Submersion Injuries

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Introduction/Epidemiology

- Ambiguous definitions and terminology
  - Near drowning, non-fatal drowning
  - Wet nonfatal drowning – aspiration of fluid into the lungs
  - Dry nonfatal drowning – asphyxia secondary to laryngospasm
  - 2019 AHA definition: “a process resulting in primary respiratory impairment from submersion or immersion in a liquid medium”
- Major cause of accidental death in the US
  - Highest in males, African Americans, low socioeconomic status, Southern states, states with pools or beaches (California, Arizona, Florida)
  - More common during the summer months

Introduction/Epidemiology

- Two age peaks
  - Age <5yo: lack of supervision in swimming pools, bathtubs, other liquid filled containers (toilets)
  - 15yo to 25yo Males: occurs at rivers, lakes, beaches
- Risk Factors
  - Inadequate adult supervision: assumption that someone else is watching
  - Inability to swim: early swimming lessons
  - Risk taking behavior…boys…
  - Alcohol and illicit drugs
  - Hypothermia: lakes, oceans, rivers during winter
  - Seizure disorder or developmental/behavioral disorder
  - Unknown cardiac arrhythmia (Long QT)

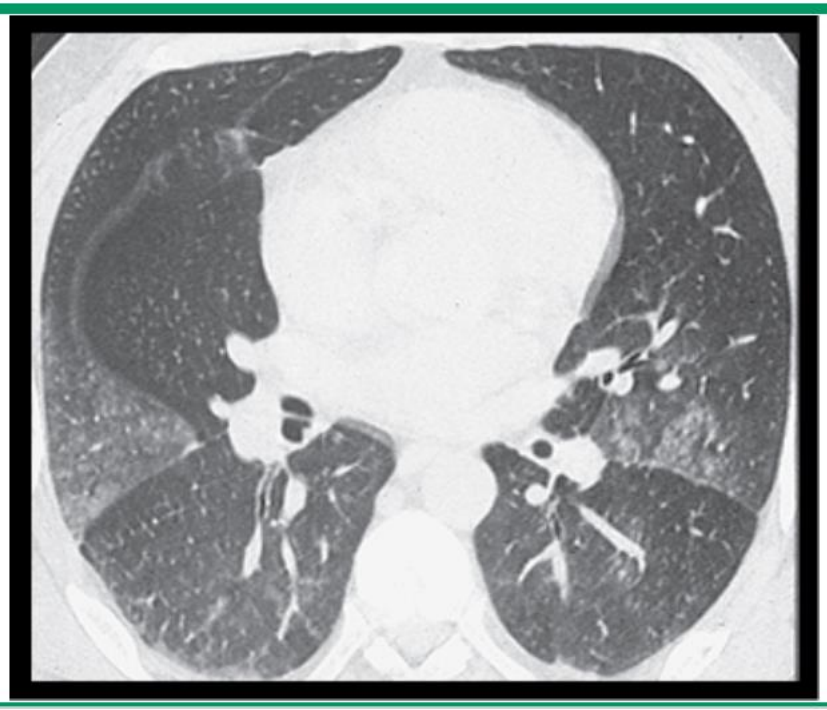
Pathophysiology

- Panic → loss of normal breathing pattern → breath holding → air hunger → reflexive inspiratory efforts
- Inspiratory efforts lead to either aspiration or reflex laryngospasm (when water hits lower respiratory tract)
- Previously thought to differ between fresh and salt water (electrolyte changes vs pulmonary edema respectively) but now thought to be only seen in DOA victims
  - Must aspirate 11ml/kg prior to blood volume changes and 22ml/kg prior to electrolyte changes
  - Rare to aspirate more than 3-4ml/kg in non-fatal drownings
- Specific end organ effects

Pulmonary

- Decreased compliance, VQ mismatch, and intrapulmonary shunting leading to hypoxemia
- Increased capillary endothelial permeability
- Wash out surfactant producing noncardiogenic pulmonary edema and ARDS
  - SXS are SOB, crackles, wheezing
  - CXR and CT show localized, perihilar, or diffuse pulmonary edema
- ARDS may be delayed by hours or days

CT scan of pulmonary edema due to near-drowning



Ground glass opacities are seen in both upper lobes. In the right lung, ground glass opacities abut the minor fissure and spare the middle lobe.

Courtesy of Paul Stark, MD.

Graphic 57578 Version 2.0

Neurologic

- Hypoxemia and ischemia result in neuronal damage → cerebral edema and increased ICP
  - Progressive rise over 24 hours thought to be reflective of severity of insult
- 20% of patients have subsequent neurologic damage
- Degree of neurologic injury related to length of cardiac arrest – injury rarely occurs without cardiac arrest
- Those who have purposeful movement and normal brainstem function w/in 24hours have good prognosis

Cardiovascular

- Arrhythmia secondary to hypothermia and hypoxemia, hypercarbia, and acidosis
- Decreased myocardial contractility
- Sinus tachycardia, sinus bradycardia, atrial fibrillation, ventricular fibrillation, asystole
- Swimming and diving can precipitate long QT syndrome type 1
- Some EKG changes have suggested ischemia secondary to Takotsubo cardiomyopathy, coronary artery spasm, or hypothermia

- Acid Base/ Electrolytes:
  - Metabolic and/or respiratory acidosis
  - Generally do not have significant electrolyte changes (except maybe in the Dead Sea due to swallowed sea water)
  - Prevention of hypoglycemia associated with better neuro outcomes
- Renal
  - Acute tubular necrosis from hypoxemia, shock, hemoglobinuria, myoglobinura
- Coagulation
  - Hemolysis and coagulopathy are rare
- Shock – may be compensated with normal BP
  - Evidenced by tachycardia, AMS, poor pulses, oliguria, acidosis
  - Fluid resuscitation and inotropes

Management

- Prehospital Care and Acute Interventions
- Emergency Department Care
- Inpatient Care

Prehospital Care and Acute Interventions

- CPR should be initiated as soon as it is safe
  - Ventilation is most important – however effects unclear in the literature
  - If no response after two good quality breaths → begin compressions
  - Watch for signs of spinal cord injury (uncommon): dive into shallow water
    - Routine C-spine immobilization not recommended as it interferes with early breaths
  - Careful search for pulses for 1 min prior to initiating compressions
  - Attempts to remove water such as Heimlich have no proven benefit and should not delay rescue breathing
  - Should use high flow oxygen delivery systems in those with spontaneous breaths
  - Apneic patients should be intubated
  - Rewarm patients <33 degrees Celcius

Emergency Department Management

- Indications for intubation
  - Signs of neurologic deterioration
  - Inability to maintain PaO2 above 60 or O2sat >90% with adequate noninvasive ventilation
- Removal of wet clothing and rewarming measures
  - Hypothermia in after drowning in warm water indicates prolonged submersion and poor prognosis
- Guidelines for admission
  - Symptomatic patients
  - Asymptomatic patients should be observed for 8 hours

Inpatient Management

- Neurologic Injury
  - Cerebral edema - elevate head of bead, intracranial pressure monitoring, diuretics
  - Control of seizure activity – increases cerebral oxygen consumption and blood flow (phenytoin - nonsedating)
  - Therapeutic hypothermia – controversial data on whether it helps
- Respiratory Failure
  - Often have bronchospasm – treated with inhaled beta agonists
  - Mechanical ventilation, occasional use of ECMO
- Infection
  - Prophylactic antibiotic use only if grossly contaminated water – Aeromonas, Pseudomonas, Proteus
  - Treatment of symptomatic pneumonia
- Hypotension
  - Hypothermia induced hypovolemia secondary to shunting of blood to core and subsequent diuresis
  - Hypoxic cardiomyopathy

Outcome

- Predictors of Poor Prognosis
  - Submersion >5 min **(most critical factor)**
  - Time to effective life support >10 min
  - Resuscitation >25 min
  - Age >14yo
  - GCS <5
  - Persistent apnea and requirement of CPR in ED
  - Arterial pH <7.1 on presentation
  - Alcohol and drug use
- No association between water temperature and a “good outcome”
- Percentage of poor neurologic outcomes increasing as more effective treatment of non-neurologic complications improve

Prevention

- Gates surrounding pools could decrease swimming pool drownings by 80 - 83% and almost exclude all cases <4yo
- Adult supervision
- Swimming with a partner
- Avoidance of drugs and alcohol
- Use of appropriate personal floatation devices
- Advising parents that toddlers can drown in shallow water – toilets, buckets, bathtubs
- Cell phones are a big distractor
- Water wings provide false security

References

- UpToDate: Drowning (Submersion Injuries)
- Pediatrics in Review: Childhood Drowning