DROWNING in Children

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Definition (by The World Congress of Drowning)

- Definition of drowning is “the process of experiencing respiratory impairment from submersion/immersion in liquid.”
- The term *drowning* does not imply the final outcome—death or survival;
- The outcome should be denoted as *fatal* or *nonfatal* drowning.

- **> 500,000 deaths/year due to drowning in the world**
- From 2010 to 2015 in USA, the highest drowning death rates were seen in children age 1-4 yr and then 15-19 yr (crude rates of 2.56 and 1.2 per 100,000, respectively).
- 4th frequent cause of all deaths in the pediatric age group
- Drowning is More frequent in pediatric age group than Adults
- Fresh water drowning > salt water drowning
- Especially in <5 y age group drowning in bathtubs are frequent
- Drowning affects healthy people in young and productive age group
- Pediatric hospitalization rates associated with drowning ranged from 4.7 to 2.4 per 100,000 between 1993 and 2008.
- The injury following a drowning event is *hypoxia*.

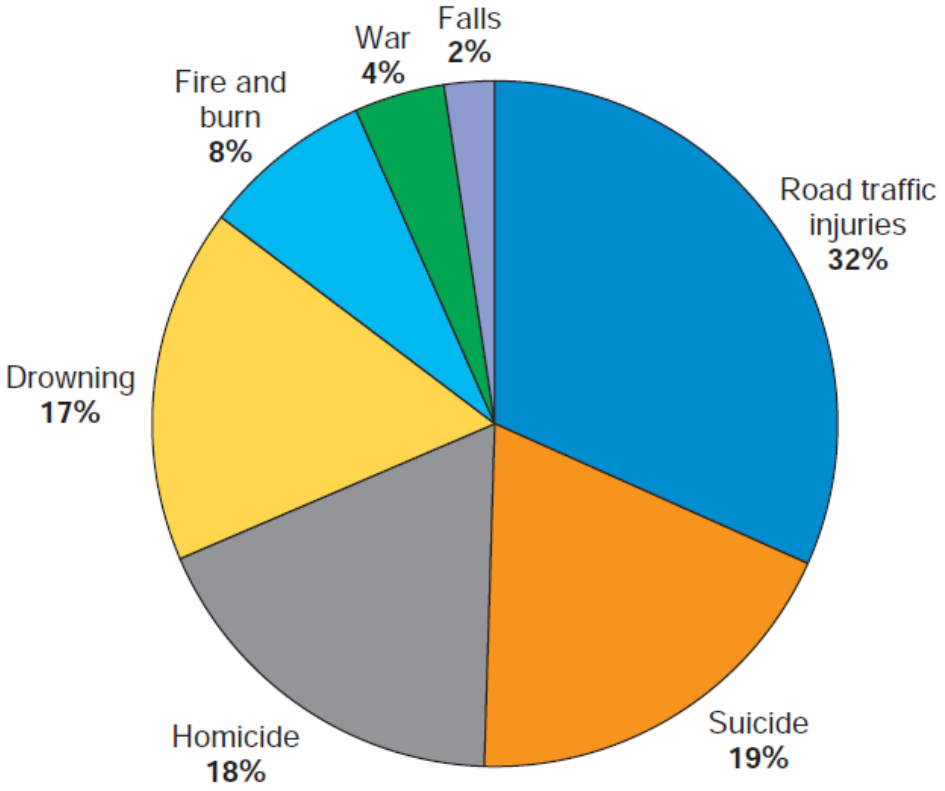


Fig. 13.1 Global injury deaths to children, adolescents, and young adults, 0-29 yr of age, 2012. *(From WHO: Injuries and Violence: The Facts 2012. Geneva: World Health Organization, 2014.)*

Drowning ranks 2nd overall as a cause of unintentional injury deaths among those age 1-19 yr, with peaks in the preschool age.

- **Drowning Risk in Different Pediatric Age Groups :**
  - **<1 y 38 (3.9%)**
  - **1-4 y 425 (44%)**
  - **5-9 y 147 (15.2%)**
  - **10-14 y 103 (10.7%)**
  - **15-19 y 253 (26.2%)**
  - **Total 966 (100%)**

Statistical Risk Factors

- Age: > 40% under 4 years old
- Location: Pools, bathtubs, lakes, rivers

- A common factor in many of these deaths is a lapse in adult supervision, often reportedly <5 min. Most U.S. drownings occur in residential **swimming pools**.

- Sex: Male 3:1
- Time of year: Warm months
- Socioeconomic Status

- **Poverty** is one of the most important risk factors for childhood injury. Mortality from fires, motor vehicle crashes, and drowning is 2-4 times higher in poor children.

Underlying Conditions

Drowning risk also relates to other host factors, including:

- **A history of seizures or epilepsy**
  - Drowning risk for children with seizures is greatest in bathtubs and swimming pools, up to 19-fold.
- **Swimming lessons.**
- **Alcohol use,**
- **Cardiac etiologies, including**
  - Arrhythmias , Myocarditis, and Prolonged QT syndromes, die suddenly in the water, particularly in those with a family history of syncope, cardiac arrest, prior drowning, or QT prolongation.
- **Drowning may also be an intentional injury:**
  - Child abuse
  - Suicide

Chain of events

Immersion in water

Drowning victims drown silently and do not signal distress or call for help

Breath holding voluntarily and with panic

Vocalization is precluded by efforts to achieve maximal lung volume to keep the head above the water or by aspiration leading to laryngospasm.

Struggle of the victim

Young children can struggle for only 10-20" & adolescents for 30-60" before final submersion.

Unvoluntarily point of cession

Aspiration of water and/or Laryngospasm **(Pathogenesis Start Point)**

- A progressive decrease in arterial blood oxyhemoglobin saturation (↓SaO2),
- Consciousness Loss from hypoxia
- Profound hypoxia and medullary depression lead to terminal Apnea.

At the same time, the cardiovascular response leads to progressively decreasing cardiac output and oxygen delivery to other organs.

Chain of events

By 3-4 min, **Myocardial Hypoxia** leads to **Abrupt Circulatory Failure**. Ineffective cardiac contractions with electrical activity may occur briefly, without effective perfusion **(Pulseless Electrical Activity)**.

The extent of the global hypoxic-ischemic injury determines the final outcome and becomes more evident over subsequent hours.

Hypoxic damage of brain

Cytotoxic cerebral odema

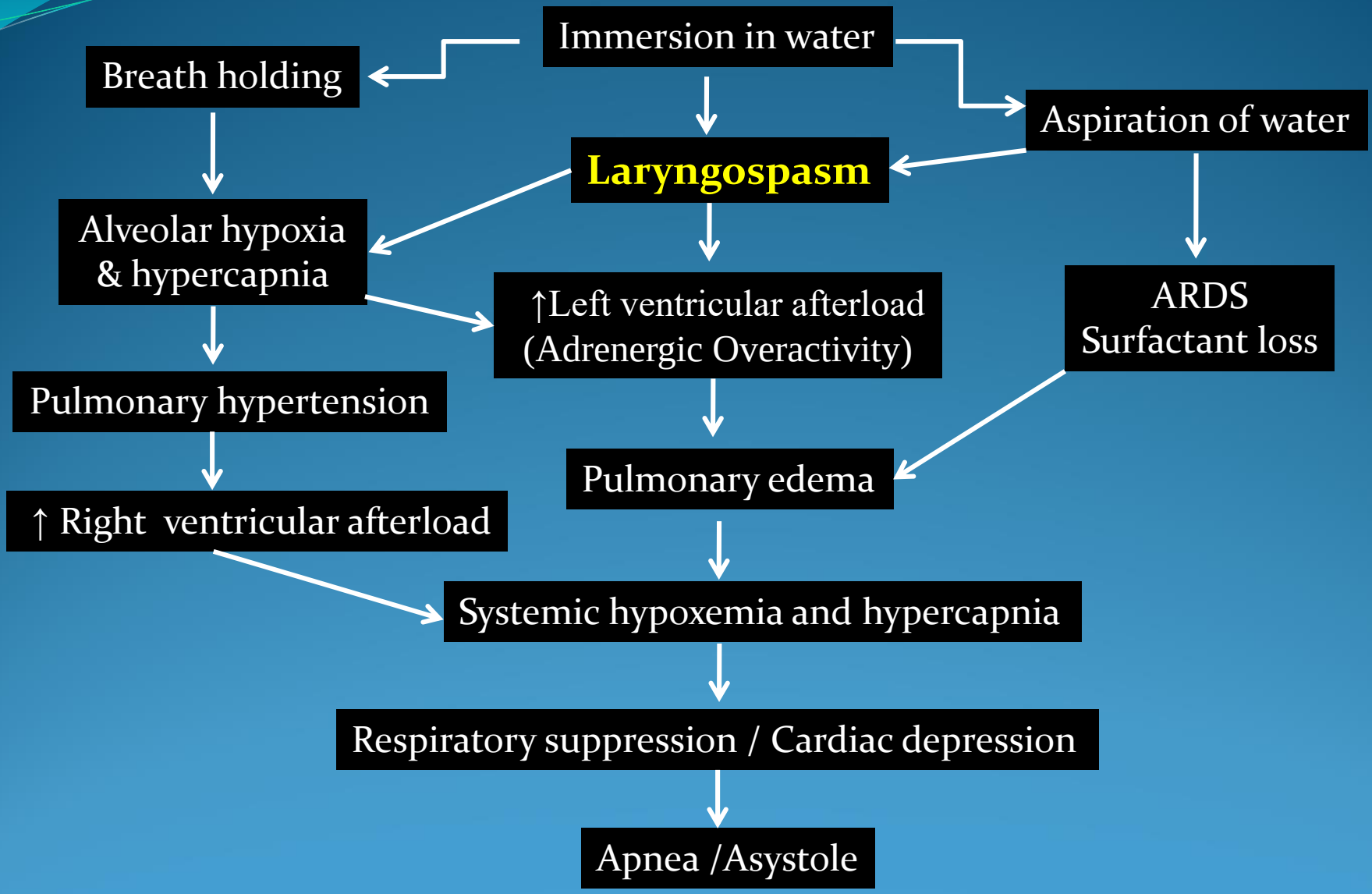
Increased intracranial pressure, decreased cerebral blood flow

Herniation → Brain Death→ Death

Cardiac arrest due to on-going hypoxia

Cardiac Death

Pathophysiology (Cardio-Pulmonary)



Fresh Water Aspiration

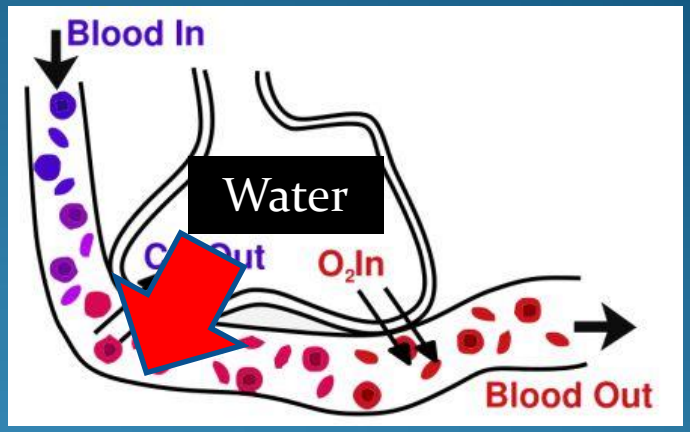
Fresh water aspiration

Hypotonic
pass into capillary easily

Hemolysis

Pulmonary surfactant dissolution
Alveolar collaps
Atelectasis

V/Q mismatch → HYPOXEMIA



Salt Water Aspiration

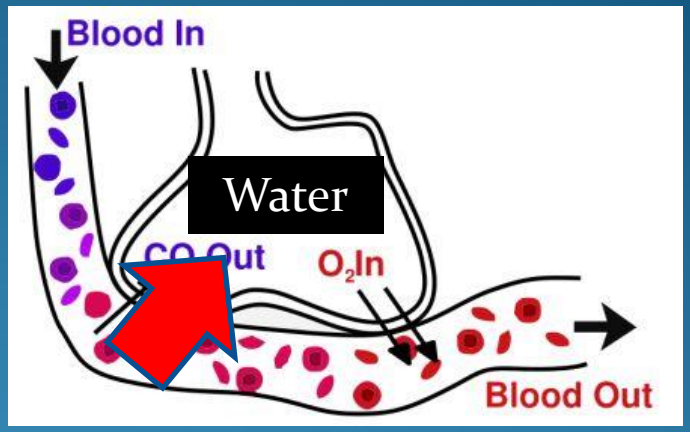
Salt water aspiration

Hypotonic
pass into alveoli easily

Hemoconsantration

Water in the alveoli

HYPOXEMIA



Electrolyte Imbalance

- Consequences of Aspiration
  - 2.2 cc/kg Hypoxia
  - 11 cc/kg Blood volume changes
  - 22 cc/kg Electrolyte changes
- Average aspiration is only 2-4 cc/kg

Cold Water Injury

- Drowning should be differentiated from **Cold Water Immersion** injuries
  - in which the victim remains afloat, keeping the head above water without respiratory impairment in cold waters.
- **The definition of cold water varies from <15 to 20°C**
- **Children are at increased risk for Hypothermia** because of:
  - Their relatively high ratio of body surface area (BSA) to mass,
  - Decreased subcutaneous fat,
  - Limited thermogenic capacity

Victims experience **Cold Water Shock**

A dynamic series of cardiorespiratory physiologic responses that can cause drowning:

- Severe bradycardia, the Diving Reflex,
- Intense involuntary reflex hyperventilation
- A decrease in breath-holding ability to <10 sec,

Cold Water Immersion

Heat loss with continued immersion can significantly decrease core temperature to hypothermic levels within 30-60 min.

After an additional 5-10 min of cold water immersion, the victim can become Incapacitated.

Mild hypothermia = 34-36°C with intact thermogenic mechanisms (shivering and nonshivering thermogenesis, vasoconstriction) and active movements.

Moderate hypothermia = 30 to <34°C

- Loss of consciousness leads to water aspiration
- Progressive bradycardia,
- Impaired myocardial contractility,
- Loss of vasomotor tone contribute to inadequate perfusion,hypotension, and possible shock

Severe hypothermia <28°C

- Extreme bradycardia with decreased cardiac output,
- Spontaneous ventricular fibrillation or asystole
- Respiratory center depression with moderate to severe hypothermia results in hypoventilation and eventual apnea.

COLD WATER

and

WARM WATER

drownings are different

Cold water has more survivors

Submersion victims
aren't dead until
they are WARM and DEAD

Cold Water Immersion: Severe Hypothermia

A Deep Coma,
with Fixed & Dilated Pupils
and Absence of Reflexes
at very low body temperatures <25-29°C
may give
the False Appearance of Death

MANAGEMENT

Duration of Submersion,
Speed of the Rescue,
Effectiveness of Resuscitative Efforts and Clinical Course
Determine the Outcome in Submersion Victims

Treatment

Begin Resuscitation at the scene of accident

Every minute that passes without the reestablishment of adequate breathing and circulation dramatically decreases the possibility of a good outcome.

- **A-B-C should be applied**
- **Mouth-to-mouth breathing should be started in water**
- **No need for cardiac massage in water, loss of time**
- **Victims usually need to be extricated from the water as quickly as possible so that effective CPR can be provided.**

Treatment

Begin Resuscitation at the scene of accident

- Initial resuscitation must focus on:
  - **Rapidly Restoring Oxygenation, Ventilation & 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. (Heimlich and Patric maneuvers)
- The cervical spine should be protected in anyone with potential traumatic neck injury

Treatment

Indication for Respiratory Support

If the victim has

Ineffective Respiration or Apnea

Respiratory support must be initiated immediately:
Mouth-to-mouth or Mouth-to-nose breathing
by trained bystanders often restores spontaneous ventilation

Treatment

Indication for Supplemental O_2 Therapy

As soon as it is available, supplemental oxygen should be administered to

All Victims

Treatment

Indication for Positive Pressure bag-mask Ventilation (PPV)

Positive pressure bag-mask ventilation with 100% inspired oxygen should be instituted in patients with

Respiratory Insufficiency

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Treatment

Indication for EndoTracheal Intubation

If there is Persistent

Apnea

Cyanosis

Hypoventilation

Labored Respiration

Trained personnel should perform endotracheal intubation as soon as possible

Intubation is also indicated to protect the airway in patients with

Depressed Mental Status

Hemodynamic Instability

Treatment

- SpO_2 should tried to be kept at 90%

Treatment in ER & ICU

Respiratory System

- Positive end expiratory pressure (PEEP) 4-6 cm H_2O to 12-14 cmH_2O
- Aim is to make SpO_2 >90%, while keeping FiO_2 < 50%
- NG tube (free ending)

Treatment

Cardiovascular System

- Concurrent with securing of airway control, oxygenation, and ventilation, the **Child's Cardiovascular Status** must be evaluated and treated according to the

Usual Resuscitation Guidelines & Protocols

- **Vascular Access** should be established as quickly as possible for the administration of intravenous (IV) fluids and vasoactive medications.
- **Intraosseous Catheter** placement is a potentially lifesaving vascular access
- Fluid replacement with appropriate solution (NS)

Treatment

Cardiovascular System

- **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.

Treatment

*Cardiovascular System – **Fluid Therapy***

- **IV Fluid**: an intravascular bolus of 0.9% **Normal Saline** or **Lactated Ringer Solution** (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.**
- **Many drowning victims may already be Hyperglycemic in first hours of treatment.**

Treatment in ER & ICU

Recognition and treatment of Hypothermia are the unique aspects of cardiac resuscitation in the drowning victim.

Thermoregulation

- Especially in children heat loss is very fast
- Wet clothes should be removed
- **In the Hemodynamically Stable patient**, **Rewarming** should be initiated in the controlled environment of the receiving ER or PICU.
- **Unstable Patients** (i.e., arrhythmias) should be warmed to 34°C
- Taking care not to overheat.

Treatment in ER & ICU

Thermoregulation

- Heat the patient slowly with blankets and light (Warmer)
- IV fluids should be heated to 36-40̊C
- O2 should be heated and humidified (HMEF-Heated humidifiers)
- Peritoneal or bladder lavage
- Rewarming efforts should usually be continued until the temperature is 32-34°C

Treatment in ER & ICU

Neurological System

- GCS <8 should be intubated and mechanically ventilated
- GCS ≤3 patients should not be resuscitated
- Increased ICP leads to bad prognosis and may not respond to treatment

EYE OPENING	
None	1 = Even to supra-orbital pressure
To pain	2 = Pain from sternum/limb/supra-orbital pressure
To speech	3 = Non-specific response, not necessarily to command
Spontaneous	4 = Eyes open, not necessarily aware
MOTOR RESPONSE	
None	1 = To any pain; limbs remain flaccid
Extension	2 = Shoulder adducted and shoulder and forearm internally rotated
Flexor response	3 = Withdrawal response or assumption of hemiplegic posture
Withdrawal	4 = Arm withdraws to pain, shoulder abducts
Localizes pain	5 = Arm attempts to remove supra-orbital/chest pressure
Obeys commands	6 = Follows simple commands
VERBAL RESPONSE	
None	1 = No verbalization of any type
Incomprehensible	2 = Moans/groans, no speech
Inappropriate	3 = Intelligible, no sustained sentences
Confused	4 = Converses but confused, disoriented
Oriented	5 = Converses and oriented

Prognosis

Factors for good prognosis

- Duration of stay in water <5 min
- Immediate CPR
- CPR duration <10 min
- Spontaneous ECG rhytm on ER admission
- GCS ≥6 on ER admission
- *Spontaneous movement and healthy brain stem function in 24 hours*

Prognosis

Factors for poor prognosis

- Duration of stay in water (submersion) >10 min
- CPR start delay > 10 min
- Cardiotonic drug need on ER admission
- GCS ≤5
- Hyperglycemia is associated with a poor outcome in critically ill pediatric drowning victims.
- No spontaneous movement after 24 hours
- Patients with **Elevated ICP** usually have poor outcomes—either death or persistent vegetative state.
- Deeply comatose drowning victims who do not show substantial improvement on neurologic examination after 24-72 hr
- Whose coma cannot be otherwise explained should be seriously considered for limitation or withdrawal of support.

Prognosis

Factors for poor prognosis

- All children with resuscitation durations >25 min either died or had severe neurologic morbidity
- All victims with submersion durations >25 min died.

Discharge from Hospital

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

PREVENTION

Table 91.1 Approach to Prevention Strategies for Drowning

	HOME	RECREATION	NEIGHBORHOOD
Water hazards	Swimming pools Ponds Bathtubs Large buckets	Playing in water-swimming, wading Playing near water Being on water—boating	Irrigation ditches Watering holes Water drainage
Common risks	Lapse in supervision Unexpected toddler exposure Delayed discovery of child Reliance on water wings or pool toys Reliance on sibling or bath seat for bathing supervision	Lapse in supervision Change in weather Unfamiliarity with or change(s) in water conditions: Steep drop-off Current/tide Low temperature Alcohol use Peer pressure	Lapse in supervision, particularly when caregiver is socializing Risky behavior when with peers
Prevention strategies	Recognize hazards and risks. Provide constant adult supervision around water. Install 4-sided, isolation fencing of pools. Install rescue equipment and phone at poolside. Learn swimming and water survival skills. Avoid bath; instead shower, if a child/teen with seizure disorder. Learn first aid and CPR.	Provide constant adult supervision. Swim in lifeguarded areas. Know when and how to wear U.S. Coast Guard–approved PFDs. Avoid alcohol and other drugs. Learn swimming and water survival skills. Teach children about water safety. Be aware of current weather and water conditions. Learn first aid and CPR.	Identify hazardous bodies of water. Prevent access to water with barriers. Provide fenced-in "safe area" for water recreation. Provide lifeguarded swim sites. Provide access to low-cost swim/water survival lessons.

CPR, Cardiopulmonary resuscitation; PFDs, personal floatation devices.


THANK YOU