LIFE FLIGHT NETWORK

Submersion Injuries

Leavenworth Paramedic Lecture Series 2019

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THERE WHEN YOU NEED US®

Objectives



- Terminology
- Definition
- Incidence
- Prognosis
- Interventions/management
- Opportunities impacting outcome

Terminology

- Drowning
  - death within 24 hours of a submersion incident

- Near Drowning
  - survive at least 24 hrs after a submersion incident

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Terminology

- Wet Drowning
  - Water identified in the lungs

- Dry Drowning
  - No water entered the lungs

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- ~~Dry Drowning~~
  - ~~No water entered the lungs~~

Definitions

- **Drowning**
  - Consensus definition: a process resulting in primary respiratory impairment from submersion in a liquid medium.
- **Outcomes:**
  - Death
  - Morbidity
  - No Morbidity

Incidence

- CDC 2005-2014 for US
  - ~3,536 fatal unintentional drownings (non-boating related) annually
  - An additional 332 people died each year from drowning in boating-related incidents
  - Leading cause of injury death among children 1-4 yrs
  - 2nd leading cause of all accidental deaths <14 yr (MVC 1st)
  - Fatality: male:female (4:1)

Incidence

- About one in five people who die from drowning are children 14 and younger. For every child who dies from drowning, another five receive emergency department care for nonfatal submersion injuries.
- 50% of drowning victims require hospitalization or transfer
- Incidence: ↑ holidays, weekends and warm weather
- Children
  - < 5 years old – pools
  - older kids and adults - open water
  - regionally specific

Morbidity & Mortality

- 15% of children admitted for drowning die in the hospital

- As many as 20% of drowning survivors suffer severe, permanent neurological disability

Risk Factors

- Lack of swimming ability
- Lack of barriers
- Lack of close supervision
- Location
- Failure to wear a life jacket
- Alcohol use
- Seizure disorders

Causes

- Toddlers:
  - Lapse of supervision
  - Afternoon/early evening-meal time
  - 84% with responsible supervising adults
  - Only 18% of cases actually witnessed



Causes

- Recreational boating
  - 90% of deaths due to drowning
    - Vast majority are not wearing life jackets
  - 1,200/yr
  - Small, open boats
  - 20% of deaths
    - Too few or no floatation devices!
- Diving
  - 700-800/yr
  - 1st dive in unfamiliar water
  - 40-50% alcohol related

Alcohol

- 25-50% of teen and adult deaths associated with water recreation
- Alcohol influences balance, coordination, and judgment, and its effects are heightened by sun exposure and heat

Causes

- Spas, hot tubs
  - Entrapment in drains, covers
- Buckets drowning
  - males>females
  - Warm months>cold
  - Consider child abuse



Causes

- Epilepsy:
  - 1.5-4.6 % had pre-existing seizure disorder
  - >5 years old, drown in bathtub, not supervised
- Long QT syndrome:
  - Swimming may be a trigger for arrest in patients with LQTS
  - Drowning may be first presentation
  - Specific gene KVLQT1 mutation associated with swimming trigger & submersion

Baby Swim Classes

- Done to “teach” babies to float
- No reported drownings in class
- Several reports of hyponatremic seizures following class
- False sense of security?



Stages of Drowning

- Stage I
  - 0-2 minutes
  - Submersion occurs
  - Aspiration and Laryngospasm
- Stage II
  - 1-2 minutes
  - Swallow water
    - Laryngospasm relaxes

      OR
    - Laryngospasm recurs

Stages of Drowning

- Stage III
  - Laryngospasm aborted
    - Aspiration of water (90%)
  - Laryngospasm recurs
    - Anoxia, seizure and death without aspiration (10%)

Pathophysiology

- **Part I**
  - Voluntary breath-holding
  - Aspiration of small amounts into larynx
  - Involuntary laryngospasm
  - Swallow large amounts
  - Laryngospasm abates (due to hypoxia)
  - Aspiration into lungs

Pathophysiology

- **Part II**
  - Decrease in oxygenation
  - Decrease in cardiac output
  - Intense peripheral vasoconstriction
  - Hypothermia
  - Bradycardia
  - Circulatory arrest
  - Extravascular fluid shifts, diuresis

Pathophysiology

- **Diving reflex**
  - Bradycardia, apnea, vasoconstriction
  - Relatively weak in humans
    - better in kids
  - Occurs when the face is submerged in water < 10-15°C
  - May occur to some extent in water at 20°C but only when the air temperature is 30°C or more (10°C temperature gradient).
  - Extent of neurologic protection in humans due to diving reflex is likely very minimal

Pathophysiology

- Asphyxia, hypoxemia, hypercarbia, & metabolic acidosis
- Fresh water vs salt water - little difference (except for drowning in water with very high mineral content, like the Dead Sea)
- Hypoxemia
  - Occlusion of airways with water & particulate debris
  - Changes in surfactant activity
  - Bronchospasm
  - Physiologic dead space increased

Pathophysiology

- Cardiac arrhythmias
- Hypoxic encephalopathy
- Renal insufficiency
- Pulmonary injury
- Global brain anoxia & potential diffuse cerebral edema

Pathophysiology – Pulmonary Injury

- Aspiration of as little as 1-3 mL/kg can cause significant effect on gas exchange
  - Increased permeability
  - Exudation of proteinaceous material in alveoli
  - Pulmonary edema
  - Decreased compliance

Pathophysiology

- Findings at autopsy
  - Wet, heavy lungs
  - Varying amounts of hemorrhage and edema
  - Disruption of alveolar walls
  - ~70% of victims had aspirated vomitus, sand, mud, and aquatic vegetation
  - Cerebral edema and diffuse neuronal injury
  - Acute tubular necrosis

Pathophysiology – Fresh vs. Salt

- Theoretical changes not supported clinically
  - Salt water: hypertonic pulmonary edema
  - Fresh water: plasma hypervolemia, hyponatremia
- Both salt and fresh wash out surfactant
  - Damaged alveolar basement membrane → pulmonary edema, Acute Respiratory Distress Syndrome (ARDS)

Pathophysiology

- Most aspirate 3-4 mL/kg
  - Aspirate > 11 mL/kg before fluid changes
  - Aspirate > 20 mL/kg before significant electrolyte changes

Cold vs Icy Water Immersion



- Usually hypothermia is an unfavorable sign
- Several case reports of dramatic neurologic recovery after prolonged (10-150 min) icy water submersions (<5°C)
- Core body temperature less than 28-30°C, or much lower
- For hypothermia to be protective, core body temperature must fall rapidly, decreasing cellular metabolic rate, before significant hypoxemia begins

Hypothermia Easier in Kids

- High Body Surface Area/mass ratio and decreased subcutaneous fat insulation
- Moderate hypothermia (core 32-35°C) increases oxygen uptake (VO_2) due to shivering thermogenesis & increased sympathetic tone
- Severe hypothermia (core <32°C) - shivering stops & the cellular metabolic rate decreases (~ 7%/°C drop in temperature)

Hypothermia & Brain Protection

- Hypothermia protects the brain and other organs from anoxia for 75-110 min in controlled circumstances where core body temperature is cooled first to 18°C and then the heart is stopped [deep hypothermic circulatory arrest (DHCA)]
- Once cell death from hypoxemia occurs (~ 5-6 min), there is no protective hypothermic effect or improved recovery

Hypothermia – Surface Cooling

- Surface cooling alone cannot decrease core temperature fast enough to yield protection
- Cooling rate in drowning victims is difficult to estimate as patient may also be swallowing or breathing in cold water
- Hypothermic protection involving surface cooling only would seem to require submersion in icy (not cold) water

Cold Water Submersion - Humans

- Few cold water victims have significant brain protection
- Hypothermia is more commonly an unfavorable prognostic sign
- King County, WA (water is cold, but rarely icy)
  - Hypothermic protection has not been observed
    - 92% of good survivors had initial core temp of >34°C
    - 61% of those who died or had severe neurologic injury had core temp <34°C
- Finnish study: Median water temp 16°C
  - Submersion duration <10 minutes had greatest sensitivity in predicting good outcome

Drowning Signs and Symptoms

- 70% develop signs and symptoms within 7 hrs
- Alertness → agitation → coma
- Cyanosis, coughing & pink frothy sputum (pulmonary edema)
- Tachypnea, tachycardia
- Low grade fever
- Rales, rhonchi & less often wheezes
- Signs of associated trauma to the head & neck should be sought

Pre-Hospital Treatment

- Rapid and cautious retrieval from the water. Safety first!
- Immediately establish the airway with C-spine precautions
- Breathing:

  Mouth-Mouth
- In-water CPR is generally ineffective and dangerous



Pre-Hospital Treatment

- CPR
- Bag-valve-mask
  - Higher pressures may be required for ventilation because of the poor compliance resulting from pulmonary edema.
- Intubation with PEEP
- Supplemental oxygen on all patients

Pre-Hospital Treatment

- Human surviving drowning victims aspirate small quantities of water
- Postural drainage or the abdominal thrusts (Heimlich maneuver) are of unproven efficacy
- Delays ventilation and transport
- Can lead to regurgitation and pulmonary aspiration



Pre-Hospital Treatment

- Treatment of hypothermia in the comatose drowning victim remains controversial and a topic of investigation.
- Most recommend removal of wet clothing and wrapping in warm blankets.
- It is generally recommended anyone with temperatures less than 32-34°C be treated.

Pre-Hospital Treatment

- Any patient with a significant episode should be transported to the hospital for evaluation
  - Even if the patient is asymptomatic

Treatment

- ED evaluation begins with immediate resuscitation and treatment of respiratory failure.
- Frequent neurologic assessment
- Evaluate associated injuries (e.g., cervical spine injury).
- Early use of intubation and PEEP (or CPAP/BiPAP in the awake, cooperative, and less hypoxic individual), if hypoxia or dyspnea persists despite 100% oxygen.

Treatment

- Disposition depends on the history, presence of associated injuries, and degree of immersion injury.

Treatment

- Patients can be discharged from the ED after 6-8 hours of observation if they meet the following criteria:
  - Able to relay a good history of minor immersion injury
  - No evidence of significant injury
  - No change in mental status or behavior
  - No evidence of bronchospasm or tachypnea/dyspnea
  - No evidence of inadequate oxygenation (by ABG analysis and pulse oximetry)

Treatment

- Victims of mild to moderately severe submersion, with mild symptoms and no abnormalities on ABG analysis, pulse oximetry and chest radiograph, are generally observed overnight.
- Patients with more severe submersions or symptoms are admitted to the hospital ward or ICU.

Treatment – ICU Respiratory

- Positive pressure ventilation, CPAP or PEEP
- Treatment of bronchospasm
- Bronchoscopy
- Steroids: no benefit
- Prophylactic antibiotics: no benefit
- Surfactant: no benefit

Recommendations

- Pre-hospital resuscitation, including early intubation, ventilation, vascular access, and administration of advanced life support medications
- Continued resuscitation and stabilization in the ED
- Full supportive care in the ICU for a minimum of 48 hrs
- ECMO?
- Consider withdrawal of support if no neurologic improvement is detected after 48 hours
  - Ancillary testing such as brainstem evoked responses, EEG, and MRI (not CT) may prove helpful to corroborate the neurologic examination

Prognosis

- Better outcomes associated with early CPR (bystander)
- C-spine protection
- Transport
  - Continue effective CPR
  - Establish airway
  - Remove wet clothes
  - Hospital evaluation

Outcome Predictors

- Poor outcomes
  - Age < 3yrs
  - Submersion time: >10 min
  - Time to BLS >10 min
  - Serum pH: <7.0
  - CPR >25 min
  - Initial core temp <33°C
  - GCS <5
  - Lactic acid >6 mmol/L

Neurologic Prognosis

- Absence of spontaneous respiration is an ominous sign associated with severe neurologic sequelae
- Permanent neurologic sequelae persists in ~20% of victims who present comatose

Outcome Predictors

- Submersion time
- Water Temperature
- Bystander CPR
- EMS response time

Outcome Predictors

- Prolonged resuscitation may increase the success of resuscitation without normal neurologic recovery

→ After 25? min of full but unsuccessful resuscitation, think “PROGNOSIS”

Case Review



In Conclusion
Prevention is Key!

WATER SAFETY TIPS TO LIVE BY

- Learn to swim.
- Always swim with a buddy; never swim alone.
- Alcohol and swimming don't mix.
- Watch out for the terrible "too"s—too tired, too cold, too drunk, too far from safety, too much sun, too much strenuous activity.
- Always wear a Coast Guard-approved personal floatation device (i.e., life jacket or vest) when boating and fishing.
- Learn CPR.
- Never leave children unattended near the water. Drowning often is a silent death; many times, no one hears a child fall in a pond or pool.
- Empty home wading pools and buckets after each use; children can drown in as little as two to three inches of water.
- Don't overload a boat with people or equipment. Check the boat's capacity plate for weight limits. Make sure the boat is balanced. In a small boat, return to shore before having people change places.



Thank You