**DEFINITION**
Drowning and Near Drowning refer to submersion injuries.
- **Drowning:** death due to suffocation within 24 hours after submersion in a liquid medium
- **Near Drowning:** those individuals through resuscitative efforts have survived this initial period of time.

**PROGNOSIS**
- The success of resuscitative measures at the scene of submersion victims is the most important determinant in the patient’s outcome.
- Those who are conscious on arrival at a hospital have an excellent chance of intact survival. Pulmonary injury can be managed successfully with newer innovative approaches to mechanical ventilation.
- The poorest prognosis is amongst patients who continue to require CPR in the ED. This is valid despite the age of the patient, duration of submersion, pH on presentation, or body temperature.
- The best predictor of outcome is return of normal neurologic function within 24-72 hours.
- It has been well documented that those who do not have a return of cognitive function within 72 hours of the hypoxic episode either do not survive or do so in a persistent vegetative state.
- Other poor prognostic findings include continuation of CPR beyond 25 minutes, pupils that are fixed and dilated, seizures, flaccidity, a GCS of < 5, and decreased cerebral blood flow. Cold-water submersions that produce severe hypothermia may influence the outcome, but not all hypothermic submersion victims escape serious neurological sequela.

**EPIDEMIOLOGY**
- In the United States, approximately 1400 drowning deaths occur each year in patients younger than 19 years.
- Highest risk groups include children less than 5 years of age and adolescent males between the ages of 5 to 19 years of age.
- For children under 5 years of age, the drowning rate is higher for white children than for African American children.
- The overall outcome for submersion injuries appears to be bimodal with children either dying or being discharged to home. A small number of children are either discharged to home with skilled nursing or to a long-term care/chronic care facility.
- The circumstances that surround submersion injuries vary by age and geographic region.
  - Bathtub submersions injuries are more common in children less than 1 year of age who are left in the care of an older sibling or are without adult
supervision. Child abuse should be suspected when bathtub submersion events occur. Bathtub submersion injuries may be associated with scald burns from the hot water found in a bathtub. A
  o Adolescent and adult drowning incidents often are associated with the use of ethanol and other neurotropic agents, which may impair judgment and increase risk-taking behaviors.

Pathophysiology of Submersion Injuries
- Asphyxia
- Anoxia
- Hypothermia
- Reperfusion injuries

Submersion ⇒ child panics ⇒ holds his/her breath ⇒ loss of consciousness ⇒ loss of cough / gag reflexes ⇒ aspiration of large amounts of water ⇒ anoxia ⇒ decreased O2 delivery to organs ⇒ arrhythmias / fibrillation ⇒ asystole

- The child’s core temperature begins to fall.
- The type of fluid aspirated may have significant effects upon the circulatory volume and electrolyte balance.
  - Freshwater: hypotonic and rapidly absorbed across the alveoli. This may result in increased blood volume, hemodilution, a reduction in serum electrolytes, and hemolysis due to a decrease in serum osmolality.
  - Salt water: hypertonic, may result in hemoconcentration, decreased blood volume, and an elevation in serum electrolytes.
  - 11 ml/kg of fluid must be aspirated for blood volume changes and at least 22ml/kg to have significant electrolyte changes. Most children aspirate less than 4 ml of fluid/kg and thus there is very little clinical relevance to the type of water in which one is submerged.
- Capillary leak secondary to asphyxia often leads to hypovolemia.
- Near drowning victims may also sustain serious injury to other organ systems:
  - Pulmonary injury due to surfactant washout, aspiration of gastric contents or contaminated water contents
  - CNS injury secondary to anoxic/ischemic events
  - Myocardial injury
  - Renal impairment
  - Injury to the gut mucosa
  - Rise in liver function studies

Other aspects of Submersion Injuries:
- Hypothermic submersions: Children submerged in very cold water (<5°C) have had astonishingly surprising outcomes. The period of submersion hypothermia may protect the CNS. Severe hypothermia results in a decrease in energy use and thus decrease the metabolic rate of the brain. For each 1°C reduction in core temperature,
the cerebral blood flow is reduced by 6-7%. Severe hypothermia may result in cardiac dysrhythmias (VF/VT), loss of consciousness, and predispose to infection.\(^3,4,11\)

- **Diving reflex:** This is a reflex found in air diving mammals such as seals and allows for submersions of 15-20 minutes. This reflex results in a marked reduction of blood flow to tissues more resistant to hypoxia while preserving blood flow to those organs more sensitive such as the brain and heart. Unfortunately, the role of the diving reflex in children is uncertain.

**The approach to the child who has sustained a submersion injury**

The approach to the victim of a severe submersion involves a minimum of 4 phases: 1) initial layperson rescue, 2) paramedic/EMS response, 3) the ED stabilization, 4) care in the PICU.

1) **At the scene:** Remove the child from the water and immediately initiate CPR while awaiting EMS personnel. The patency of the airway should be assessed and any debris removed. Use a mask / or bag-mask if available (as maybe the case particularly at public pools), in resuscitative efforts.

2) **Paramedic/EMS response**
   - Continue CPR
   - Place the patient on monitors
   - Begin bag-mask-ventilation if not already initiated
   - Establish vascular access

3) **Emergency Department (ED):**
   - Initial evaluation: ABCs
     - Continue resuscitative efforts
     - Place the patient on monitors
     - Stabile the airway
     - Establish vascular access
     - Careful examination including a trauma survey if appropriate
       - Head injury, C-spine injury, thoraco-abdominal injury
   - **Disposition**
     - Those who are well saturated in room air and have age appropriate responses and a normal Glasgow Coma Score may be discharged after monitoring for 4-8 hours. Patients who have an oxygen requirement or abnormal sensorium require hospital admission, potential intubation, and may need further imaging studies while in the ED.
     - Patient’s who were intubated in the field but are now more appropriate will require careful evaluation in the ED before being extubated. At most institutions, these children will probably remain intubated, mechanically ventilated and transferred to the closest PICU.
4) Management in the PICU:
Efforts in the PICU primarily focus on preventing any secondary injury status post the initial hypoxic-ischemic event. Supportive therapy is optimized as the patient’s multiple involved organs recover. If all medical treatment is optimized and the patient continues to decompensate, Extra Corporeal Membranous Oxygenation (ECMO) has been used on occasion. ECMO can be initiated either for re-warming in severe hypothermic submersion or for resistant respiratory or hemodynamic failure.

- **Pulmonary support:** Usually the lungs are the most seriously affected.

  Reduction in FRC $\Rightarrow$ Hypoxia & hypercarbia

  Aspiration pneumonia picture $\Rightarrow$ Pulmonary edema

  Alterations in surfactant

  Acute lung injury (ALI) or Acute Respiratory Distress Syndrome (ARDS)

  - If spontaneous respirations – administer oxygen and monitor.
  - Intubate – if patient cannot protect airway, GCS <8, poor respiratory effort, apnea. Lung protective ventilatory strategies including low tidal volumes, FiO$_2$ less than 60%, optimal PEEP should be utilized to manage the ARDS and prevent ventilator induced lung injury.

- **Hemodynamic support:** Myocardial contractility may be significantly affected secondary to the period of hypoxia / anoxia.
  - Hydrate the patient with 20-40 ml/kg of NS since capillary leak may lead to hypovolemia.
  - Dopamine, epinephrine should be initiated if hemodynamic instability persists despite adequate fluid resuscitation since the cardiogenic component may be related to hypoxic injury, dysrhythmias induced injury, or metabolic acidosis.
  - Any persistent arrhythmias should be treated aggressively. Patients found in cold-water submersion may have very low core body temperatures. Ventricular fibrillation cannot be corrected in patients with a core temp of $<28^\circ$C until the patient is rewarmed.
Central Nervous System protection: Profound CNS dysfunction is the ultimate complication of submersion injuries and the duration of hypoxia and hypotension determine the severity of the neurological injury. The mechanism of CNS injury is complex and includes increased intracranial pressure, vasogenic changes in autoregulation and cytotoxic cerebral edema, accumulation of various metabolites and oxygen free radicals, and reperfusion injury after CNS blood flow is established. Neuro protective strategies should be instituted.

- Prevent
  - Hypoxia
  - Hypotension
  - Hyperthermia
  - Hyperglycemia
- The efficacy to cooling the patient to 32-34°C for up to 72 hours after the hypoxic event has proven effective in adult and neonatal population, but no pediatric data exists. Given the data, an active discussion regarding this treatment should occur if not instituted.
- Seizure activity should be treated quickly and aggressively.
- ICP monitoring has not proven to be of benefit for these patients.

Multi-system organ dysfunction / support: Depending on the degree of hypoxia, other systemic findings may include:
- Gastric ulcers: place on gut protective agents
- DIC: correct coagulopathy particularly if active bleeding exists
- Liver injury
- Renal failure secondary to ATN: consider renal replacement therapy
- A predisposition to infection: consider antibiotics as required

If over the next 72 hours, the patient demonstrates no signs of meaningful recovery, discussions regarding a guarded neurologic prognosis should occur with the family. A multi-disciplinary approach to such a family conference may prove beneficial.