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PEDIATRIC CRITICAL CARE: A NEW MILLENNIUM

DROWNING

Rescue, Resuscitation, and Reanimation

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> It is one of Nature's greatest ironies that man should spend the first nine months of his existence continously surrounded by water, but the rest of his life with an inherent fear of submersions.
>
> B. A. GOODEN

Each year, drowning is responsible for an estimated 500,000 deaths around the world. The exact number is unknown because many drowning deaths go unreported.[11] This accident has been of major concern since the beginning of civilization.

The World Health Organization (WHO)[52] has released statistics on the Global Burden of Injury (Table 1 (Table Not Available)) that showed that drowning is the leading cause of death worldwide among females aged 5 to 14 years and is the fifth leading cause of death for females in the same age group. For both sexes combined, drowning was the fourth leading cause of death, exceeded only by acute lower respiratory infections, malaria, and injuries from motor vehicle accidents in the 5- to 14-year age group. Drowning as a cause of death ranked 11th for children aged 0 to 4 years and 10th for people aged 15 to 44 years. For both sexes, drowning as a cause of death in high-income countries in the Americas ranked sixth for children aged 0 to 4 years and fourth for children aged 5 to 14 years. For low- and middle-income countries in the Americas, drowning ranked as the 11th leading cause of death in children aged 0 to 4 years and second in children aged 5 to 14 years. According to WHO, in China, drowning is the leading cause of death for children aged 5 to 14 years for both sexes and ranks fourth for children aged 0 to 4 years and ninth for people aged 15 to 44 years.[52]

TABLE 1 -- INJURY-RELATED MORTALITY WORLDWIDE, 1998

(Not Available)
From Krug E, for the World Health Organization: Injury: A Leading Cause of the Global Garden Disease. Geneva, WHO, 1999; witl

In the United States, drowning is the third commonest cause of unintentional injury death for all ages and ranks second for people aged 5 to 44 years.[2] [9] Drowning is the second leading cause of accidental death in children aged 1 to 4 years in the United States and Africa (40% of deaths)[9] and the leading cause in this age group in Australia.[20] In 1995, the Brazilian population reached 155 million inhabitants, of whom 7020 (4.5/10,000 inhabitants) died because of drowning.[42] Drowning is the third leading cause of accidental death for people of all ages in Brazil and second for children aged 1 to 14 years (Fig. 1).

Figure 1. Mortality, outward cause, Brazil 1995. In each group of four: first bar = car accident; second bar = drowning; third bar = homicide; fourth bar = foreign body airway obstruction. ***(Data from Ministerio da Saude: DATASUS, 1995.)***

Ironically, 90% of all drowning deaths occur within 10 m of safety.[11] The patterns of drowning deaths are highly dependent on geographic factors. An estimated 40% to 45% of drowning deaths happen during swimming.[8] In nautical sports, drowning is responsible for 90% of deaths. Twelve to twenty-nine percent of drowning deaths are associated with boating accidents.[8] In one study of patterns of drowning deaths in Australia from 1992 to 1997, Mackie[20] reported that the incidence of overall accidental, nonboating, drowning deaths was 1.44 per 100,000 population per year and that the incidence of drowning deaths occurring from boating accidents was 0.29 per 100,000 population per year. The commonest sites for nonboating drowning accidents were oceans or estuaries (22%), private swimming pools (17%), nontidal lakes and lagoons (17%), surfing beaches (10%), and bathtubs (7%). Approximately 22% of victims were less than 5 years of age (4.6/100,000 population/year), and few of those drowned in the ocean or in boating accidents.

Freshwater drowning deaths are commoner among children than among adults and are especially common among children less than 10 years of age. In 1993, 4390 victims died in the United States,[8] of whom 53% drowned in swimming pools. In the United States, 50,000 new pools are built each year in addition to the 2.2 million residential pools and 2.3 million nonresidential pools already in existence. In the temperate areas of the United States, Australia, and South Africa, 70% to 90% of the deaths from drowning happen in residential pools.[11] In Brazil, where the number of residential pools is much smaller, freshwater drownings happen more commonly in rivers, lakes, and dams, contributing to half of the deaths by drowning.[46]

In Brazil, the drowning death rate among people aged 20 to 29 years is without distinction among states with or without a coastline. Considering all ages, males die fivefold more often than do females. There is no sex distinction in death rates among children less than 1 year of age, but among people aged 20 to 29 years, men drown 8.7-fold more frequently than do women in this age group.[41]

In 1996, the United States Lifesaving Association reported 62,747 rescues on the shores of US beaches, with estimates of eight cases of near-drowning for each reported death.[46] On Rio de Janeiro beaches, data show approximately 290 rescues for each reported death (0.34%), and one death for each 10 victims admitted for medical care in the Drowning Recuperation Center (DRC) (10%).[47] In the past 31 years of work, the Rescue Service of Rio de Janeiro made approximately 166,000 rescues by lifeguards on the beaches, and 8500 victims needed medical attention in the DRC. Of all of those victims, 75% were male, 83% were unmarried, 46.6% thought they knew how to swim, and 71.4% resided far from the beach.[47] Most drownings occur in young, healthy, and productive people with life expectencies of many years.

NOMENCLATURE AND DEFINITION

Drowning is defined as death resulting from suffocation within 24 hours of submersion in a liquid medium, and *near-drowning,* as survival of at least 24 hours after an episode of suffocation caused by submersion in a liquid medium.[35] Modell[27] proposed the following definitions in 1971, with slight modifications in 1981: "**Drown** without aspiration was to die from respiratory obstruction and asphyxia while submerged in a fluid medium. **Drown** with aspiration: to die from the combined effects of asphyxia and changes secondary to aspiration of fluid while submerged. Near **drowning** without aspiration: to survive, at least temporarily, following asphyxia due to submergence in a fluid medium. Near **drowning** with aspiration: to survive, at least temporarily, following aspiration of fluid while submerged." Others have defined ***drowning*** as death after submersion or immersion or death that occurs after hospital admission, and *near-drowning,* as survival after submersion or immersion. WHO went so far as to recommend three levels: **drowning**, near-drowning, and near-near-drowning.

In using these terms, it should be considered that the time limit for survival, as a part of the definition, is not a scientific concept and is not in accordance with outcome parameters as used in the internationally accepted Utstein style.[10] There is no other accident or disease for which the term *near* is used as a modifier. Clinicians do not speak of a "near" motor vehicle death, "near" poisoning, or "near" burn death. Even the older terminology of *near-miss sudden infant death syndrome* has been abandoned. The incidence of **drowning** without aspiration may be lower or nonexistent because such a diagnosis can be confused with that of someone who suffers foul play and then enters the water, or someone who suffers sudden cardiac death and then submerges.[28] These definitions also must include the word *immersion* in addition to *submersion* to clarify that it is not obligatory to be totally covered by water (submersion) to be drowned or near-drowned[5] (conscious victims typically are found immersed, whereas unconscious victims could be found immersed or submersed). Also, these definitions should exclude cases of body fluid aspiration, such as vomit, blood, saliva, bile, or meconium. For many years, these definitions were used in a near-drowning and **drowning** classification system that was supposed to imply prognosis but did not.

It seems clear that these terms and definitions are awkward and confusing and should be abandoned. Therefore, this type of accident simply should be known as ***drowning,*** and its definition should be "suffocation by immersion or submersion in any liquid medium, caused by the entrance of liquid into the airways, that partially or fully compromises ventilation or oxygen exchange." Furthermore, any submersion or immersion incident without evidence of liquid aspiration should be considered a *water rescue.*

From this point on, *near-drowning* and ***drowning*** are referred to only by the word ***drowning,*** and *death* is mentioned if it is important to readers' understanding.

Drowning is usually a primary accident but at times is secondary to some other illness or accident that renders the victim unconscious or compromised and precipitates the **drowning**. On Rio de Janeiro beaches, secondary **drowning** happens in 13% of all **drowning** cases; drugs (36.2%; almost always alcohol), convulsion (18.1%), trauma (including boating accidents; 16.3%), cardiopulmonary diseases (14.1%), skin diving and SCUBA diving (3.7%), diving injuries with head or spinal cord injury, and others (e.g., homicide, suicide, syncope, cramps, or immersion syndrome; 11.6%) are causes. The use of alcohol is considered the most important factor in the cause of secondary **drowning** or **drowning** as the result of some other accident or disease.[49] Some years ago, the term *secondary* ***drowning*** was used to mean a complication of a **drowning** or a delayed onset of respiratory distress, but these designations are now in disuse.[28]

The immersion syndrome (also called the *immediate disappearance syndrome*) is syncope provoked by bradycardia, tachycardia, or arrhythmia precipitated by sudden contact with water at a temperature of at least 5°C less than body temperature. It can happen, therefore, in water as warm as 31°C. The larger the temperature difference, the greater the risk for immersion syndrome. The syncope produces a loss of consciousness and secondary **drowning**. Explanations of vagal stimulation leading to sudden asystole or ventricular fibrillation caused by massive release of adrenaline secondary to cold or exercise have been proposed as the cause of this syndrome.[51] Studies suggest that the occurrence of this type of accident can be reduced by wetting the face and head before entering the water.

PATHOPHYSIOLOGY

Despite some pathophysiologic differences between **drowning** in fresh or salt water in experimental models, from a clinical and therapeutic view, there are no important differences between **drowning** in fresh water and seawater in humans. The most significant pathophysiologic alterations are hypoxia[16] with resultant metabolic acidosis and respiratory acidosis from hypercarbia.

The aspiration of water initially causes breathholding or laryngospasm, leading to hypoxia. After a time, water is swallowed actively and passively by the victim, and, with the hypoxic termination of laryngospasm or breathholding, water is aspirated into the lungs. The respiratory disturbance depends less on water composition and more on the amount of water aspirated. The aspiration of fresh or salt water produces surfactant destruction, alveolitis, noncardiogenic pulmonary edema, blockage of alveolar-capillary gas exchange, and increased intrapulmonary shunt leading to profound hypoxia.[3] [14] [31] In animal research, the aspiration of 2.2 mL of water per kilogram of body weight decreases the arterial oxygen pressure (Pa_{O_2}) to approximately 60 mm Hg within 3 minutes.[25] In humans, it seems that as little as 1 to 3 mL/kg of water aspiration produces profound alterations in pulmonary gas exchange and decreases pulmonary compliance by 10% to 40%.[14] [15] [25] [31]

Studies conducted in dogs drowned in 44 mL/kg fresh water demonstrated that ventricular fibrillation (VF) was secondary to disturbances in the blood levels of potassium.[25] This occurrence rarely is reported in humans, however, probably because humans rarely aspirate sufficient water to provoke significant electrolyte disturbances. In a study of 187 electrolyte measurements in 2304 **drowning** cases,[44] no victims needed initial electrolyte correction. VF in humans, when it occurs, is related to hypoxia and acidosis and not to hemolysis and hyperkalemia. Decreased cardiac output and arterial hypotension and increased pulmonary arterial pressure and pulmonary vascular resistance are the results of hypoxia.[32] Also common is intense peripheral vasoconstriction caused by hypoxia, epinephrine release, and hypothermia.

RESCUE AND RESUSCITATION

The panicked and struggling **drowning** victim can be dangerous to a would-be rescuer. A victim attempting to cling to life and breathe can **drown** their would-be rescuer. For this reason, it is always best to approach a struggling victim with an intermediary object. Lifeguards use rescue or torpedo buoys for this purpose that also can double as a neck flotation device to keep the head of an unconscious victim out of the water.

Pia [38] has described the *instinctive* ***drowning*** *response.* Contrary to popular opinion and the picture popularized by film and television, the victim does not wave or call for help. Because breathing instinctively takes precedence, the **drowning** victim is unable to cry for help; he or she is typically in an upright posture, with arms extended laterally, thrashing and slapping the water. Individuals close by may not recognize that the victim is struggling and may assume that the victim is playing and splashing in the water. The victim may submerge and surface his or her head several times during this struggling activity but is unable to call for help. Pia has shown that children can struggle for only 10 to 20 seconds before final submersion and that adults may be able to struggle for up to 60 seconds.[38]

The most important step in the rescue of a **drowning** victim is the immediate institution of resuscitative measures. For the apneic victim, this means commencing pulmonary resuscitation as soon as the rescuer reaches and quickly assesses the victim. For a victim who is away from shore or the side of a pool, pulmonary resuscitation must be instituted where the victim is retrieved instead of rushing the victim to shore before assessment and pulmonary resuscitation.

Unfortunately, external cardiac compressions cannot be performed effectively in the water, and so assessment for pulse and external cardiac message must be delayed until the victim is out of the water.

No attempts to drain fresh or salt water from the lungs should be made before pulmonary resuscitation is begun. In freshwater **drowning** victims, water has moved rapidly out of the lungs and into the vascular system, and in seawater **drowning** victims, noncardiogenic pulmonary edema fluid continually is produced. Any delay in instituting pulmonary resuscitation exacerbates hypoxia. Airway patency should be assessed, but the airway usually does not need to be cleared of any debris or vomitus. If debris or vomitus is detected, the finger-sweep maneuver or suctioning to clear the oropharynx is needed.

The Heimlich maneuver should not be performed except in cases in which repeated attempts to position the airway and ventilate the victim have failed and an obstructed airway is suspected. The Heimlich maneuver does not remove water from the airways or lungs, causes emesis, and predisposes the victim to gastric acid aspiration. Chest compressions to clear a potentially obstructed airway are preferable to abdominal thrusts because abdominal distention is common among **drowning** victims and it predisposes them to vomiting.[43]

Emesis and aspiration of gastric contents are major problems among **drowning** victims because the victims have swallowed much more water than has been inhaled, and pulmonary resuscitation distends the stomach further with air. Studies have shown that 25% to 60% of **drowning** victims vomit,[20] and the emesis can interfere technically and aesthetically with pulmonary resuscitation. It is recommended that spontaneously breathing **drowning** victims be placed and transported in the right lateral decubitus position, with the head lower than the trunk, to reduce the risk for aspiration if vomiting occurs.[20] Cricoid pressure (the Sellick maneuver) during mouth-to-mouth or bag-valve-mask ventilation may reduce the risk for gastric aspiration by preventing regurgitation and reducing abdominal distention during ventilation. The Sellick maneuver requires an additional rescuer to perform the cricoid pressure.

Pulmonary edema and decreased pulmonary compliance are also major problems in resuscitating **drowning** victims. They make effective ventilation difficult, and the pulmonary edema may be sufficiently severe to interfere with attempted pulmonary resuscitation.

In seawater **drownings**, suctioning pulmonary edema fluid from the airway may be necessary if its presence interferes with effective ventilation. Once the victim is intubated, frothy pulmonary edema fluid and water can be suctioned from the airway, but most important, victims can be oxygenated and ventilated effectively even through copious pulmonary edema fluid. The first priorities are adequate oxygenation and ventilation. Szpilman [48] has shown that, on sloping beaches, rescuers are most successful when they position the victim parallel to the water instead of trying to drain water from the airway using a victim position in which the head is lower than the body (as was common in the past), especially if external cardiac massage is needed.

Cardiopulmonary resuscitation (CPR) should be continued for as long as needed during transport to an emergency care facility. Oxygen, at the highest concentration attainable, should be administered to the victim as soon as available and throughout transport.

Automatic external defibrillation may have a role in treating pulseless **drowning** victims. Although VF is uncommon, especially in pediatric victims of **drowning**, some adults may develop VF possibly as a consequence of coronary artery disease, and VF and ventricular tachycardia may be a consequence of Advanced Cardiac Life Support (ACLS) therapies, such as epinephrine.

Venous or intraosseous access is the preferred route for the administration of ACLS drugs. Although some ACLS drugs can be administered endotracheally with copious, noncardiogenic pulmonary edema fluid, whether the drugs would be absorbed and what dose to use are unclear.

Apneic or respiratory compromised **drowning** victims are managed best with endotracheal intubation. The Sellick maneuver should be used, if possible, during intubation to prevent regurgitation and aspiration. Intubation isolates the airway, protects against aspiration of gastric contents, and enables effective oxygenation and ventilation even through copious pulmonary edema fluid. Continuous positive airway pressure at 5 to 10 cm H_2O should be applied initially, with careful attention to effects on oxygenation and blood pressure. If oxygenation is inadequate (<90% saturation) and blood pressure is acceptable, the positive end-expiratory pressure (PEEP) or continuous positive airway pressure (CPAP) should be increased to 10 to 15 cm H_2O. If blood pressure is low or decreases, the PEEP or CPAP may need to be reduced.

DROWNING CLASSIFICATION

In 1997, Szpilman[49] proposed an updated **drowning** classification system based on the Menezes and Costa system[22] that guides prognosis and treatment based on severity in the prehospital environment. An analysis[49] of 1831 **drowning** victims showed that severity of **drowning** could be classified into seven levels, with the seventh level being **drowning** without aspiration, called, simply, *rescue.* The **drowning** classification system proposed by Szpilman[49] takes into consideration the degree of respiratory insufficiency based on the initial evaluation at the accident site.

This **drowning** classification system is important for guiding lifeguard procedures because it is based on clinical findings at initial assessment. Grade 1 victims usually do not need any oxygen or respiratory assistance. Grade 2 victims need only oxygen by nasal cannula (93.2% of Grade 2 cases) or no invasive respiratory assistance (no mechanical ventilation). Grade 3 victims need mechanical ventilation (72.4% of Grade 3 victims) or oxygen only by nasal cannula (27.6% of Grade 3 victims). Grades 4 to 6 victims need invasive respiratory assistance (100% of Grades 4-6 victims).[49]

Hospitalization is recommended for all **drowning** victims of grades 2 to 6 (Fig. 2) . Table 2 (Table Not Available) shows general mortality rates for each grade of severity, hospitalization need, and prehospital and in-hospital mortality rates.

Figure 2. Grade 1, Do not spend time trying to drain the water from lungs--this only will increase the occurrence of vomiting or regurgitation and complications--and do not aspirate foam enthusiastically while ventilating. Grade 2, Do not use diuretics or water restriction to treat pulmonary edema. Grace 3, Do not use antibiotics before 48 h except if the accident occurred in an area of high water bacterial colonization. Grade 4, Do not use steroids except in case of refractory bronchospasm. Grade 5, Always treat hypothermia. Do not stop cardiopulmonary resuscitation until body temperature rises to 34°C. Grade 6, There is no difference in advanced cardiac life support (ACLS) support between different kinds of water **drowning**. CPA = Cardiopulmonary arrest; OTT = oro-tracheal tube; PEEP = positive end-expiratory pressure.

TABLE 2 -- OUTCOMES OF SZPILMAN **DROWNING** CLASSIFICATION SYSTEM BASED ON INITIAL ASSESSMENT A VICTIMS

(Not Available)

*From Szpilman D: Near-drowning and **drowning** classification: A proposal to stratify mortality based on the analysis of 1,831 cases. permission.*

The **drowning** classification system is important for on-scene decision making by lifeguards and EMS technicians, who typically initiate care, and also for teaching Basic Life Support (BLS). The BLS algorithm was developed and adapted with simple language based on the data of the ACLS algorithm (Fig. 3 ; see also Fig. 2) .

Figure 3. Heimlich maneuver is indicated only with strong suspicion of foreign body obstruction: there is no difference in basic life support between different types of water **drowning**.*If the victim is Grade 5, ventilation in water can reduce mortality by almost 50%. CPA = Cardiopulmonary arrest.

The victim's consciousness level should be assessed upon arrival at the emergency department and immediately after successful CPR, using the Glasgow Coma Scale (GCS).

Any **drowning** victim who was submerged for more than 1 minute, was cyanotic or apneic, or required pulmonary resuscitation, should be hospitalized or observed in an emergency holding area for a minimum of 24 hours regardless of how healthy he or she seemed on arrival at the hospital or emergency facility. The literature reports that, rarely, **drowning** victims who seem healthy on assessment in the emergency department, including having normal chest radiography, develop fulminant pulmonary edema as long as 12 hours after the accident. Whether this late-onset pulmonary edema is delayed acute respiratory distress syndrome (ARDS) or neurogenic pulmonary edema secondary to hypoxia is unclear. Late-onset neurologic deterioration secondary to cerebral edema also has been described. Both require careful observation and assessment for at least 24 hours after the accident to prevent a fatal outcome.

Decision making in the emergency department about admission to an ICU or hospital bed versus observation in an emergency department holding area or discharge home should include thorough history of the accident and previous illness, a physical examination with emphasis on pulmonary and central nervous system function, and a few diagnostic studies, including chest radiography and arterial blood gas (ABG) measurement. In some cases, a toxicologic screen for suspected alcohol or drug ingestion also may be warranted.

Patients who have required CPR or ventilatory support or have abnormal chest radiography or ABG on arrival at the emergency department should be admitted to an ICU for close observation and therapy.

REANIMATION

Serial ABG measurement has an indispensable role in the management of **drowning** victims with respiratory, cerebral, or other vital organ compromise. An arterial line provides the minimum in invasive monitoring of these patients in the ICU. Electrolytes, blood urea nitrogen, creatinine, and hemoglobin also should be assessed serially, although, as stated earlier, perturbations in these laboratory tests are unusual among **drowning** victims.

Oxygen therapy with or without mechanical ventilatory support is the first-line therapy for **drowning** victims. The apneic victim obviously requires mechanical ventilatory support. In the spontaneously breathing **drowning** victim, oxygen therapy alone (by mask or nasal cannula) may suffice if a Pao_2 of more than 90 or Sao_2 of more than 90% can be maintained with an Fio_2 of 0.50 or less. A patient with a Pao_2 :Fio_2 ratio of 300 or less or a (shunt) QS:QT of 15% or more usually needs positive airway pressure in addition to oxygen. In most cases, this necessitates intubation of the patient and provision of the positive airway pressure by CPAP or PEEP. With CPAP, the patient breathes entirely on his or her own. With PEEP, mechanical ventilatory support is provided to varying degrees. In select cases, CPAP may be provided by mask (e.g., in cooperative adolescents) or nasal cannula (in infants who are obligate nasal breathers), but pulmonary edema usually necessitates intubation. In most **drowning** victims, positive airway pressure is provided optimally by a nasotracheal or orotracheal tube. Intubation not only ensures the adequate and continuous provision of the needed positive airway pressure but also enables good bronchiopulmonary hygiene and removal of secretions.[35] Positive airway pressure should be initiated at a level of 5 cm H_2O and then increased by 2 to 3 cm H_2O increments until the desired QS:QT of 20% or less or Pao_2 :Fio_2 of 300 or more is achieved. As soon as possible, the Fio_2 should be reduced to 0.50 or less to avoid adding oxygen toxicity to the pulmonary injury. Once the desired oxygenation is achieved at a given level of positive airway pressure, that level of PEEP or CPAP should be maintained unchanged for 24 to 48 hours before attempting to decrease it to permit adequate surfactant regeneration.

Mechanical ventilation in addition to positive airway pressure is indicated whenever the victim's spontaneous ventilation is inadequate, as assessed by a $Paco_2$ of more than 35 mm Hg or an Sao_2 of less than 90% or an abnormally high respiratory rate (in children, usually > 50 bpm) to maintain adequate ABG, such that the patient is consuming large amounts of energy breathing and is likely to tire.[35]

Acute respiratory distress syndrome (ARDS) is common after significant **drowning** episodes. The management of **drowning** victims with ARDS is similar to that of other patients with ARDS, including efforts to minimize volutrauma and barotrauma. Lung salvage involving permissive hypercapnia probably is not suitable for **drowning** victims with significant hypoxic-ischemic brain injury, however. Instead, mild to moderate hyperventilation, aiming for a $Paco_2$ in the range of 28 to 35 mm Hg probably is indicated, together with other therapeutic measures to control cerebral edema. Despite aggressive management, neurologic injury and sequelae, including persistent vegetative state, are problematic in the management of **drowning** victims.

In patients who are hemodynamically unstable or have severe pulmonary dysfunction, pulmonary artery catheterization improves the ability to assess and treat the victim. Pulmonary artery catheterization enables the clinician to monitor cardiac function (cardiac output and right and left heart pressures), pulmonary function (QS:QT and pulmonary artery pressures), and tissue adequacy of oxygenation and perfusion (arteriovenous oxygen delivery and extraction) and to assess the response of these parameters to various therapies. Echocardiography to assess cardiac function and ejection fractions can guide the clinician in deciding on inotropic agents, such as dobutamine.

Some studies have shown that cardiac dysfunction caused by hypoxia with low cardiac output is common after **drowning** accidents in fresh water or sea water.[31] [32] The low cardiac output is associated with high pulmonary capillary occlusion pressure, high central venous pressure, and high pulmonary vascular resistance and persists for a long time after reoxygenation and reperfusion. The result is the addition of cardiogenic pulmonary edema to the noncardiogenic pulmonary edema of ARDS. Despite the depressed cardiac output and elevated central venous pressures, furosemide therapy, even in freshwater **drowning** victims, probably is not a good idea. One study even has suggested that volume infusion benefits freshwater **drowning** victims. Studies suggest that dobutamine infusion to improve cardiac output is the most logical and potentially beneficial therapy.

Prophylactic antibiotics are of doubtful value in the intensive care management of the **drowning** victim and tend to select out only more resistant and more aggressive organisms. A preferable approach is daily or twice-daily monitoring of tracheal aspirates with Gram stain, culture, and sensitivity. At the first sign of pulmonary infection, as gauged by fever, leukocytosis, pulmonary infiltrates, and leukocyte response in the tracheal aspirate, antibiotic therapy is selected on the basis of predominant organism sensitivities or predominant organisms on Gram stain, pending culture and sensitivity studies. Likewise, corticosteroids for pulmonary injury are, at best, of doubtful value and probably should not be used.

Other important supportive measures for **drowning** victims in the ICU include nasogastric tube placement to prevent further aspiration and Foley catheter placement to monitor urine output. Renal insufficiency or renal failure is rare in **drowning** victims but can occur secondary to anoxia, shock, or hemoglobinuria. The clinician must be aware of and constantly vigilant for potential complications of therapy and underlying pulmonary injury, namely, volutrauma and barotrauma.[35] Spontaneous pneumothoraces are common secondary to positive pressure therapy and local areas of hyperinflation. Any sudden change in hemodynamic stability should be considered a pneumothorax or other barotrauma until proved otherwise. Another common problem is infection, and vigilance for not only pulmonary but also other septic complications is important.

The most significant and important complication of **drowning** accidents in addition to pulmonary injury is the anoxic-ischemic cerebral insult. Most late deaths and long-term sequelae of **drowning** accidents are neurologic in origin.[35] Every effort in the early stages after rescue of **drowning** victims should be directed at resuscitating the brain and preventing further neurologic damage. These steps include provision of adequate oxygenation and perfusion and careful monitoring for the development of cerebral edema. Cerebral edema is common after significant anoxic-ischemic insult secondary to a **drowning** accident.

Any victim who remains comatose and unresponsive after successful CPR or deteriorates neurologically should undergo careful and frequent neurologic function assessment. The clinician also should be cognizant of possible head or spine trauma or drug intoxication contributing to the accident, but these are uncommon in pediatric **drowning** victims. They are, however, common in adolescent **drowning** victims. Hyperpyrexia can occur secondary to the cerebral insult, and the maintenance of normothermia with external cooling can simplify management. In select cases, the induction of moderate hypothermia to 30° to 31°C or induction of barbiturate coma can control cerebral edema and intracranial hypertension when other therapies are unsuccessful. Dexamethasone also may help in controlling cerebral edema in the long term but is of no value for acute episodes.

Unfortunately, the studies that have evaluated the results of cerebral resuscitation measures in **drowning** victims have failed to demonstrate that therapies directed at controlling intracranial hypertension and maintaining cerebral perfusion pressure (CPP) improve outcome. These studies have shown poor outcomes (i.e., death or moderate to profound neurologic sequelae) when the intracranial pressure was 20 mm Hg or more and the CPP was 60 mm Hg or less, even when therapies are directed at controlling and improving these pressures. Further research and improvements in cerebral resuscitation are needed.

Various prognostic scoring systems have been developed to predict which pediatric patients will do well after a **drowning** accident with standard therapy and which patients are likely to have a significant cerebral anoxic encephalopathy and will require aggressive measures to resuscitate and protect the brain. One scoring system by Orlowski delineated five unfavorable prognostic factors, including age of 3 years or less, estimated submersion time of more than 5 minutes, no attempts at resuscitation for 10 minutes after rescue, coma on admission to the emergency department, and severe acidosis with an ABG pH value of 7.10 or less.[34] Patients with two or fewer poor prognostic factors had a 90% likelihood of good recovery with standard therapy, whereas patients with three or more poor prognostic factors had only a 5% likelihood of good recovery.

Neurologic classification of pediatric **drowning** victims based on level of consciousness as assessed by the GCS also has been used for prognostic purposes and to assess patient's response to various treatment protocols.[35] Good correlation between GCS and the prognostic scoring system of Orlowski has been demonstrated, and both are fairly accurate in predicting outcome. The failure of intracranial pressure monitoring, barbiturate coma, induced hypothermia, and neuromuscular blockade to improve the outcome of severely comatose **drowning** victims with predetermined poor prognoses, however, has produced some new and potentially important prognostic data. Because of the typical delay of 2 to 6 hours between rescue and transfer from an outlying emergency facility to a pediatric ICU, many patients with severe anoxic-ischemic cerebral insults and coma have had multiple determinations of neurologic status and level of consciousness before definitive therapy is begun. Data suggest that patients who remain profoundly comatose (i.e., decorticate, decerebrate, or flaccid) 2 to 6 hours after the **drowning** accident are brain dead or have moderate to severe neurologic impairment. Patients who are improving but remain unresponsive have a 50% likelihood of a good outcome. Most patients who are definitely improving and are alert or are stuporous or obtunded but respond to stimuli 2 to 6 hours after the accident have normal or near-normal neurologic outcomes. These prognostic variables are important in counseling family members of **drowning** victims in the early stages after the accident and in deciding which patients are likely to have a good outcome with standard supportive therapy and which victims should be candidates for experimental cerebral resuscitation therapies.[35]

New therapeutic interventions for **drowning** victims, such as extracorporeal membrane oxygenation, artificial surfactant, nitric oxide, and liquid lung ventilation, are still in the investigational stage.

SUMMARY

Several myths about **drowning** have developed over the years. This article has attempted to dispel some of these myths, as follows:

1. **Drowning** victims are unable to call or wave for help.
2. "Dry **drownings**" probably do not exist; if there is no water in the lungs at autopsy, the victim probably was not alive when he or she entered the water.
3. Do not use furosemide to treat the pulmonary edema of **drowning**; victims may need volume.
4. Seawater **drowning** does not cause hypovolemia, and freshwater **drowning** does not cause hypervolemia, hemolysis, or hyperkalemia.
5. **Drowning** victims swallow much more water than they inhale, resulting in a high risk for vomiting spontaneously or on resuscitation.

No discussion of **drowning** would be complete without mentioning the importance of prevention. Proper pool fencing and water safety training at a young age are instrumental in reducing the risk for **drowning**. Not leaving an infant or young child unattended in or near water can prevent many of these deaths, especially bathtub **drownings**. Also crucial is the use of personal flotation devices whenever boating. Proper training in water safety is crucial for participation in water recreation and sporting activities, including SCUBA diving. The incidence of pediatric **drowning** deaths in the United States has decreased steadily over the past decade, perhaps as a result of increased awareness and attention to drowning-prevention measures (Box 1).

PREVENTIVE MEASURES TO AVOID DROWNING

Beaches

1. Always swim near a lifeguard.
2. Ask the lifeguard for safe places to swim or play.
3. Do not overestimate your swimming capability (46.6% of swimmers overestimate).
4. Always look out for your children.
5. Swim away from piers, rocks and stakes.
6. Avoid drinking alcohol and having a heavy meal before swimming.

7. Take lost children to the nearest lifeguard tower.
8. More than 80% of ocean **drownings** occur in rip currents.

    - The rip current is usually the most falsely calm deep place between two sandbars. The rip current takes you away from the shore.
    - If caught in a rip current, swim transversally to the current or let it take you away without fighting and wave for help.

9. Never try to help rescue someone without knowing what you are doing. Many people have died trying to do so.
10. If you are fishing on rocks, be cautious with waves that may sweep you into the ocean.
11. Do not dive in shallow water; cervical spine injury could happen.
12. Keep away from marine animals.
13. Read and follow warning signs posted on the beach.

Pools and Similar

1. More than 65% of **drowning** deaths occur in fresh water or pools, even in hot areas along the coast.
2. Children always should have close adult supervision.
3. Never leave a child alone near a pool or in a bathtub.
4. Fence off your pool and include a gate. Fencing must be 1.50 m with 12 cm or less between vertical slats. This procedure has decreased **drowning** deaths by 50% to 70%.
5. Do not allow children to use arm buoys.
6. Avoid toys around and in the pool that could be attractive to young children.
7. Turn off pump filters when using the pool.
8. Use portable phones at pool areas so that you are not called away to answer the phone.
9. Do not try to hyperventilate to increase your submersion time.
10. Do not dive in shallow water; cervical spine injury could occur. Have warning signs around the pool.
11. Watch the children carefully. Approximately 84% of **drowning** deaths occur because of inadequate adult supervision. Most occur around lunch hour.
12. Children should begin swimming lessons at age 2 years.
13. If you have a pool, learn CPR. More than 42% of pool owners are unaware of first aid techniques. Be careful.

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