

# Pediatric Readiness Program Education Session



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# Drowning in children: A Case-Based Review



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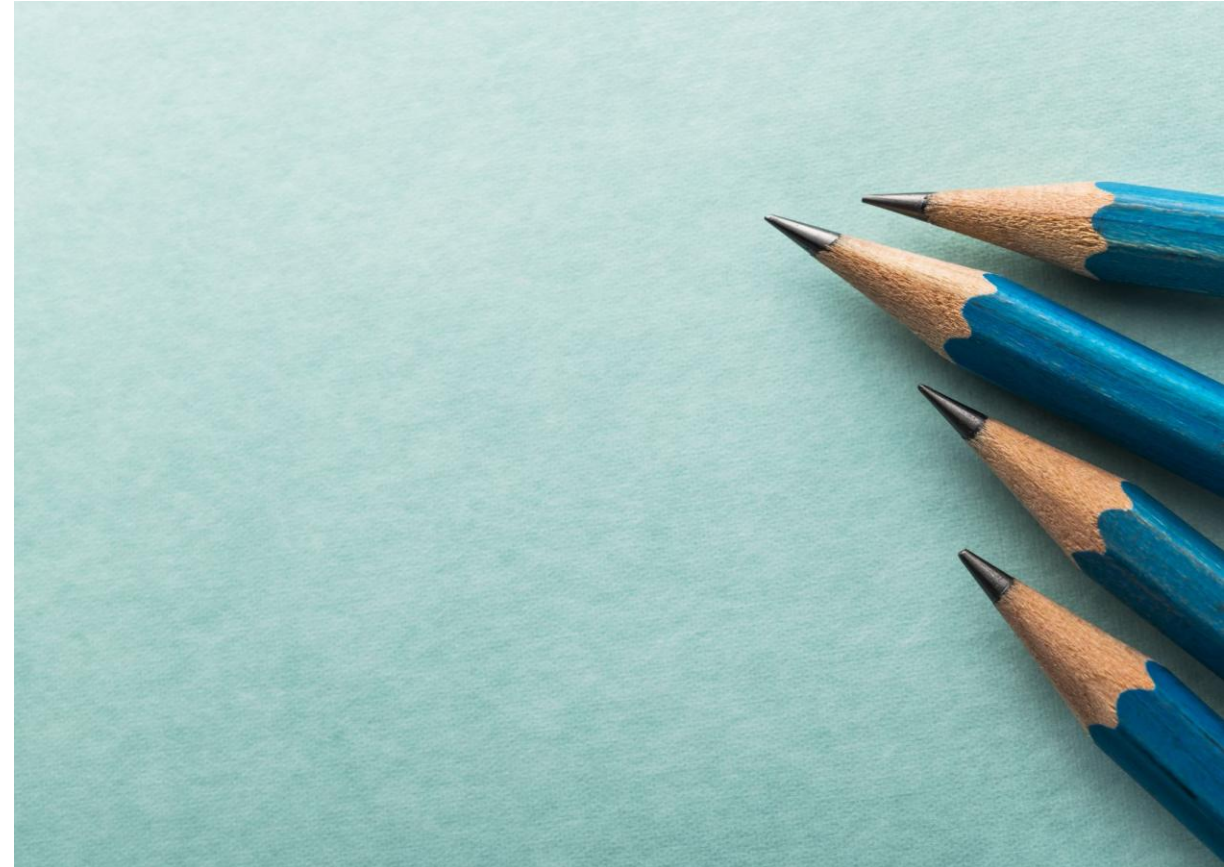


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# OBJECTIVES

- Understand the pathophysiology of drowning and the range of symptoms that can result
- Characterize appropriate treatment for a drowning episode
- Recognize consequences of drowning that can complicate resuscitation



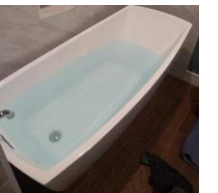
# Case 1

- 6 mo girl extricated from a bathtub
- Mother giving her a bath, found child slumped over, face in the water, pulled her from the water, gave a few rescue breaths. Coughing and spluttering, MS normalized
- Brought to the Emergency Department for evaluation
- Well appearing. Breathing comfortably, intermittent cough, HR 137, SpO2 98, BP 89/64, RR 24, T 37.4. Exam non-focal.



# Case 1

- 6 mo girl extricated from a bathtub
- Trauma activation? Spine precautions?
- Do you obtain imaging? If so, what type?
- What symptoms do you monitor for? For how long?
- Do all patients with symptoms need admission?



# Case 2

- 12 yo old boy found down in a lake, unsupervised for 3 minutes. GCS 6 in the field, SpO2 83, RR 10, HR 87, BP 98/57
- Coming with lights and sirens, will be arriving in 20 minutes.



# Case 2

- 12 yo old boy found down in a lake
- Trauma activation? Spine precautions?
- Do you obtain imaging? If so, what type?
- What additional testing will you order?
- What resuscitation will be required and what could make resuscitation especially challenging in this case?



# Case 3

- 3 yo boy, found down by his mother in their pool, estimated down time 15 minutes. Cold, blue, apneic. Bystander and then prehospital team initiates CPR, intubates, gives 2 rounds of IM epinephrine en route.
- On arrival, CPR ongoing. No pulse after 2 minutes at pulse check. Asystole. Patient is very cold.



# Case 3

- 3 yo boy found down in pool
- How long do you continue CPR?
- What factors are modifiable to increase your chances of ROSC?
- Trauma activation?





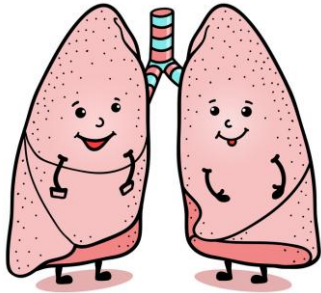
## Epidemiology

- >320,000 deaths per year worldwide
- ~4,000 deaths per year in the US
- 2nd leading cause of unintentional injury death in US and leading cause in ages 1-4
- For every child that dies, 7 will be seen in ED for treatment, and 40% of those require hospitalization

# Drowning

- Sequence of events that occur following submersion:
  - Breath holding
  - Laryngospasm
  - Hypoxia and hypercarbia
  - Swallowing
  - Water inhalation
  - Surfactant washout, pulmonary hypertension, shunting
  - Worsening hypoxia
  - Loss of consciousness
  - Death

# Pathophysiology



Lungs



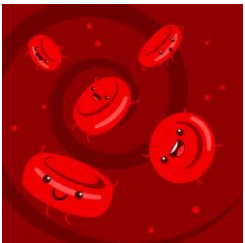
- Ischemia → cerebral edema → incr ICP
- Convulsive or subclinical seizures
- 6-20% sustain neurologic damage!

## Hypoxemia

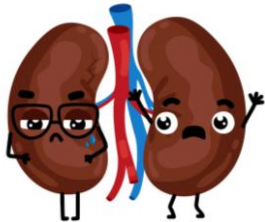
- Surfactant washout
- Non cardiogenic pulmonary edema
- ARDS



- Arrhythmias



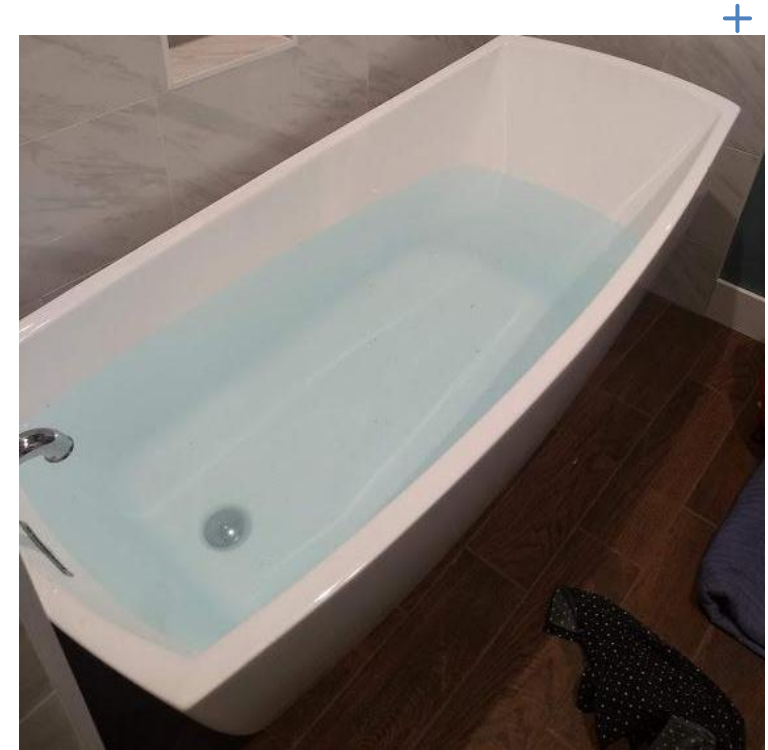
Hemolysis  
Coagulopathy

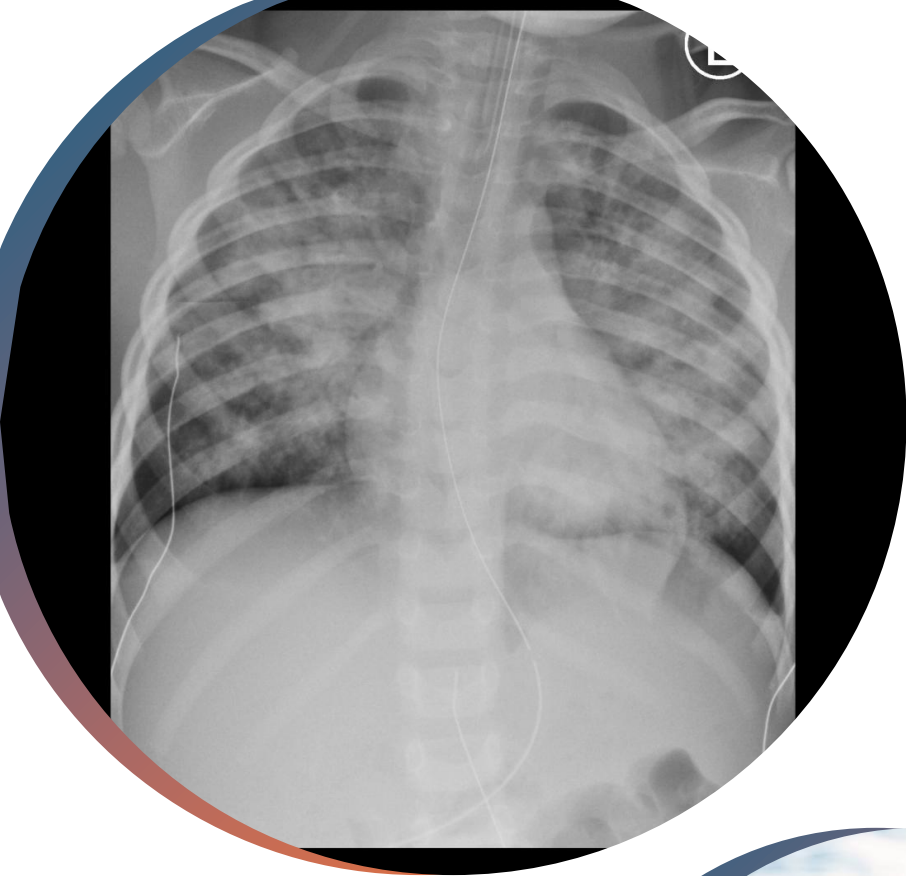


- AKI due to ATN
- Metabolic and/or respiratory acidosis (other electro changes rare)

# Case 1 Revisited

- 6 mo girl extricated from a bathtub
- Well appearing. Breathing comfortably, intermittent cough, HR 137, SpO2 98, BP 89/64, RR 24, T 37.4.  
Exam non-focal
- No trauma entry, no cervical collar
- Obtain BMP, liver panel, coags, a blood gas, CBC, CXR, and +/- EKG
- Duration of observation??





+



## How long after the drowning event can symptoms become apparent?

- Tachypnea, retractions, rales, or wheezing
- Usually develop in 4-6 hours, in several studies all within 7...



# Do all kids with symptoms need to be admitted?

## **Symptomatic patient with normal oxygen saturation —**

- ANY Respiratory symptoms = 8 hours of Observation
- If SpO<sub>2</sub> normal and CXR normal after observation, discharge appropriate only if ALL of the following:
  - Normal mentation
  - No new or worsening respiratory symptoms
  - If the patient has a cough, it should be improving prior to discharge
  - Any subjective dyspnea should resolve prior to discharge
  - Normal age-adjusted vital signs
  - Supplemental oxygen requirement does not develop
  - Normal pulmonary auscultation

# Case 1 Resolution

- At hour 4 developed mildly increased WOB with wheezing bilaterally. SpO2 94%, repeat CXR showed mild bilateral ground glass opacities
- Admitted to ward for observation, required supplemental oxygen, bronchodilators
- Improved within 24 hours and weaned off oxygen
- Discharged home with education on drowning prevention after 48 hours



# Case 2 Revisited

- 12 yo old boy found down in a lake
- GCS 6 in the field, SpO2 83, RR 10, HR 87, BP 98/57
- Trauma activation? Spine precautions?



# How common is cervical spine injury in drowning?

Jones T, Rennie A. BET 1: cervical spine immobilisation in the management of drowning victims, *Emergency Medicine Journal* 2019;**36**:766-767.

‘In patients with drowning episodes does routine immobilization of the surgical spine improve neurologic outcomes or reduce mortality?’

3 studies: 1 large multicenter, 2 small single centers

Watson: 11/2,244 < 0.5% overall, no bathtub or swimming

Hwang: 7/143, all teenagers, all at a pool, 6 diving, 1 assault

Heming: Drowning after falling from bridge. 0/10

In no paper was a cervical spine injury present in a patient without a clear traumatic mechanism.



# But why not just to be safe?

- ‘Cervical spine (C-spine) immobilization in trauma patients has been associated with increasing time to definitive care, difficult airways, increased mortality in patients with penetrating injuries, and also with pressure ulcers. Thus, C-spine immobilization of the drowning patient should be limited to those cases with a mechanism of injury concerning for significant C-spine injury.’
    - ED Management of Drowning, Helmen A. ACEP NOW, 7/6/2023
-

# Case 2 Revisited

- 12 yo old boy found down in a lake
- GCS 6 in the field, SpO2 83, RR 10, HR 87, BP 98/57
- Trauma activation? Spine precautions?
- What resuscitation might be required and what could make resuscitation especially challenging in this case?



# Case 2 Revisited

- On arrival EMS is providing CPR. Attempted to intubate and were unsuccessful.
- After 1 cycle of CPR pulses return.
- What factors could make this airway more difficult?

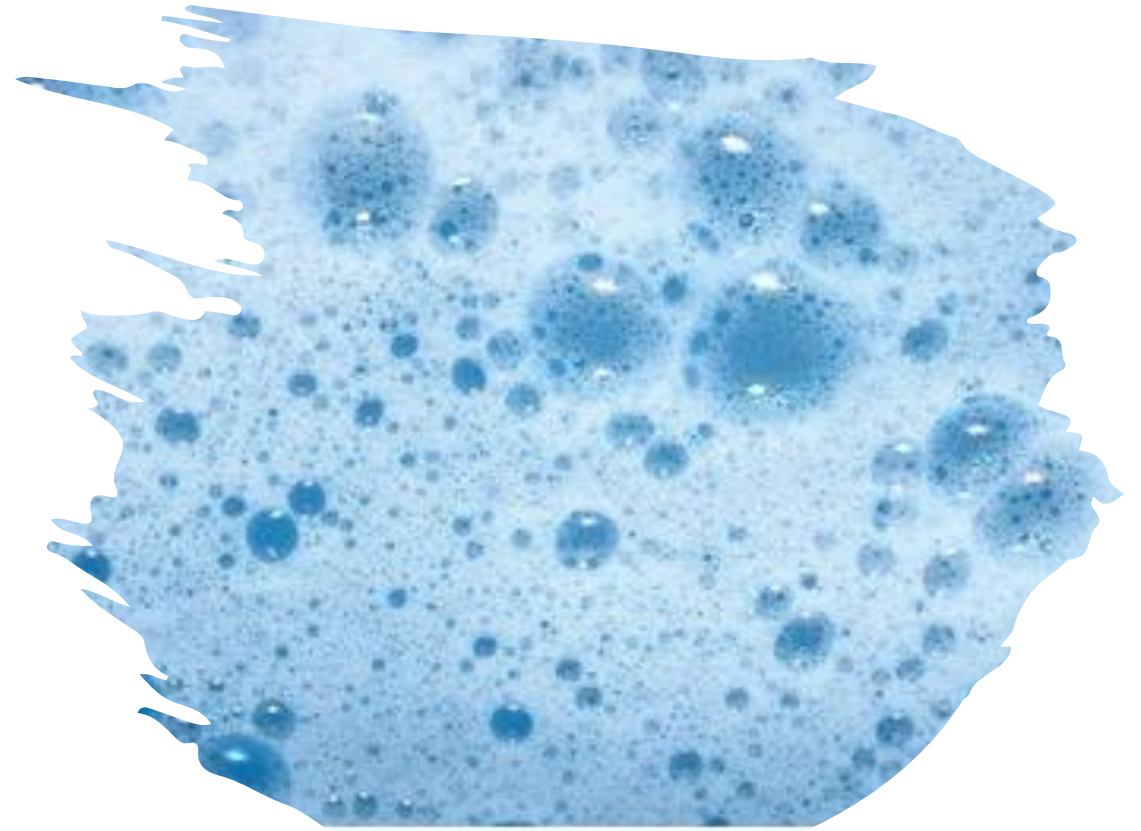


# What's all that foam?

Foam = water + surfactant

PPV is appropriate

Foam from upper airway =  
indication for intubation



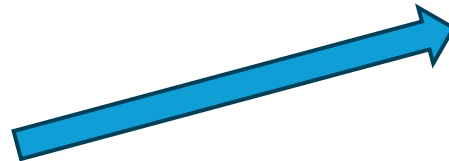


- 10 yr study in Australia: 66% who got rescue breathing, 86% who got compressions and ventilation vomited
- Suction vomitus, don't PPV into the lungs

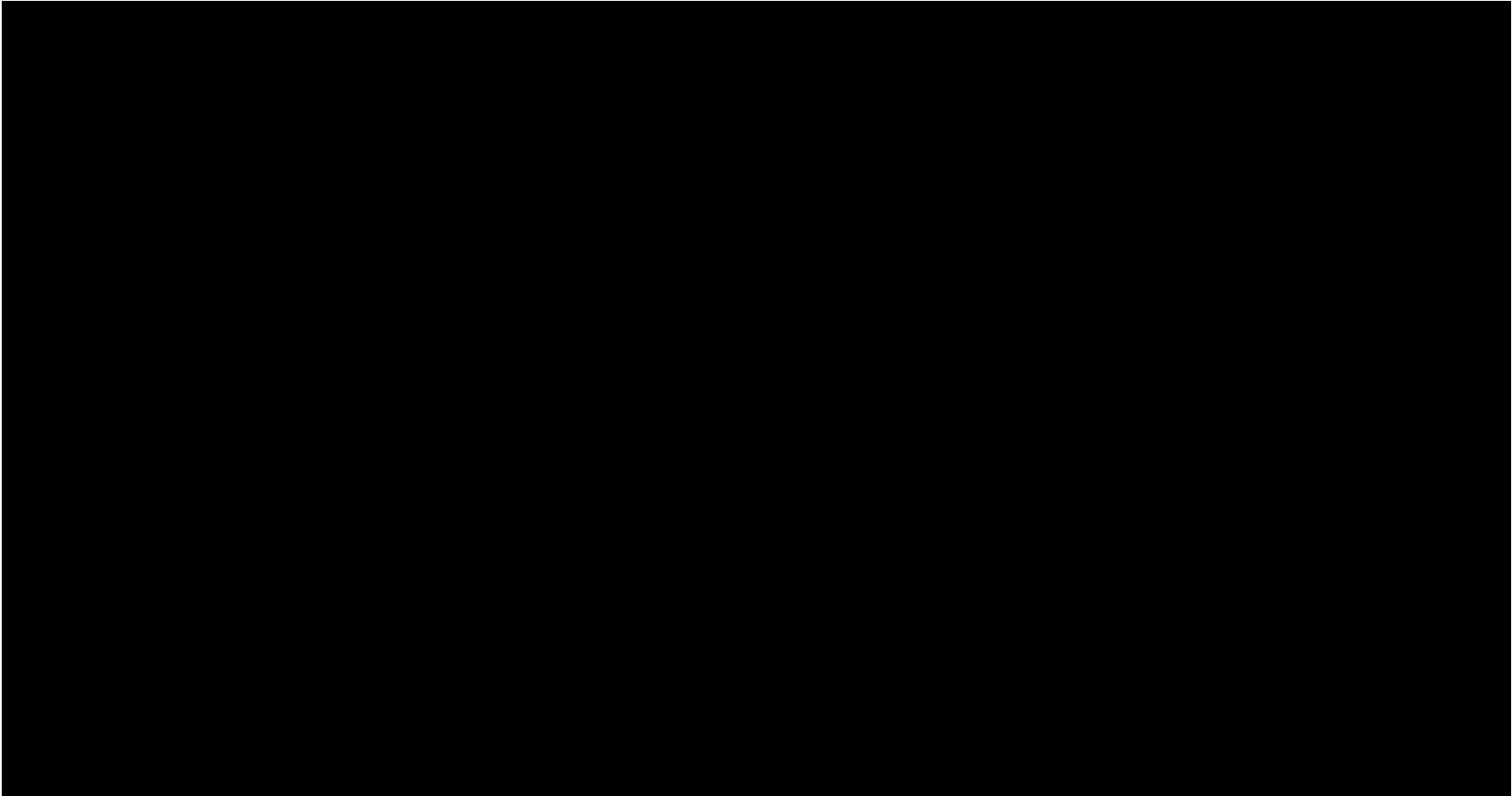
# Expect Vomiting

# The Soiled (and Therefore Difficult) Airway

- Direct Laryngoscopy 1<sup>st</sup> Line
- Rigid, Large-Bore Suction Catheter
- Back up plan, and back up for the back up
- Consider Suction Assisted Laryngoscopy and Airway Decontamination



# Suction Assisted Laryngoscopy and Airway Decontamination (SALAD)





**D**isplacement  
**O**bstruction  
**P**neumothorax  
**E**quipment  
**S**tacked breaths



What happened IRL and what did we do?

# Initial Ventilator Strategy

## Lung Protective Ventilation:

- Low tidal volume ventilation (6ml/kg PBW)
- Higher PEEP
- Typically may involve permissive hypercapnia, but should be avoided in patients with concern for hypoxic-ischemic brain injury

# Case 2 Resolution



ARDS



PRVC: RR 30, PEEP up to 18, albuterol q4 hrs, extubated after 1 week to HFNC, RA 1 day later



HIE  
Subclinical seizures



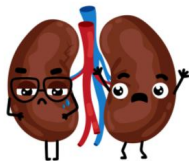
Continuous EEG  
Keppra Load



Hypotension (no  
ensuing arrhythmias)



Epinephrine and milrinone gtts, weaned  
over 4 days



AKI due to ATN,  
Cr 0.89



Persistent hypertension → amlodapine,  
isradipine, clonidine → amlodapine at D/C



Coagulopathy, INR  
2.25, DVT in external  
Iliac



Vitamin K x 3 days, then Lovenox x 3 months

# Case 3 Revisited

- 3 yo boy, found down by his mother in their pool, estimated down time 15 minutes. Cold, blue, apneic. Bystander and then prehospital team initiates CPR, intubates, gives 2 rounds of IM epinephrine en route.
- On arrival, CPR ongoing. No pulse after 2 minutes at pulse check. Asystole. Patient is very cold.
- How long do you continue CPR?
- What factors are modifiable to increase your chances of ROSC?
- Trauma activation?



# Cardiac Arrest in Drowning Patients

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## Cardiac arrest

mnemonic: 4H's & 4T's

- H** hypoxia
- H** hypovolaemia
- H** hypo/hyperkalaemia/  
metabolic
- H** hypothermia
- T** thrombosis-cardiac/  
pulmonary
- T** tamponade-cardiac
- T** toxins
- T** tension pneumothorax





# Severity of Hypothermia

## staging, physiology, and typical therapies of hypothermia

Severity	Neurologic	Cardiac	Pulmonary	Renal	Typical therapy <sup>&amp;</sup>
<b>Mild (HT1)*</b> 32-35C 90-95F	<b>Alert, shivering*</b> Ataxia Impaired judgement	Tachycardia Hypertension	Tachypnea Bronchorrhea	Cold diuresis	- Exposure-related: Passive external rewarming (e.g. blankets)  - Spontaneous: Warming blanket
<b>Moderate (HT2)*</b> 28-32C 82-90F	<b>Drowsy, non-shivering*</b> Delirium Paradoxical undressing Dilated pupils	Bradycardia Hypotension Atrial fibrillation	Hypoventilation	Cold diuresis	<u>Active external rewarming</u> - Warming blanket - Warmed/humidified air  (If possible, fluid being administered should be warmed)
<b>Severe (HT3)*</b> 24-28C 75-82F	<b>Unconscious with pulse*</b> Coma Fixed dilated pupils Areflexia	Heart block Cardiogenic shock	Pulmonary edema Agonal respirations	Oliguria	- Active external rewarming (see above). - If refractory shock or hypothermia, also consider active internal warming (e.g. thoracic/bladder lavage).
<b>Pulseless (HT4)*</b> <24C <75F	Appears dead	<b>Pulseless*</b> - Ventricular arrhythmia - Asystole	Apnea		Active external rewarming plus Active internal rewarming - Ideally: ECMO or cardiopulmonary bypass - Alternative: thoracic lavage

Staging and treatment of hypothermia. The provided temperature ranges generally correlate with clinical findings, but this correlation isn't perfect. When classifying the severity of hypothermia, both the temperature and clinical manifestations should be considered.

\* Key clinical features which may be used to stage patients in the field (if immediate temperature measurement isn't available).

\* Swiss Staging system for hypothermia.

& Therapy depends on clinical details, response to prior treatments, available resources, and risk/benefit calculus for each intervention. Listed treatments in this column are merely provided to give a general concept of how these patients might often be managed.

-The Internet Book of Critical Care, by @PulmCrit

# Treatment for Hypothermia

Severity	Typical therapy <sup>&amp;</sup>
<b>Mild (HT1)*</b> 32-35C 90-95F	- Exposure-related: Passive external rewarming (e.g. blankets)  - Spontaneous: Warming blanket
<b>Moderate (HT2)*</b> 28-32C 82-90F	<u>Active external rewarming</u> - Warming blanket - Warmed/humidified air  (If possible, fluid being administered should be warmed)
<b>Severe (HT3)*</b> 24-28C 75-82F	- Active external rewarming (see above). - If refractory shock or hypothermia, also consider active internal warming (e.g. thoracic/bladder lavage).
<b>Pulseless (HT4)*</b> <24C <75F	Active external rewarming plus Active internal rewarming - Ideally: ECMO or cardiopulmonary bypass - Alternative: thoracic lavage



## Severity

## Typical therapy<sup>&</sup>

### Mild (HT1)\*

32-35C

90-95F

- Exposure-related: Passive external rewarming (e.g. blankets)

- Spontaneous: Warming blanket

- Avoid further cooling:
  - Remove wet clothing
  - Turn off AC
  - Quickly dry them
- Apply warm blankets



## Severity

## Typical therapy<sup>&</sup>

### Moderate (HT2)\*

28-32C

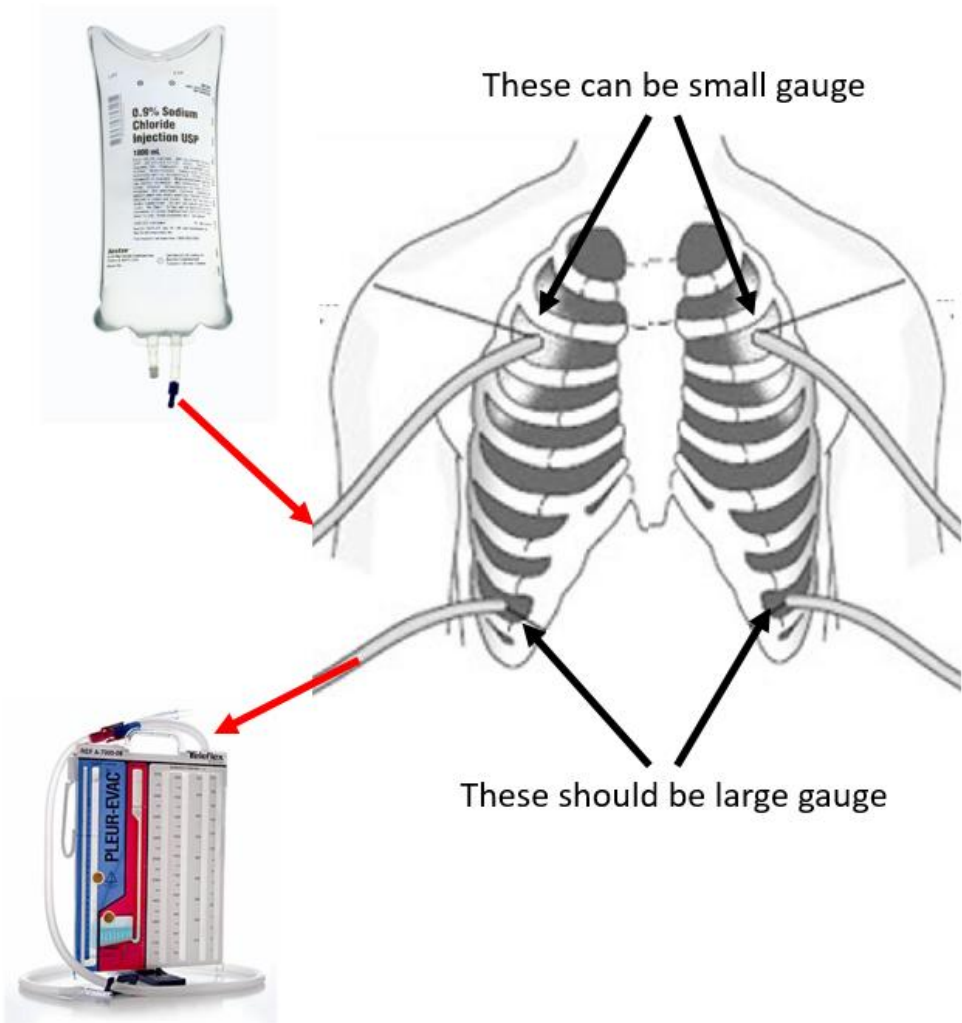
82-90F

### Active external rewarming

- Warming blanket
- Warmed/humidified air

(If possible, fluid being administered should be warmed)





**Severity**

**Typical therapy<sup>&</sup>**

**Severe (HT3)\***

24-28C  
75-82F

- Active external rewarming (see above).
- If refractory shock or hypothermia, also consider active internal warming (e.g. thoracic/bladder lavage).

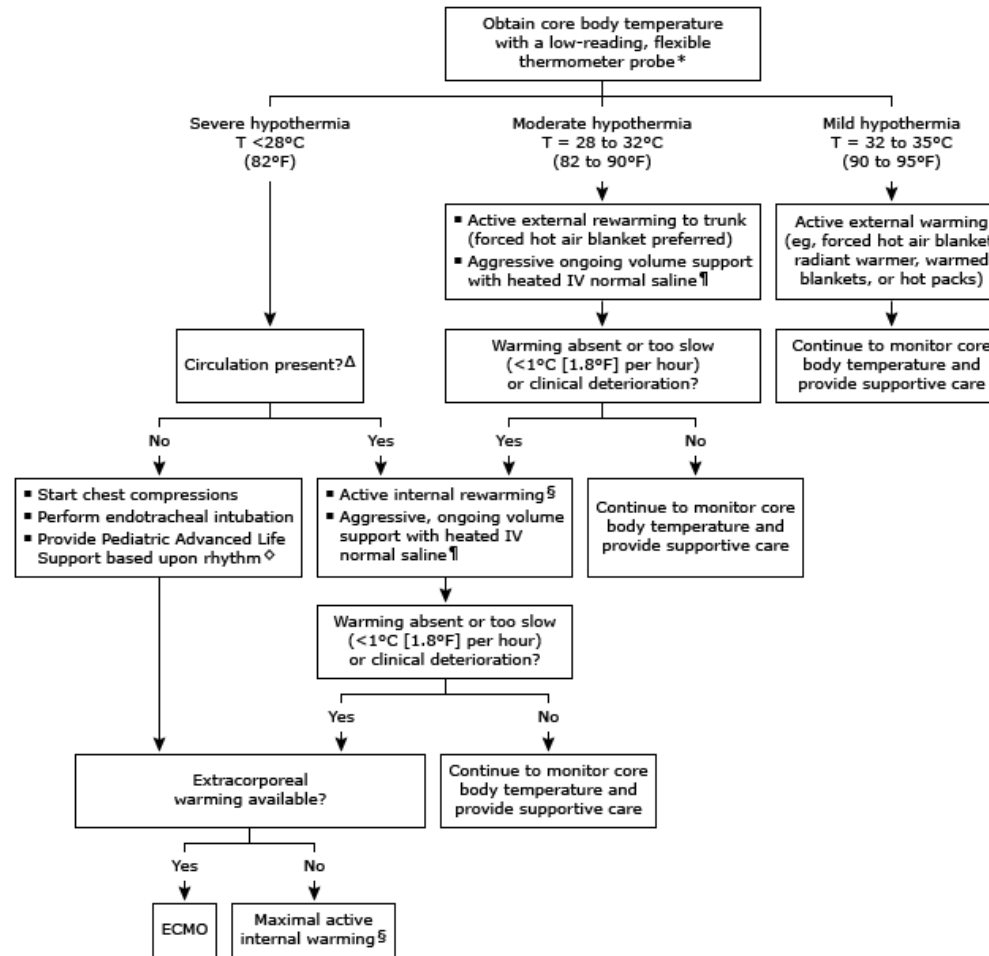
**Pulseless (HT4)\***

<24C  
<75F

- Active external rewarming plus Active internal rewarming
- Ideally: ECMO or cardiopulmonary bypass
- Alternative: thoracic lavage



## Rewarming of children with hypothermia



Rewarming should begin alongside stabilization of the airway, breathing, and circulation. Further cooling should be prevented by:

- Removal of wet clothing and application of dry blankets.
- Inhaled humidified oxygen heated to a temperature of 41 to 45°C (105.8 to 113°F).
- Intravenous fluids should be administered through a high-capacity warmer and tubing at a temperature of 40 to 44°C (104 to 111°F).

Refer to UpToDate content on hypothermia in children for further detail regarding recognition and treatment of hypothermia in children.

What  
temperature in  
arrest do we  
warm to?

Neuroprotective effects lost  
above 32

$T \geq 34$  C, okay to stop CPR –  
'for legal and ethical reasons'

T 32-34 C, clinician's  
discretion

# Case 3 Revisited

- 3 yo boy, found down by his mother in their pool, estimated down time 15 minutes. Cold, blue, apneic. Bystander and then prehospital team initiates CPR, intubates, gives 2 rounds of IM epinephrine en route.
- On arrival, CPR ongoing. No pulse after 2 minutes at pulse check. Asystole. Patient is very cold.
- How long do you continue CPR?
- What factors are modifiable to increase your chances of ROSC?
- Trauma activation?





# Case 3 Resolution

- NOT AN OHSU CASE
- No core temperature
- CPR Time 16 minutes
- Agonal respirations noted after efforts discontinued



# Summary

- Hypoxia is the villain
- In milder cases, monitor for 8 hours
- In more severe cases, anticipate difficult airway and ARDS
  - Consider SALAD
  - Evaluate for multisystem organ dysfunction (consider cont. EEG)
- For hypothermia:
  - Obtain core temperature.
  - Classify degree of hypothermia
  - Rewarm if hypothermia implicated before stopping CPR
  - Understand passive, active, external, and internal rewarming and when to deploy

# Thank you



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