 2hr CPR, ECMO, full recovery

Special Situations

Drowning: see Tipton, Resuscitation 2011 for:

- drowning outliers (2 page table)
- Tipton's proposed rule:
  - >6°C water for >30min DNR
  - <6°C water for >90min DNR

Consider using history (submersion vs. immersion) rather than a rule to make clinical decisions

Pediatric patients that suffer simultaneous rapid cooling and submersion (hypoxic cardiac arrest) may benefit from prolonged resuscitation & extracorporeal rewarming

Special Situations

Avalanche:

- **<35min** burial: hypothermia is not the cause of cardiac arrest (not enough time to cool below 32^{o}C)
- **>35min** burial: if the airway is patent, hypothermia may be the cause of cardiac arrest

Who is Cold & Dead?

- History of arrest prior to cooling
- Core temp >32^{o}C (hypothermia not the cause)
- Frozen solid (chest not compressible)
- K>12mmol L^{-1}
- Special circumstances: (drowning, trauma, avalanche)

Objectives

- ~~Who is cold and dead~~
- ~~Special circumstances (trauma, drowning, avalanche)~~
- Step by step resuscitation of severe hypothermia
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Accidental Hypothermia Simplified

3 steps:

1. Is CPR required?
2. Determine transport destination
3. Supportive care and rewarm

Unconscious with vital signs

Step by Step Resuscitation:

- Active external and minimally invasive rewarming:
  - warm environment or full body insulation
  - chemical, electrical, or forced-air hearing blankets (under & over patient)
- Airway management as required
- Warm (38-42°C) IV fluids titrated to clinical volume status (expect significant volume requirements during rewarming)
- +/- Warm (38-42°C) bladder lavage
- Cardiac monitoring, minimal & cautious movements

Unconscious with vital signs

Not to worry: (should resolve with warming)

- Bradycardia
- Mild hypotension
- Atrial fibrillation

Prepare for cardiac arrest: (ECMO/CPB center)

- Ventricular arrhythmias
- Hypotension out of proportion
- Very low core temperatures….28, 24…..

Not recommended: (incr complications, no benefit)

- body cavity lavage, endovascular devices
- extracorporeal heating systems without CV support

Unconscious with vital signs

Vasopressors:

- Hypothermia causes profound vasoconstriction and myocardial irritability
- Risk of arrhythmia likely greater than benefit early in resuscitation
- If rewarming induced vasodilatation starts causing significant hypotension, reconsider risk / benefit
- Careful if concurrent frostbite

Hypothermic Cardiac Arrest

Step by step resuscitation:

- High quality CPR
- Transport to ECMO/CPB (upto 6hr reasonable if good history)
- Prevent further heat loss
- Trial of electricity +/- epinephrine
- If you truly can’t transport to ECMO/CPB:
  - Thoracic lavage, bladder lavage

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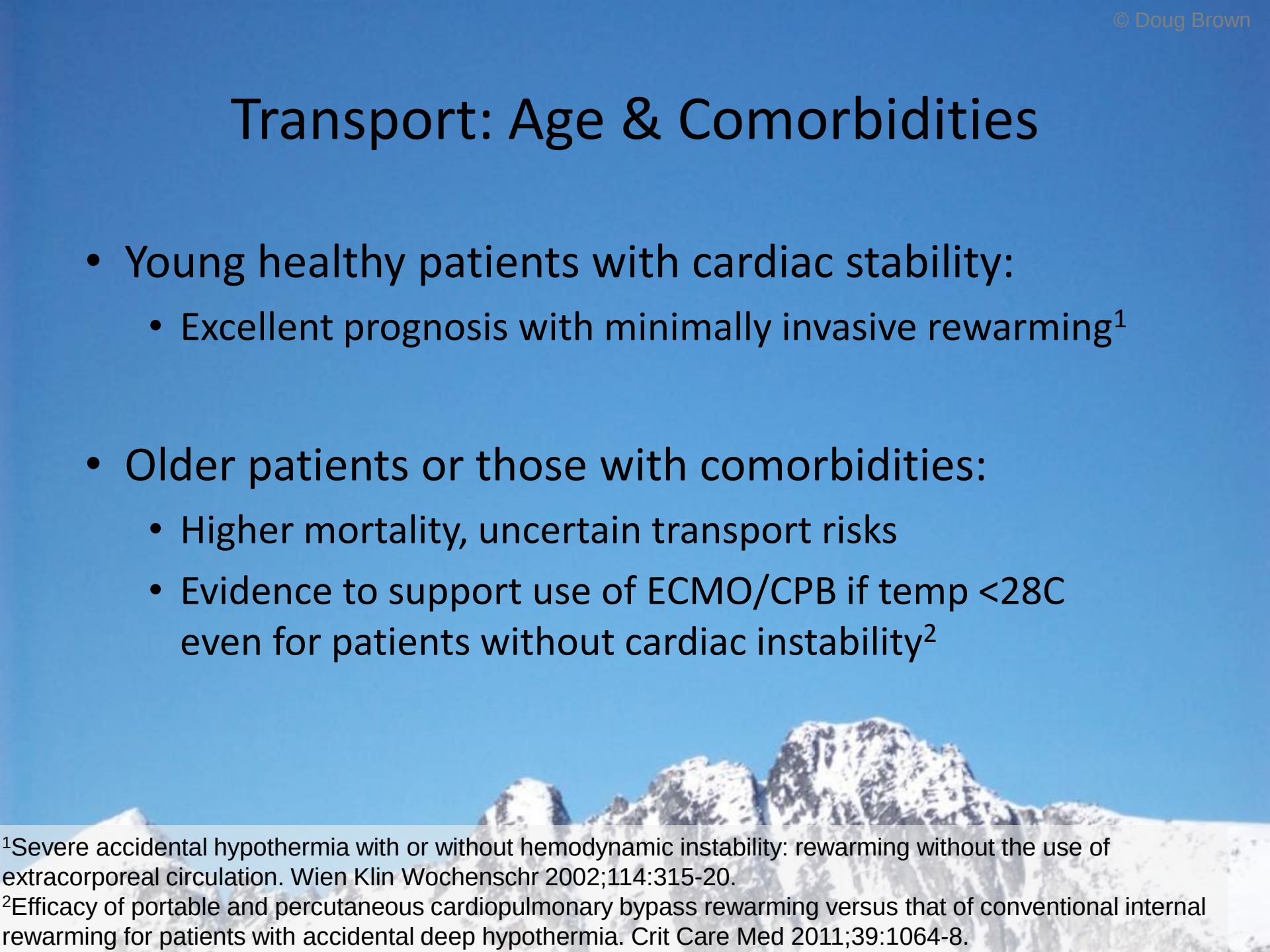
Transport Issues

- Risk of long transport vs. benefit of ECMO/CPB:
  - Duration of CPR not a predictor of outcome
  - Several case reports: ~4hr CPR -> ECMO/CPB
  - Outlier: 6.5hr CPR, no ECMO/CPB (Norway, Artic Med Resuscitation, 1991)
- Effect of age and comorbidities
- Keep patient cold vs. warm

Transport: Age & Comorbidities

- Young healthy patients with cardiac stability:
  - Excellent prognosis with minimally invasive rewarming[1]
- Older patients or those with comorbidities:
  - Higher mortality, uncertain transport risks
  - Evidence to support use of ECMO/CPB if temp <28C even for patients without cardiac instability[2]



[1]Severe accidental hypothermia with or without hemodynamic instability: rewarming without the use of extracorporeal circulation. Wien Klin Wochenschr 2002;114:315-20.

[2]Efficacy of portable and percutaneous cardiopulmonary bypass rewarming versus that of conventional internal rewarming for patients with accidental deep hypothermia. Crit Care Med 2011;39:1064-8.

Transport: Cold vs. Warm

- Prehospital rewarming is important to prevent further cooling but is unlikely to significantly rewarm the patient[1]

- Opinion: simplify management by recommending minimally invasive rewarming for all patients (controversial with cardiac arrest patients)

- Risk of Not Rewarming:
  - Further temperature drop increases risk of multi-organ failure, coagulopathy, arrest and death
- Risk of Warming:
  - If brain rewarmed prior to provision of adequate blood flow then neuroprotection may be lost

[1]Lundgren et al. Scandinavian Journal of Trauma, Resuscitation and Emergency Medicine 2011, 19:59

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Next Steps

Hypothermia Chain of Survival in BC:

- BC Clinical Practice Guideline promoting best care for HT I – IV
- Education of front line->quaternary care providers
- BCAS, BCPTN, EPOS & Critical Care Transport Advisers triage potential cases and refer to ECMO providers
- Invest in equipment for prolonged transport of patients in cardiac arrest

Thank You