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Hypothermia and Frostbite

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Boy revived after hours in frigid weather

Associated Press

ROYALTON, Minn. — A 4-year-old boy spent 2½ hours in frigid temperatures after his dog mauled him, arriving at the hospital with a body temperature of only 75 degrees.

Kyle Zimmerman's condition improved slightly Tuesday but doctors said it was still too early to know his prognosis. He was in critical but stable condition, said Lynda Nordeen, a spokeswoman for Children's Hospital in St. Paul. He recognized his parents and was answering yes-and-no questions, she said.

"We really didn't expect (to save him), but you never give up," said Dr. Oliver Wiger, who helped revive the boy after the incident Sunday.

A neighbor dropped Kyle off at home around 5:30 that evening. But before he made it into his house, his dog caught him and pulled him around the yard, ripping off his clothes. Meanwhile, his mother thought he was still at the neighbor's house.

When Kyle's father, Gary, found him around 8 p.m., the boy had no pulse and wasn't breathing. The outside temperature at the time was about 8 degrees.

Zimmerman called for help, telling sheriff's dispatcher Renee Park "My baby boy, my baby boy! ... Oh, God, he's frozen solid!"

Park gave resuscitation instructions to the Zimmermans over the telephone until help arrived.

The family hadn't had previous problems with the dog, a 60-pound mixed breed, said Park. It was destroyed.

 Newspaper article from the Spartanburg Herald-Journal. February 17, 1993

Soldiers die of exposure during Ranger training

By Bill Kaczor
Associated Press

EGLIN AIR FORCE BASE, Fla. — Four soldiers died of exposure after struggling through chilly, chest-deep swamp waters in the last days of a stressful two months of Army Ranger training, officials said yesterday.

Three died after they were rescued Wednesday and the body of a fourth was found yesterday morning after an all-night search.

Four others suffering from hypothermia were rescued Wednesday night.

Hypothermia is caused by severe loss of body heat, leading to extreme fatigue, drowsiness, disorientation, and sometimes death.

The Ranger training, some of the most demanding in the military, has been halted until Army investigators can determine what happened.

The soldiers had already been tested in the forest, desert and mountains to prepare them for extreme war conditions.

A decision to cross chilly streams swollen by rain in the swampy grounds of Eglin Air Force Base was blamed for their exposure, Army officials said.

The water temperature was 52 degrees, just above the 50-degree threshold set in 1977 after two soldiers died from hypothermia during Ranger training.

 Newspaper article from The News. February 17, 1995

Hypothermia

- **Definition :**
  - **Body temperature < 35 degrees C (95 °F)**
- **Severe hypothermia :**
  - **Body temperature < 28° C**

Hypothermia : Disjointed Facts

- 1987 multicenter study : 16 % of cases reported from Florida
- Probably causes 700 deaths / year in U.S.
- Age > 75 are 5X as likely to die from accidental hypothermia

Hypothermia : Mortality

- If severe trauma and hypothermic : 69 % mortality
- Mild (> 32 °C) hypothermia : 0 to 10 % mortality
- If underlying disease : up to 90 % mortality
- Presence of ETOH : not correlated

Hypothermia : Body Heat Production

- 1/2 of body heat generated by the liver, heart and brain
- At rest, muscle contributes 25 %
- Exposure to cold leads to increase in muscle tone which increases body heat production by 50 to 100 %
- Shivering increases body heat production 400 %

Hypothermia : Body Heat Dissipation

- Radiation (infrared) : 65 %
- Conduction : increased 25X by water immersion
- Convection : loss by air currents ("wind chill")
- Evaporation : 20 to 30 %

Conditions Predisposing to Hypothermia

1. Extremes of age
2. Metabolic diseases
   - Hypothyroidism
   - Diabetes
   - Renal failure
   - Hypoadrenalism
3. CNS diseases
   - Cerebrovascular disease
   - Any degenerative CNS disease
   - Head trauma
   - Parkinson's
4. Shock
   - AMI / CHF
   - Hemorrhage
5. Malnutrition
6. Drugs
   - Any CNS depressant
   - ETOH
7. Dermal diseases
8. Paget's disease
9. Infections
10. Pancreatitis

Causes of Vulnerability to Hypothermia by the Elderly

- Lack of ability to shiver
- Thinner epidermis ; less effective insulator
- Lack of cardiovascular reserve for compensation
- Tendency toward baseline dehydration
- Movement impairment
- Effects of concurrent medications

Other Potential Effects of Exposure to Cold

- Diuresis from decreased reabsorption in the kidney
- Greater susceptibility to viral infections
- Greater risk of pneumonia
- Increased incidence of acute M.I. in the winter
  - Sudden breathing of very cold air can provoke angina ; may be partially preventable by wearing cloth mask over face
- Remember also the increased incidence of carbon monoxide poisoning in the winter from malfunctioning heaters

Time of Onset of Hypothermia

- Onset time depends on temperature differential between body & environment
  - Risk of hypothermia starts at about 65° F (differential of 30° F) ; time of onset then is > 2 hours to days
  - If differential 60 to 70 degrees : time of onset about one hour
  - If differential 100 degrees or more: time of onset just a few minutes
  - If associated with water immersion : time of onset accelerated

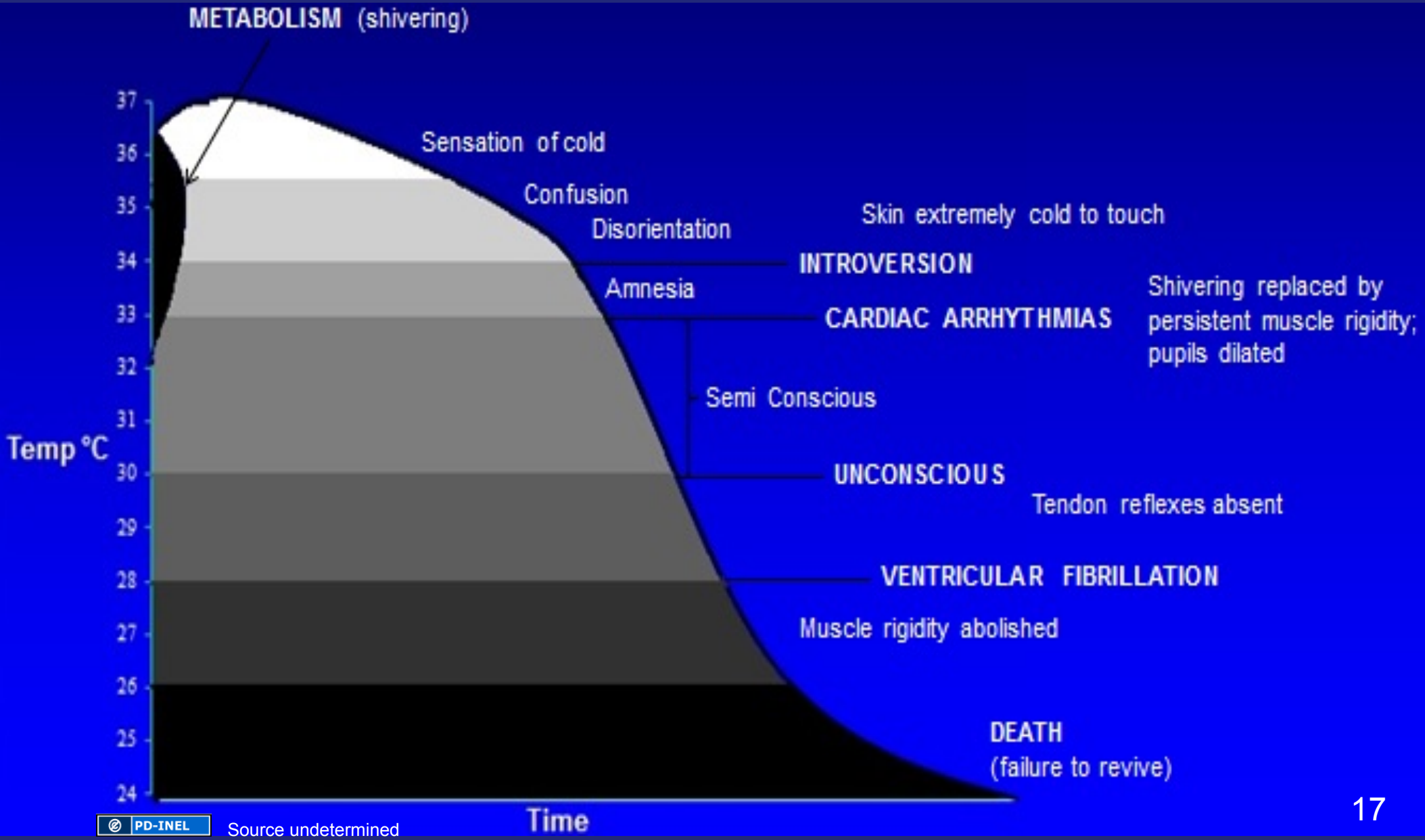
Hypothermia in Trauma Patients

- If occurs, shown to increase mortality compared to that expected from their Injury Severity Score (ISS)
- Can occur in just a few minutes after E.D. arrival
- Exacerbated by soak dressings for burns or wounds
- Often first manifested by sudden coagulopathy & capillary bleeding
- Always should not just measure temp. early, but also continue to monitor core temp.
- Can cause "masking" of pain from injuries

Hypothermia : Typical Clinical Findings at Specific Body Temperatures

- 35 degrees
  - mild confusion, lethargy, shivering
- 34 degrees
  - amnesia
- 32 degrees
  - semiconscious, muscle rigidity, pupils dilated
- 30 degrees
  - Unconscious, tendon reflexes absent, resp. rate decreased to < 10 per minute

Curve representing behavior of body temperature during cold water immersion

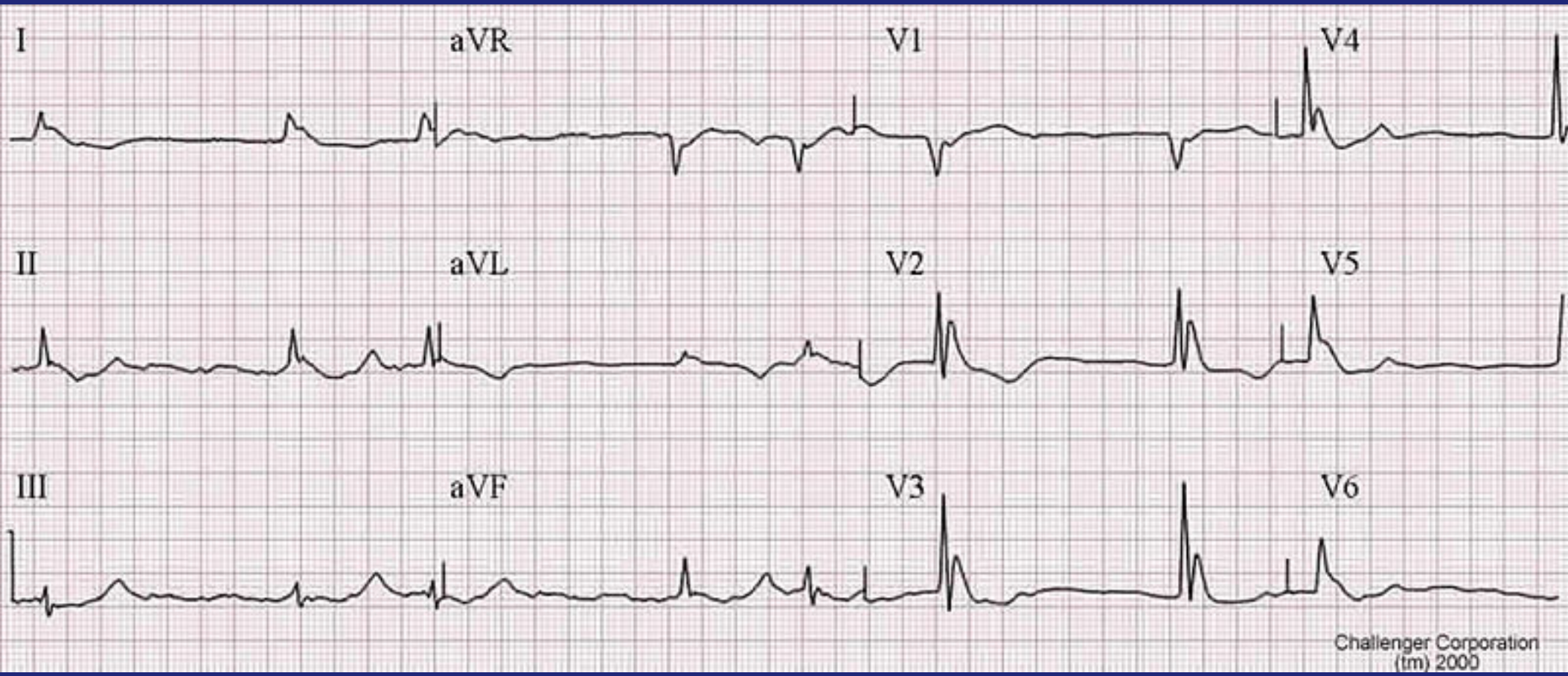


Hypothermia : Neurologic Effects

- Cerebral blood flow decreased by 6 to 7 % for each 1° F decrease in core temperature
- May cause fatigue / confusion : "paradoxical undressing"
- EEG flat line below 20°C (68 °F)

Hypothermia : Typical Cardiac Rhythms

Temp. (C) °	Rhythms
33 to 36	Sinus tachycardia
32 to 35	Sinus bradycardia
28 to 32	Atrial fibrillation
< 28	Ventricular fibrillation
< 26	Asystole



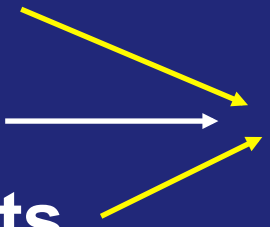
Osborn J wave in a hypothermic person

Hypothermia : Laboratory Values

- ABG's : 30 % show acidosis, 25 % show alkalosis
- CBC : Hemoconcentration, leukopenia, thrombocytopenia
- Glucose : high-acute, low-chronic and subacute
- Amylase : elevated in up to 50 % in old reports
- PT / PTT : coagulopathies common at < 35 degrees

Effect of Decreased Temperature on Arterial Blood Gas (ABG) Values

- Blood gas machines warm sample to 37 degrees C for measurement
- pCO2 decreases 4.4 %
- pO2 decreases 7.2 %
- pH increases 0.015 units
- Use of temperature correction table now thought to not be necessary



per degree C drop

Temperature Correction for Arterial Blood Gas Values

Body Temperature		Correction Factors*		
°F	°C	PCO_2	PO_2	pH
98.6	37.0	1.00	1.00	0.00
95.0	35.0	0.92	0.89	+0.03
90.0	32.3	0.82	0.76	+0.07
88.0	31.1	0.78	0.72	+0.09
86.0	30.0	0.74	0.67	+0.10
84.0	28.9	0.71	0.63	+0.12
82.0	27.8	0.68	0.59	+0.14
80.0	26.7	0.64	0.56	+0.15
78.0	25.6	0.61	0.52	+0.17
76.0	24.4	0.59	0.49	+0.18
74.0	23.3	0.56	0.46	+0.20
72.0	22.2	0.53	0.43	+0.22

PCO_2 decreases 2.4% per degree F fall in temperature.
PO_2 decreases 3.3% per degree F fall in temperature.
pH increases .006 units per degree F fall in temperature.

*See sidebar, Determining Correction of Arterial Blood Gas Values in Hypothermic Patients

Acid - Base Status in Hypothermia

- No consistent predictable acid-base pattern is seen
- Decreased CO_2 production but also usually hypoventilation
- O_2 consumption is decreased 50 % at temp. of 30 degrees C
- Acidosis more prevalent in some series, but alkalosis found in 1/2 of cases in other series
- Routine use of Na HCO_3 not indicated

Hematologic Effects of Hypothermia

- Rise in hematocrit (hemoconcentration)
- Increase in viscosity
- Leukopenia
- Thrombocytopenia
- Altered function of coagulation proteins
- WBC count not predictive of presence of infection or of mortality

Lab Values Not Consistently Altered by Hypothermia

- Serum sodium & potassium
- Plasma cortisol
- Serum creatinine (BUN sometimes increased due to hemoconcentration)
- TSH & T4 levels
- Insulin levels
- Liver & muscle enzymes
- Amylase (some old reports however had high incidence of pancreatitis)

Core Temperature Measurement Techniques

- Best techniques (in rough order of accuracy) :
  - Esophageal
  - Thermistor in central IV line or Swan-Ganz catheter
  - Tympanic (anesthesia monitoring probe type)
  - Urine ; accurate; can be done by thermistor in foley
  - Rectal ; lags behind esophageal during rewarming
- Important in all cases to have a low-reading thermometer (standard oral / rectal mercury thermometers only go down to 33 to 34^{o} C)

General Management of the Hypothermic Patient

- ABC's first ; oxygen always
  - Support ventilation
- Obtain accurate temp. by low reading thermometer
- Start rewarming measures
- Rehydrate ; may need to be rate cautious in elderly patients; may need central line to assess fluid resuscitation status
- Foley / NG tube
- Continuous core temp. & cardiac monitoring
- Assess for & treat associated illnesses & injuries
- Consider ICU admission

Factors to Assess Which Influence the Severity and Prognosis of Hypothermia

- Body temperature (severe if < 28 degrees C)
- Patient age
- State of consciousness
- Cardiorespiratory status
- Metabolic status
- Associated diseases
- Associated injuries
- Etiology of hypothermia
- Duration of hypothermia
- Response to initial care measures

Lab Tests to Consider for Most Cases of Profound Hypothermia

- ABG +/- carboxyhemoglobin
- CBC, glucose
- Electrolytes, BUN, creatinine, calcium
- PT, PTT, platelets
- Amylase
- Alcohol +/- drug levels
- Thyroid function tests
- Serum cortisol
- Liver function tests, muscle / cardiac enzymes
- Cultures, etc. if infection suspected
- Type & crossmatch

Effect of Hypothermia on Medications

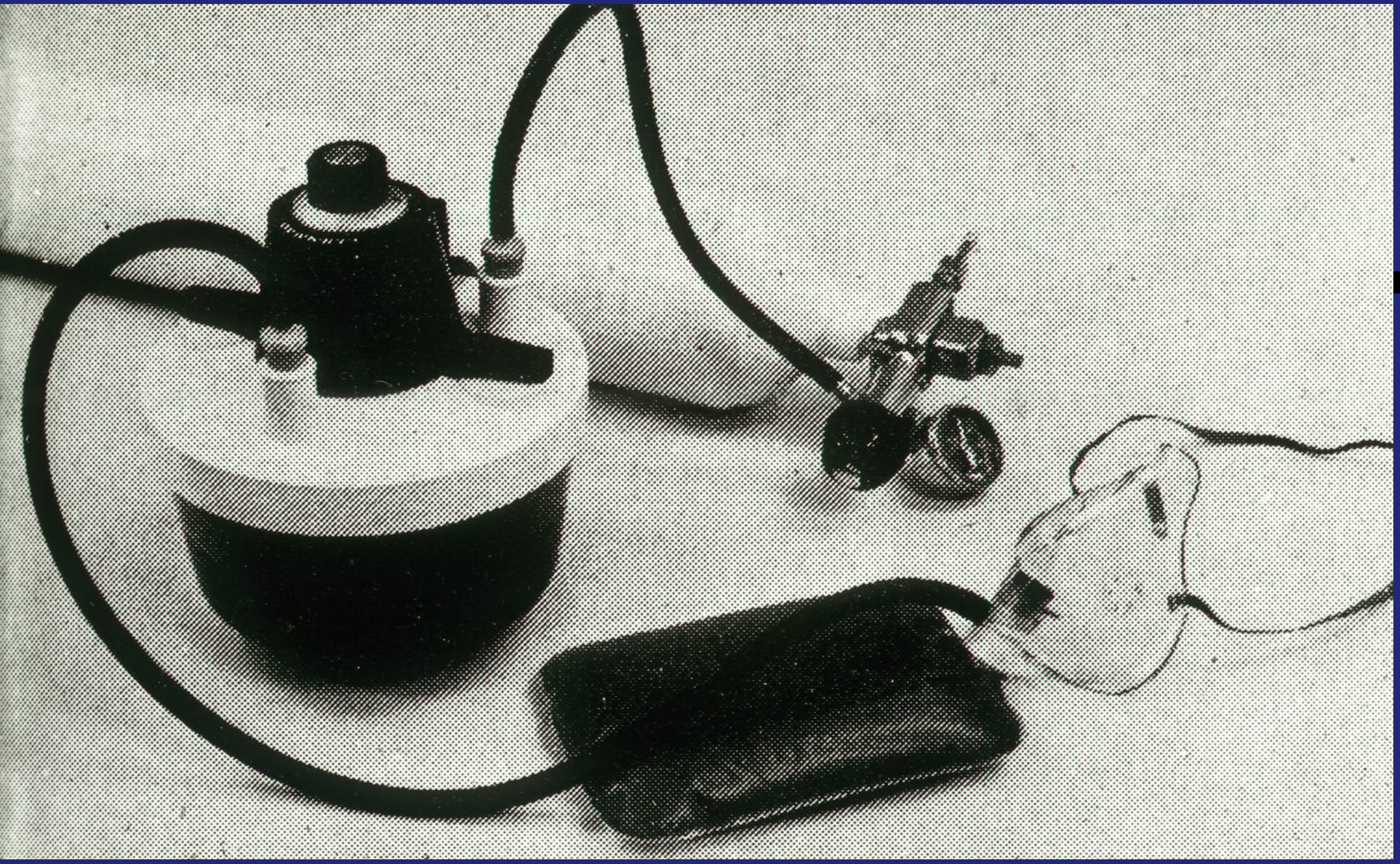
- Antiarrhythmic meds generally ineffective if core temp. < 30 degrees C
- Few case reports of "chemical defibrillation" by bretylium at core temp. < 30 degrees C
- Medications administered early may show sudden exaggerated effects once core temp. increases & circulation restored (especially insulin)

Hypothermia : Rewarming

- Objective of rewarming :
  - Core temperature rise $\geq 1^{o}$ C per hour
  - If this cannot be achieved, then either more aggressive rewarming measures need to be done, or the patient is dead & unresuscitatible

Hypothermia : Core Rewarming Techniques

1. Warmed O2 (42) by FM or ETT
2. Warmed IV fluid (42) °
3. Nasogastric tube lavage
4. Rectal tube lavage
5. Peritoneal dialysis catheter lavage
6. Chest tube lavage
7. Thoracotomy / mediastinal lavage
8. Cardiopulmonary bypass (fem-fem)



Inhalation rewarming apparatus

Hypothermia : External Rewarming Techniques

- Warm blankets ; cover scalp
- Warm environment (heat the room or ambulance)
- Hypo / hyperthermic blanket (water pump)
- Warm water bath
- Axillary / groin hot packs

Disadvantages of Active External Rewarming as Sole Rewarming Technique

- May cause :
  - Core temp. "afterdrop"
    - May result in V-fib
  - Hypotension / cardiovascular collapse from peripheral vasodilatation
  - Increased hypoxia & acidosis if peripheral metabolism increases but the "cold" heart not yet able to compensate

"Afterdrop" Phenomenon

- This is defined as a drop in core temperature after external rewarming is started
- Thought to be due to shunting of cold blood from the skin & extremities (due to vasodilation induced by external rewarming) to the core of the body
- Older series reported higher mortality with external versus passive rewarming, and "afterdrop" was thought to be the cause
- Some of this mortality may have instead been due to cardiovascular collapse from hypovolemia from peripheral vasodilation

Core Rewarming by Immersion

- Two early reports of this technique had respectively zero, and one in 18 mortality
- Uses Hubbard tank with 40 to 42 degree C water
- All hypothermic patients in one report were admitted directly to the burn center
- All patients in one series were rewarmed to 37 degrees C in < 3 hours

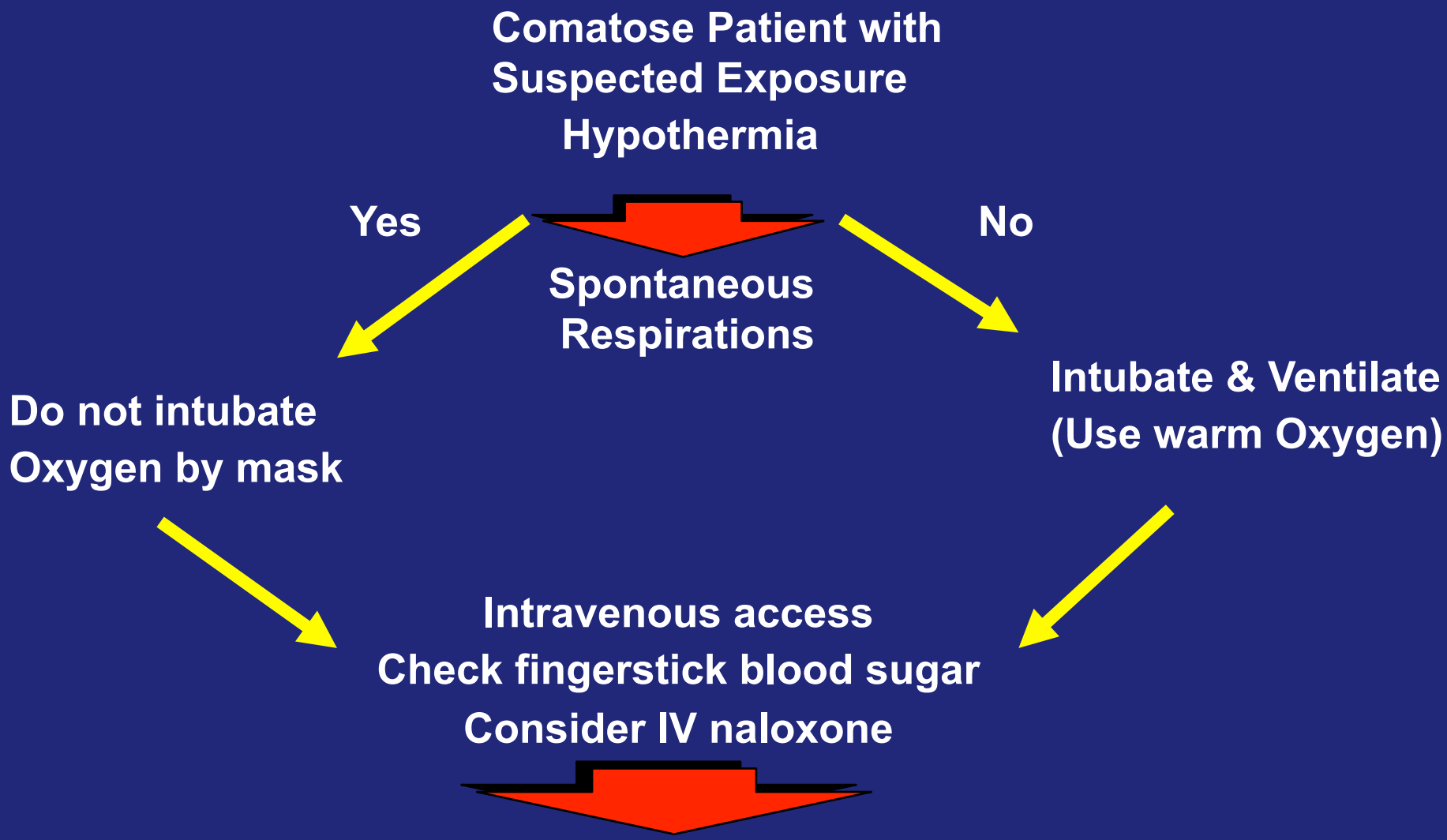
Hypothermia : Field Care

- Core Temperature < 28 C°
- Hold CPR if :
  - No monitor available
  - Any patient movement observed
  - Respiratory rate 4 to 6 breaths / min.
  - Sinus bradycardia or atrial fib on monitor
  - Pulse present (even if slow)

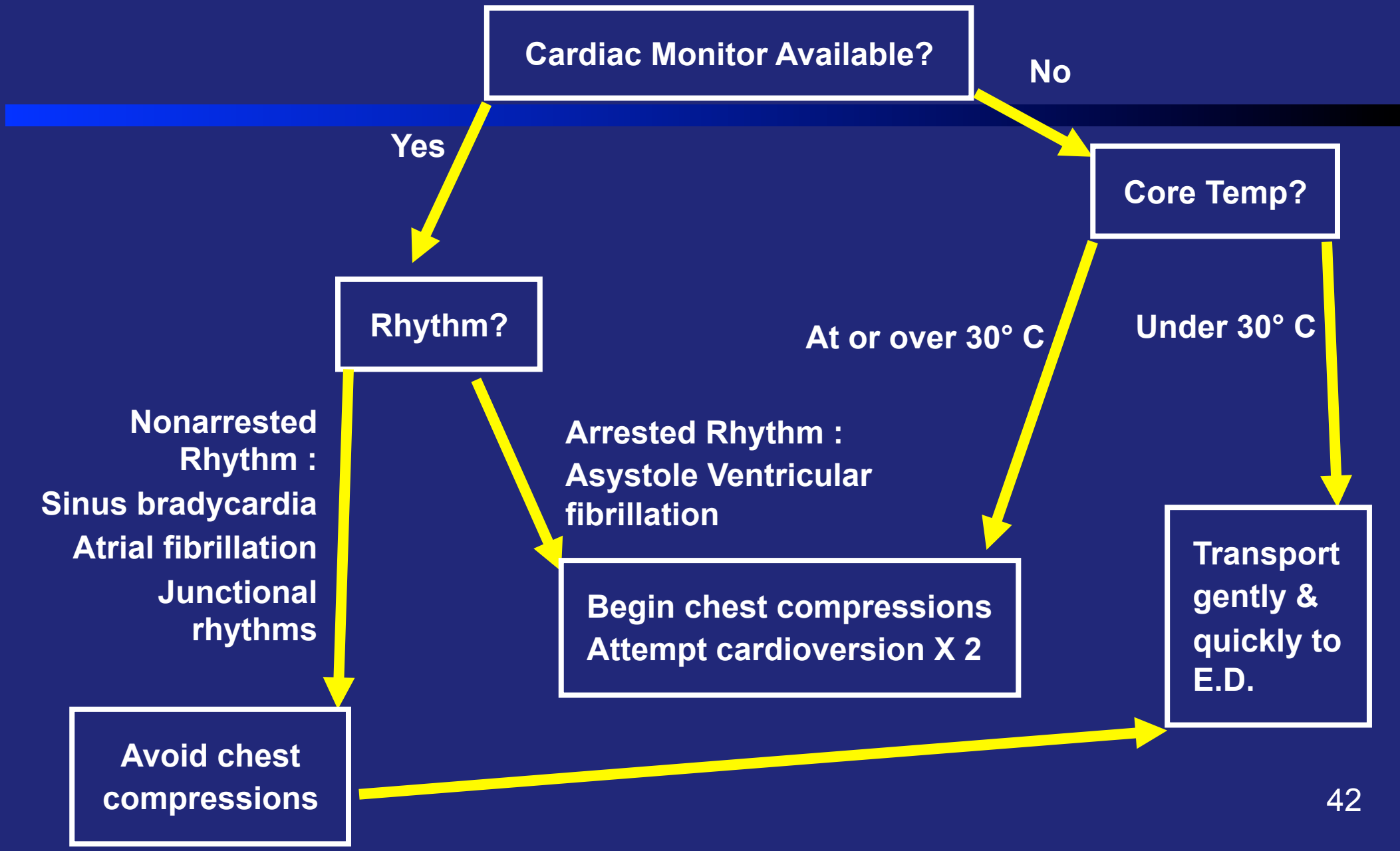
Hypothermia : Field Care

- CPR if :
  - VF or asystole on monitor
  - Arrested and only mild hypothermia (32°to 35°C)
- IV Glucose or checking dextrostick should be routine (+/- naloxone)

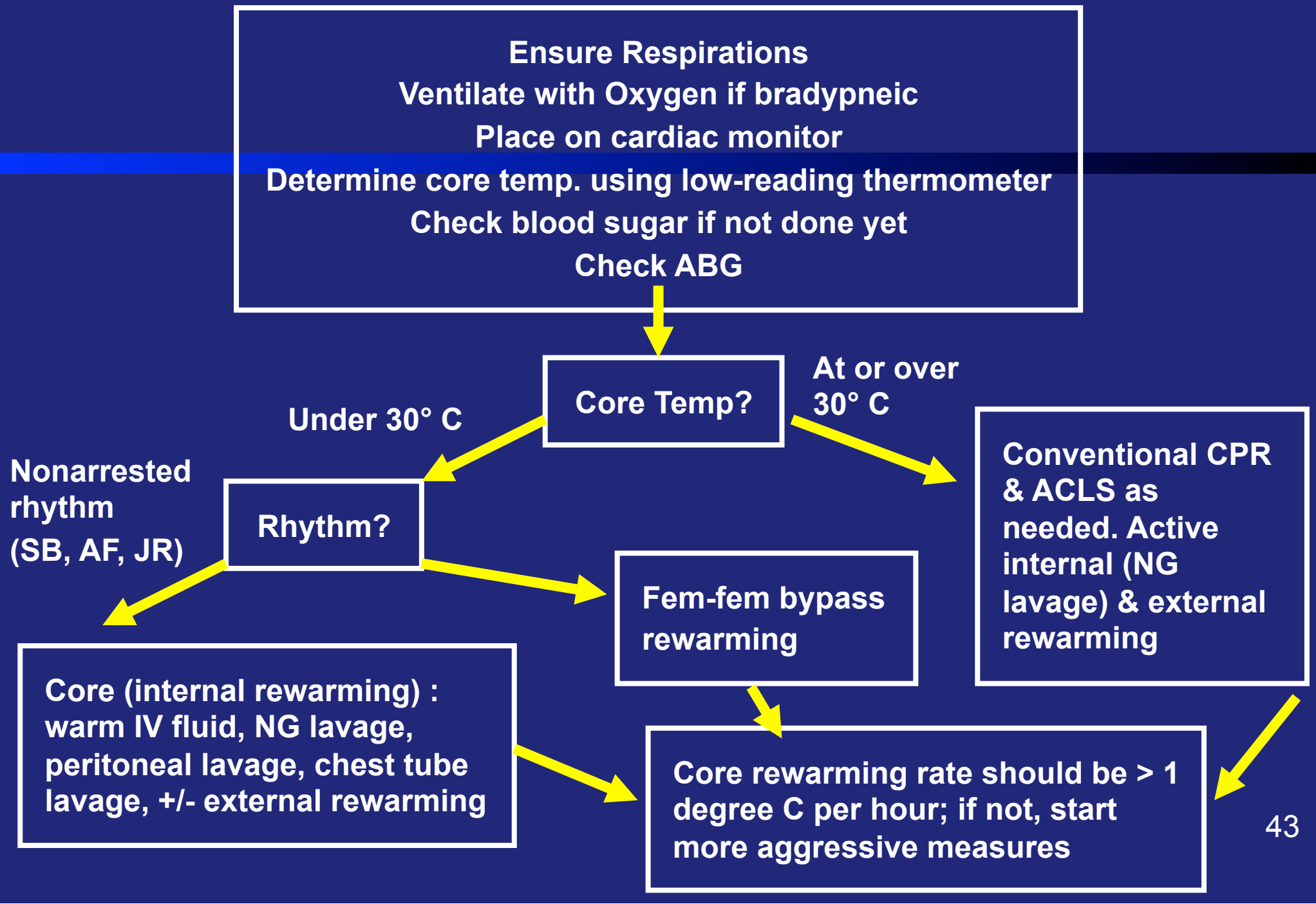
Field Care Algorithm For Hypothermia



Hypothermia Field Care Algorithm (cont.)



E.D. Hypothermia Care Algorithm



Hypothermia: Potential Complications

- Interventions that can cause Ventricular Fibrillation if body temp. < 28°C :
  - Endotracheal intubation
  - Nasogastric intubation
  - Central (intracardiac) IV catheters
  - Chest compression

Use of Corticosteroid Rx for Hypothermia

- IV corticosteroids (at least 100 mg hydrocortisone or equivalent) are indicated if adrenal insufficiency or myxedema coma suspected
- For severe exposure hypothermia with exertional exhaustion, some advocate routine use
- No clear benefit for most cases, & especially minor cases

Prevention of Hypothermia in Trauma Patients

- Warm the trauma resuscitation room
  - Should have separate thermostat from rest of E.D.
  - Limit personnel traffic in & out of room
- Heating lamps
- Heating blanket
  - Have in place before patient placed on stretcher
- Warm all IV fluids & blood
- Cover patient's scalp once it is examined
- Maintain coverage of patient's body with blankets once exam is complete

Prevention of Hypothermia in the Elderly

- Consider home visit by health professional for environmental assessment
  - Improve insulation +/- add storm windows +/- carpeting
  - Eliminate air leak drafts
  - Check furnace function
  - Keep thermostat at 68 degrees F or higher
  - Check for adequate bedding material +/- electric blankets
  - Wear layers of clothing even when indoors
  - Proper nutrition & fluid intake
  - Consider alternative supplemental heaters
    - Usually hazardous however

General Prevention Measures for Exposure Hypothermia

- Adequate clothing in layers
- Cover scalp
- Avoid alcohol / sedatives
- Limit wind exposure
- Maintain fluid intake
- Change wet clothes promptly
- If getting wet is unavoidable, use wool garments (wool maintains insulation effect even when wet, unlike cotton)
- Trip planning
- If immersed in cold water, extend survival time by remaining still, huddling in group, and H.E.L.P. posture

Survival Times in 50°F Water

Situation	Hours of Survival
No Flotation	
Drownproofing	**1.5**
Treading water	**2.0**
With Flotation	
Swimming	**2.0**
Holding still	**2.7**
H.E.L.P.	**4.0**
Huddle	**4.0**

Heat Escape Lessening Position (HELP)

The heat escape lessening position (HELP) is a way to position oneself to reduce heat loss in cold water. The HELP reduces exposure to high heat loss areas of the body. Wearing a personal flotation device allows a person to draw their knees to their chest and arms to their sides.

PD-GOV United States Government (Wikimedia Commons)

- Adapted from Wikipedia

Factors That Predispose Sports Participants to Cold Injuries

Factor	Mechanism
Wind Moisture Inadequate clothing	Increase heat loss
Alcohol consumption Fatigue	Increased heat loss, impaired judgment
Injury Loss of consciousness	Increased heat loss
Tobacco use Constricting garments	Diminished peripheral blood supply
Contact with metal or hydocarbons (eg, fuels)	Increased thermal conductivity
High altitude	Hypoxia

Frostbite

- Freezing cold injury = frostbite
- Nonfreezing cold injury
  - Trenchfoot (immersion foot) : due to exposure to wet cold for 1 to 2 days; causes skin damage like partial thickness burns ; deep damage rare
  - Chilblain (pernio) : due to prolonged exposure of limb to dry cold : small painful ulcers over exposed areas

Frostnip

- The initial clinical response to cold (reversible)
- Skin becomes blanched and numb, followed by sudden cessation of cold & discomfort
- If treated quickly with rewarming, will not progress to frostbite

Frostbite : Pathophysiology

- Extracellular ice formation
- Intracellular ice formation
- Cell dehydration and shrinkage
- Abnormal intracellular electrolytes
- Thermal shock
- Lipid-protein denaturation

Frostbite : Pathophysiology

- Pre-freeze phase (38 to 50 °F)
  - Vasospasticity and vascular leak
- Freeze-thaw phase (5 to 21 °F)
  - Ice crystal formation
- Vascular stasis phase
  - Blood vessel dilation, coagulation
- Late ischemic phase
  - From thrombosis and shunting

Frostbite : Two Types

- Superficial : skin is cold, pale, gray, bloodless, but pliable and soft beneath the surface
- Deep : tissue feels woody or stony
- Can diagnose these only prior to thawing

Superficial Frostbite: Clinical Progression

- 24 hours : large clear blisters
- 2 to 7 days : skin blackens, demarcates (dry gangrene)
- Several months : peels off, revealing sensitive new skin

Deep Frostbite

- May include muscle, bone or tendon necrosis
- Distal portions remain cold and cyanotic after rewarming
- Risk of rhabdomyolysis

Frostbite : Clinical Presentation

- First degree
  - Erythema, yellowish plaque
- Second degree
  - Skin vesicles filled with clear or milky fluid
- Third degree
  - Skin vesicles filled with bloody fluid
- Fourth degree
  - Injury across dermis ; dysfunction and damage of deep structures

Frostbite : Treatment

- Rapid rewarming in 42°C water (do not thaw in field if refreezing might occur)
- Narcotics
- Tetanus prophylaxis
- Topical antibiotics as for 2nd degree burns
- No debridement surgery for at least several months unless wet gangrene / infection occur
- If large amounts of tissue involved, watch for rhabdomyolysis / renal failure

Treatments Shown to Not be Effective for Rx of Frostbite

- Heparin
- Oral anticoagulants
- Dextran
- Surgical sympathectomy
- Steroids
- Vasodilator drugs

Prognostic Signs for the Recovery of Frostbitten Tissue After Thawing *

Favorable	Unfavorable
Sensation to pinprick	Cold, cyanotic distal part
Normal color	Late appearance of small dark bullae that do not extend across the affected part
Warmth of tissues	Absence of edema
Early appearance of large, clear bullae that extend across the affected part	

***Interpret these signs with caution; extent of injury is often overestimated**

Frostbite : Sequelae

- Hyperhydrosis
- Joint stiffness
  - Scarring
  - Bone injury
- Premature closure of epiphyses
- Nail and nail color abnormalities
- Cold intolerance

General Prevention Measures for Frostbite

- Adequate clothing & footwear
  - Cover digits & ears
- Limit wind exposure
- Rapidly rewarm area if frostnip occurs
- Don't thaw frostbitten part if refreezing will occur before accessing medical care
- Avoid weight-bearing on frostbitten foot prior to accessing medical care

Frostbite on Toes – Same Day

Frostbite on Toes – 12 Days Later

Frostbite on Toes – 3 Weeks Later

Extreme Frostbite Can Lead to Gangrene

Extensive frostbite of both feet makes the patient at risk for rhabdomyolysis, *which is a condition in which damaged skeletal muscle tissue breaks down rapidly.*

- **Adapted from Wikipedia**

Extreme frostbite may result in fingers and toes being amputated if the area becomes infected with gangrene, which is a condition that arises when considerable mass of body tissue dies.

- **Adapted from Wikipedia (1, 2)**

Hypothermia & Frostbite Summary

- Evaluate & support ABC's first
- Check temp. with low-reading thermometer
- Start internal (core) rewarming first if profoundly hypothermic
- Add more aggressive rewarming measures if temp. increase is inadequate
- Also directly & quickly rewarm possible frostbitten areas
- Limit meds use until patient is rewarmed