## IN THE NAME OF GOD

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# NEAR DROWNING

#### **EPIDEMIOLOGY**

• Compared with other types of injuries, drowning has one of the highest case fatality rates and is in the top-10 causes of death related to unintentional injuries for all pediatric age-groups.

• The highest drowning death rates were seen in children age 1-4 yr and 15-19 yr (crude rates of 2.56 and 1.2 per 100,000, respectively).

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According to the Utstein guidelines, drowning refers to: "a
 process resulting in primary respiratory impairment from
 submersion or immersion in a liquid medium".

 The Utstein guidelines further suggest that ambiguous or confusing terms such as "near-drowning," "secondary drowning," and "wet drowning" should not be used

#### RISK FACTORS

- Inadequate adult supervision.
- Inability to swim or overestimation of swimming capabilities.
- Risk-taking behavior.
- Use of alcohol and illicit drugs (more than 50 percent of adolscent drowning deaths are believed to be alcohol-related).
- Hypothermia, which can lead to rapid exhaustion or cardiac arrhythmias.
- Concomitant trauma, stroke, or myocardial infarction.
- Seizure disorder or developmental/behavioral disorder

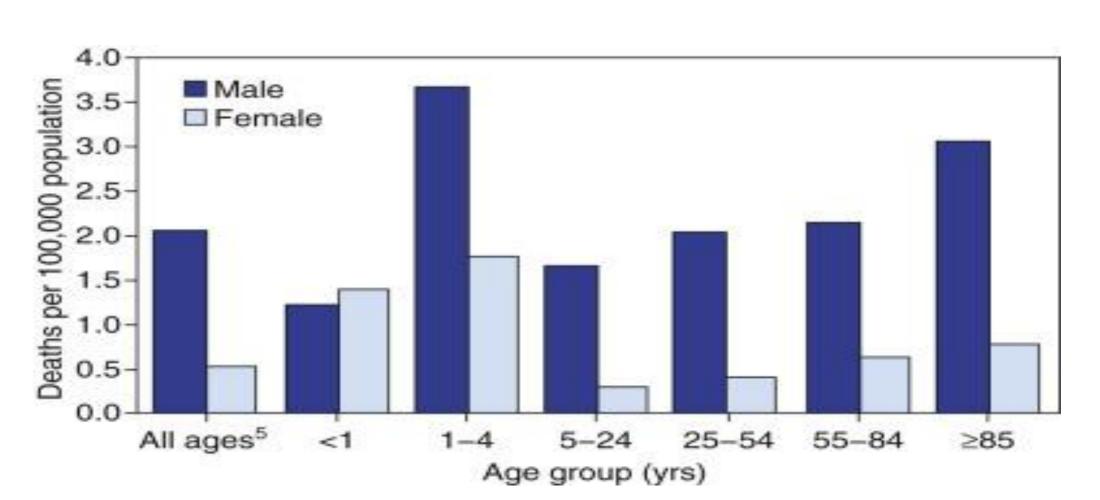
# CARDIAC ARRHYTHMIA & DROWNING

- Undetected primary cardiac arrhythmia (may be a more common cause of drowning than generally appreciated)
- As an example, cold water immersion and exercise can cause fatal arrhythmias in patients with the congenital long QT syndrome type 1.
- Similarly, mutations in the cardiac ryanodine receptor (RyR)-2 gene, which is associated with familial polymorphic VT in the absence of structural heart disease or QT prolongation, have been identified in some individuals with unexplained drowning

# DROWNING& CEREBRAL HYPOXIA

- Hyperventilation prior to a shallow dive. Swimmers commonly hyperventilate in order to prolong the duration of underwater swimming, and by so doing they reduce the arterial partial pressure of carbon dioxide (PaCO<sub>2</sub>) while the content of oxygen (CaO<sub>2</sub>) does not increase appreciably.
- As the individual swims, oxygen is consumed and the partial pressure of oxygen (PaO<sub>2</sub>) falls to 30 to 40 mmHg before the PaCO<sub>2</sub> rises sufficiently to trigger the urge to breathe. This can lead to cerebral hypoxia, seizures, and loss of consciousness, which can result in drowning.

# DEATH RATES FROM UNINTENTIONAL DROWNING\* BY AGE-GROUP AND SEX—UNITED STATES,



#### PATHOPHYSIOLOGY

- . Vocalization is precluded by efforts to achieve maximal lung volume to keep the head above the water or by aspiration leading to laryngospasm.
- Young children can struggle for only 10-20 sec and adolescents for 30-60 sec before final submersion.
- A swimmer in distress is vertical in the water, pumping the arms up and down. This splashing or efforts to breathe are often misconstrued by nearby persons as merely playing in the water, until the victim sinks.

#### ANOXIC-ISCHEMIC INJURY

- CNS injury is the most common cause of mortality and long-term morbidity.
- Although the duration of anoxia before irreversible CNS injury begins is uncertain, it is probably on the order of 3-5 min.
- Submersions <5 min are associated with a favorable prognosis, whereas those >25 min are generally fatal.
- Several hours after cardiopulmonary arrest, **cerebral edema** may occur, although the mechanism is not entirely clear.
- Severe cerebral edema can elevate intracranial pressure (ICP), contributing to further ischemia; intracranial hypertension is an ominous sign of profound CNS damage.

#### COMPLICATION

- acute respiratory distress syndrome (Aspiration may also compound pulmonary injury.
- Myocardial dysfunction (so-called stunning), arterial hypotension, decreased cardiac output, arrhythmias, and cardiac infarction may also occur.
- Acute kidney injury, cortical necrosis, and renal failure are common complications of major hypoxic-ischemic events
- Vascular endothelial injury may initiate disseminated intravascular coagulation, hemolysis, and thrombocytopenia.
- Many factors contribute to gastrointestinal damage; bloody diarrhea with mucosal sloughing may be seen and often portends a fatal injury.
- Serum levels of hepatic transaminases and pancreatic enzymes are often acutely increased.
- Violation of normal mucosal protective barriers predisposes the victim to bacteremia and sepsis.

### Pulmonary Injury

- wash out surfactant and cause alveolar instability, ventilation-perfusion mismatch, and intrapulmonary shunting.
- In humans, aspiration of small amounts (1-3 mL/kg) can lead to marked hypoxemia and a 10-40% reduction in lung compliance.
- The composition of aspirated material can also affect the patient's clinical course: Gastric contents, pathogenic organisms, toxic chemicals, and other foreign matter can injure the lung or cause airway obstruction.
- Clinical management is not significantly different in Saltwater and freshwater aspirations, because most victims do not aspirate enough fluid volume to make a clinical difference.

#### **NEUROLOGIC COMPLICATION**

- Hypoxemia and ischemia cause neuronal damage, which can produce cerebral edema and elevations in intracranial pressure
- Some authors consider the progressive rise in intracranial pressure that is sometimes observed approximately 24 hours after injury to reflect the severity of the neurologic insult rather than its cause
- Approximately 20 percent of nonfatal drowning victims sustain neurologic damage, limiting functional recovery despite successful cardiopulmonary resuscitation

#### **ARRHYTHMIAS**

- Arrhythmias secondary to hypothermia and hypoxemia are often observed in nonfatal drowning victims.
- The initial arrhythmias described following nonfatal drowning include
- sinus tachycardia,
- sinus bradycardia, and atrial fibrillation.
- In addition, swimming (including diving) can precipitate fatal ventricular arrhythmias in patients with congenital long QT syndrome type 1.

#### RENAL COMPLICATION

 Renal failure rarely can occur after submersion, and is usually due to acute tubular necrosis resulting from hypoxemia, shock, hemoglobinuria, or myoglobinuria

Diuretics, fluid restriction, and dialysis are occasionally needed to treat fluid overload or electrolyte disturbances; renal function usually normalizes in survivors. **Rhabdomyolysis** after drowning has been reported.

#### **HYPERGLYCEMIA**

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- Hyperglycemia is associated with a poor outcome in critically ill pediatric drowning victims. Its etiology is unclear, but hyperglycemia is possibly a stress response.
- Glucose control in patients after drowning should be focused on avoiding hypoglycemia, hyperglycemia, and wide or rapid fluctuations in serum glucose, to prevent further harm.

#### HYPERTHERMIA AFTER DROWNING

- Hyperthermia after drowning or other types of brain injury may increase the risk of mortality and exacerbate hypoxic-ischemic CNS damage.
- Imost half of drowning victims have a fever during the 1st 48 hr after submersion. Hyperthermia is usually not caused by infection and resolves without antibiotics in approximately 80% of patients.
- Generally, prophylactic antibiotics are not recommended.
- However, there is general consensus that fever or hyperthermia (core body temperature >37.5°C [99.5°F]) in comatose drowning victims resuscitated from cardiac arrest should be prevented at all times in the acute recovery period (at least the 1st 24-48 hr).

#### **COLD WATER INJURY**

- The definition of cold water varies from <15 to 20°C (<59 to 68°F).
- Heat loss through conduction and convection is more efficient in water than in air.
- Children are at increased risk for hypothermia because of their relatively high ratio
  of body surface area (BSA) to mass, decreased subcutaneous fat, and limited
  thermogenic capacity.
- Body temperature may also continue to fall because of cold air, wet clothes, hypoxia, and hospital transport.
- Hypothermia in pediatric drowning victims may be observed even after drowning in relatively warm water and in warm climates.

#### COLD WATER INJURY

- Victims experience cold water shock, a dynamic series of cardiorespiratory physiologic responses that can cause drowning.
- , immersion in icy water results in intense involuntary reflex hyperventilation and to a decrease in breath-holding ability to <10 sec, which leads to fluid aspiration.
- Severe bradycardia, the *diving reflex*, occurs in adults but is transient and rapidly followed by supraventricular and ectopic tachycardia and hypertension. There is *no evidence* that the diving reflex has any protective effect.

#### COLD WATER INJURY

- Lower core temperatures lead to impaired cognition, coordination, and muscle strength and with it, less ability to self-rescue.
- With moderate hypothermia (30 to <34°C [86 to <93.2°F]), loss of consciousness leads to water aspiration. Progressive bradycardia, impaired myocardial contractility, and loss of vasomotor tone contribute to inadequate perfusion, hypotension, and possible shock.
- At body temperatures <28°C (82.4°F), extreme bradycardia is usually present with decreases in cardiac output, and the propensity for spontaneous ventricular fibrillation or asystole is high.
- Central respiratory center depression with moderate to severe hypothermia results in hypoventilation and eventual apnea.
- A deep coma, with fixed and dilated pupils and absence of reflexes at very low body temperatures (<25-29°C [77-84.2°F]), may give the false appearance of death.

## INITIAL EVALUATION AND RESUSCITATION

- Initial management of drowning victims requires coordinated and experienced prehospital care following the ABCs (airway, breathing, circulation) of emergency resuscitation.
- CPR of drowning victims must include providing ventilation. Children with severe hypoxic injury and symptoms often remain comatose and lack brainstem reflexes despite the restoration of oxygenation and circulation
- . Subsequent ED and PICU care often involve advanced life support (ALS) strategies and management of multiorgan dysfunction with discussions about end-of-life care.

## INITIAL EVALUATION AND RESUSCITATION

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- Initial resuscitation must focus on rapidly restoring oxygenation, ventilation, and adequate circulation.
- The airway should be clear of vomitus and foreign material, which may cause obstruction or aspiration.
- Abdominal thrusts should not be used for fluid removal, because many victims have a distended abdomen from swallowed water; abdominal thrusts may increase the risk of regurgitation and aspiration.
- In cases of suspected airway foreign body, chest compressions or back blows are preferable maneuvers

#### TREATMENT OF HYPOTHERMIA

- Recognition and treatment of hypothermia are the unique aspects of cardiac resuscitation in the drowning victim.
- Core temperature must be evaluated, especially in children, because moderate to severe hypothermia can depress myocardial function and cause arrhythmias.
- Wet clothing should be removed to prevent ongoing heat losses, although in the hemodynamically stable patient, rewarming should be initiated in the controlled environment of the receiving ED or PICU.
  - Unstable patients (i.e., arrhythmias) should be warmed to 34°C (93.2°F), taking care not to overheat.
  - Trials are investigating if therapeutic hypothermia might be helpful, or if avoiding hyperthermia is the key element to long-term neurologic survival.

- intravenous (IV) fluids and vasoactive medications are required to improve circulation and perfusion.
- Vascular access should be established as quickly as possible for the administration of fluids or pressors. Intraosseous catheter placement is a potentially lifesaving vascular access technique that avoids the delay usually associated with multiple attempts to establish IV access in critically ill children.
- Epinephrine is usually the initial drug of choice in victims with bradyasystolic cardiopulmonary arrest (IV dose is 0.01 mg/kg using the 1:10,000 [0.1 mg/mL] solution given every 3-5 min, as needed). Epinephrine can be given intratracheally (endotracheal tube dose is 0.1-0.2 mg/kg of 1:1,000 [1 mg/mL] solution) if no IV access is available.
- An intravascular bolus of lactated Ringer solution or 0.9% normal saline (10-20 mL/kg) is often used to augment preload; repeated doses may be necessary.
- Hypotonic or glucose-containing solutions should not be used for intravascular volume administration of drowning victims.

## Most pediatric drowning victims should be observed for at least 6-8 hr, even if they are asymptomatic on presentation to the ED.

- At a minimum, serial monitoring of vital signs (respiratory rate, heart rate, blood pressure, and temperature) and oxygenation by pulse oximetry, repeated pulmonary examination, and neurologic assessment should be performed in all drowning victims.
- Almost half of asymptomatic or minimally symptomatic alert experience some level of respiratory distress or hypoxemia progressing to pulmonary edema, usually during the 1st 4-8 hr after submersion.
- Most alert children with early respiratory symptoms respond to oxygen and, despite abnormal initial radiographs, become asymptomatic with a return of normal room-air pulse oximetry oxyhemoglobin saturation (Sp o  $_2$ ) and pulmonary examination by 4-6 hr

- Consequently, in most cases, discontinuation of CPR in the ED is probably warranted for victims of non–icy water submersion who do not respond to resuscitation within 25-30 min.
- Final decisions regarding whether and when to discontinue resuscitative efforts must be individualized, with the understanding that the possibility of good outcome is generally very low with protracted resuscitation efforts.

- In comatose victims, irreversible CNS injury is highly likely
- Comatose drowning patients are at risk for intracranial hypertension.
- There is little evidence that ICP monitoring and therapy to reduce intracranial hypertension improve outcomes for drowning victims. Patients with elevated ICP usually have poor outcomes—either death or persistent vegetative state.

### Children with normal ICP can also have poor outcomes, although less frequently.

- Seizures after hypoxic brain injury are common, although detection is often difficult in the ICU because these patients are frequently sedated, thus masking clinical signs.
- Continuous electroencephalographic (EEG) monitoring in critically ill patients revealed a 13% incidence of seizures, 92% of which were exclusively nonconvulsiv

- With optimal management, many initially comatose children can have impressive neurologic improvement, but usually do so within the 1st 24-72 hr.
- Unfortunately, half of deeply comatose drowning victims admitted to the PICU die of their hypoxic brain injury or survive with severe neurologic damage.
- Many children become brain dead.
- Deeply comatose drowning victims who do not show substantial improvement on neurologic examination after 24-72 hr and whose coma cannot be otherwise explained should be seriously considered for limitation or withdrawal of support.

#### HYPOTHERMIA MANAGEMENT

- Full CPR with chest compressions is indicated for hypothermic victims if no pulse can be found or if narrow complex QRS activity is absent on ECG
- . When core body temperature is <30°C (86°F), resuscitative efforts should proceed according to the American Heart Association guidelines for CPR, but IV medications may be given at a lower frequency in moderate hypothermia because of decreased drug clearance.
- When ventricular fibrillation is present in severely hypothermic victims (core temperature <30°C [86°F]), defibrillation should be initiated but may not be effective until the core temperature is ≥30°C (86°F), at which time successful defibrillation may be more likely.</li>

- Victims with profound hypothermia may appear clinically dead, but full neurologic recovery is possible, although rare.
- Attempts at lifesaving resuscitation should not be withheld based on initial clinical presentation unless the victim is obviously dead (dependent lividity or rigor mortis).
- Rewarming efforts should usually be continued until the temperature is 32-34°C (89.6-93.2°F);
- if the victim continues to have no effective cardiac rhythm and remains unresponsive to aggressive CPR, resuscitative efforts can be discontinued.

- many investigators cautiously recommend that hypothermic drowning victims who
  remain unresponsive because of hypoxic-ischemic encephalopathy after restoration
  of adequate spontaneous circulation should NOt be actively
  rewarmed to normal body temperatures.
- Active rewarming should be limited to victims with core body temperatures <32°C (89.6°F), but temperatures 32-37.5°C (89.6-99.5°F) should be allowed without further rewarming efforts.

#### **PROGNOSIS**

•submersion duration <10 min is most strongly related to good outcome, not water temperature.

• In another study of comatose drowning patients admitted to pediatric intensive care unit (PICU), 65% of hypothermic patients (body temperature <35°C [95°F]) died, compared with a 27% observed mortality rate in nonhypothermic victims. Similarly,



