ABSTRACT

Childhood water submersion remains a major public health problem in many countries with significant morbidity and mortality. Near-drowning occurs when the child recovers from water submersion, whereas, drowning is defined as suffocation and death from such submersion. Many people (estimated at 500,000/year) die from drowning worldwide, with the majority occurring in developing countries. Among all pediatric accidental deaths in the United States, drowning is the second leading cause accounting for more than 1000 deaths annually. However, the estimated annual hospitalizations associated with drowning declined from 4.7/100,000 in 1993 to 2.4/100,000 in 2008. The rates declined for all age groups, and for both males and females. Similar data from developing countries are lacking. However, it is important to note that for every child who drowns, at least 3 receive emergency room care for near-drowning, and more children are never brought to the hospital. The frequency of near-drowning is therefore, much higher because of under-reporting. The aim of this article is to present an updated overview of the topic with data from our region and special attention to prevention strategies.

Risk factors and predisposition. Males are always at higher risk when compared to females. Most drowning occurs in fresh water, particularly residential swimming pools. The use of portable pools also poses a significant risk for younger children. However, children less than 5 years of age often drown in washing containers, up to 55% of cases in one study from Saudi Arabia. Open wells are also a special risk in our region. In general, predisposing circumstances depends on the child's age. Infants are at higher risk of drowning in bathtubs, bathrooms, toilets, or traditional washing.
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Clinical manifestations. Multiple body systems are affected in varying severity by near-drowning and the associated hypoxic ischemic injury. During the submersion, the child initially will hold breath; try to surface, panic, followed by water aspiration. The patient then becomes hypoxic, loses consciousness, and stops breathing. Silent drowning occurs in less than 10% of cases when laryngospasm is triggered by initial water aspiration resulting in dry rather than wet lungs. Water inhalation is usually associated with bronchospasm and atelectasis with subsequent intrapulmonary shunting of blood through poorly ventilated tissues. This further reduces ventilation and oxygenation. If the patient is rescued, one should watch for later development of pulmonary edema and adult respiratory distress syndrome. Neurological manifestations occur in up to 10% of near-drowning patients depending on the duration and severity of the initial hypoxic-ischemic insult. These patients should be monitored for brain edema during the first 3 days post injury. Other manifestations and complications include cardiac dysfunction, arrhythmias, acidosis, electrolyte imbalance, hypotension, and hypothermia. Hypothermia may result in significant hypovolemia as a result of peripheral vasoconstriction. Differences in the osmolality of fresh and salt water may result in specific fluid and electrolyte abnormalities. Fresh water is hypotonic relative to plasma causing hypervolemia and dilutional hyponatremia, while salt water is hypertonic causing hypovolemia and hypernatremia. However, such significant changes in fluids or electrolytes are less common in clinical practice. In fact, metabolic acidosis is more common than electrolyte disturbances. Patients with more severe near-drowning may develop shock with associated anemia, acute tubular necrosis and disseminated intravascular coagulation.

Acute management. Acute management should start as soon as possible in order to prevent unfavorable neurological outcome. Cardio-pulmonary resuscitation (CPR) should be started at the scene. Due to lack of training, families rarely try to perform such resuscitation. Cervical spine immobilization should be performed if a high impact event is suspected, such as diving or falls. The airway, breathing, and circulation should be assessed. However, maneuvers to remove fluid from the lungs, such as chest or abdominal compressions, are no longer recommended because of lack of efficacy. As well, these compressions may delay CPR, and increase the risk of vomiting and aspiration. The CPR can be performed with fluid in the lungs as long as there is no airway obstruction.

Once in the hospital, the cervical spine needs to be examined and x-rayed for possible injuries or fracture. This is uncommon in young children and should not delay or interfere with acute management. Complete blood count, electrolytes, blood gas, and chest x-ray should be obtained promptly. Respiratory support and management of bronchospasm or pulmonary edema is critical. Nebulized beta agonist and furosemide are used for this purpose. Antibiotics and steroids should not be used routinely unless the water is contaminated. In such cases, bronchoscopy and bronchial lavage may be needed to remove aspirated particulate matter. Finally, surfactant and extracorporeal membrane oxygenation can be utilized in severe cases. Treatment of other manifestations and complications, such as hypotension, seizures, and renal dysfunction is needed. Cerebral...
edema should be promptly treated in order to improve the neurological outcome. Hypothermia is common in children because of their relative large surface area and tends to improve quickly by rewarming.

**Outcome and neurological morbidity.** Most patients improve quickly with acute management. If the child does not improve or deteriorates, other etiologies or complications should be considered, including head injury, blood loss, alcohol, or drug ingestion. Children generally either survive with no neurological sequelae, or die following water submersion. Most children who are rescued quickly will recover neurologically intact.\(^7\) Most deaths occurred in young children (<5 years) who were unsupervised, or in older children who swam in open water. As mentioned earlier in the introductory segment, there is some recent evidence that pediatric hospitalization rates for drowning, as well as fatal drowning have decreased over the past 16 years.\(^4\) Only 5-10% develops severe neurological sequela.\(^28\) Factors that correlated with neurological morbidity included submersion or CPR for more than 25 minutes.\(^29\) Hyperglycemia (glucose ≥10 mmol/L) correlated with bad outcome in one Saudi study.\(^30\) In another study, hypothermia was the only independent predictor of poor neurological outcome.\(^31\) Few other published reports described a relatively better neurologic outcome following submersion in very cold water.\(^32\)

**Prevention strategies.** Restricting access to water and close adult supervision once in the water are paramount in preventing near-drowning and drowning.\(^33\) Children must always be supervised, regardless whether they can swim well, or not. In a Saudi report, no adults were watching the children when the accidents occurred in all mortality cases.\(^6\) Most young children drown in their own pool, or in family or friend’s pool because of easy access and lack of strict supervision.\(^34\) Such pools should be fenced or completely isolated from the yard in order to reduce the risk of submersion.\(^35\) It is preferred if the fence is at least 1.4 meters tall, and have a self-closing gate.\(^36\) Safety accessories and equipment are not always provided in residential swimming pools, particularly in lower socioeconomic families.

In our region, most of the private swimming pools do not meet the required safety regulations.\(^11,30\) In addition, all public or commercial pool facilities should have a telephone and a monitoring system. Pool covers could add further security when the pool is not used or closed. The CPR training of parents and pool owners will ensure early and more effective rescue, and therefore improves the outcome of such incidents. Pediatricians should encourage parents to take CPR courses, and teach their children how to swim well.

In our community, CPR knowledge or training is virtually nonexistent.\(^11,30\) Educating the general public regarding drowning prevention is also essential. The media, as well as government authorities should play a major role in increasing public awareness to minimize such incidents. No single strategy will prevent all submersion deaths and injuries; therefore a strong and pervasive education campaign is needed to make the public aware of these dangers. High-risk groups, such as new or young parents, lower socioeconomic families, and families with prior child protective services referrals, should be targeted with drowning prevention programs. Such increased awareness and safety campaigns can be successful in reducing near-drowning and saving precious young lives.

**References**

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