AMERICAN COLLEGE OF EMERGENCY PHYSICIANS
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# Management of the Near-Drowning Victim

Drowning is the third leading cause of accidental deaths in the United States. Many persons experience serious submersion incidents. Despite the frequency of this problem, controversy persists about the relative importance of issues, such as whether the water was fresh or salt, cold or warm. The lecturer will examine some of these controversies and provide guidelines about the appropriate evaluation and treatment of the near-drowning victim. The lecturer explore the mechanism by which victims of prolonged submersion can survive without neurologic dysfunction.

- Describe the pathophysiology of drowning.
- Describe the controversies associated with drowning resuscitation, including issues related to cold water and saltwater versus fresh-water drowning.
- Describe an approach to the evaluation and management of near drowning.
- Describe the risk factors associated with near-drowning incidents.

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**FACULTY**

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## MANAGEMENT OF THE NEAR-DROWNING VICTIM

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## EPIDEMIOLOGY

There are approximately 150,000 deaths due to submersion injury worldwide and 5,000 deaths in the U.S. alone. Of the 5,000 U.S. deaths, the majority are children, adolescents, and young adults.

Drowning is the third leading cause of death in the 1 to 14 year age group. In some states, for instance Florida, Arizona, and California, drowning is the number one cause of death in the 1 to 5 year age group. Submersion is more common in males than females.

There is a bimodal distribution with peaks at 2 and 18 years of age. Teenage males usually get into trouble on a dare when their ability to swim is exceeded, or when they are under the influence of drugs or alcohol. Among females, the death rate is highest at age 1 year of age, then decreases sharply and does not rise again. The most important risk group is the unsupervised toddler. Forty to 50 percent of all submersions occur in the age group 0 to 4 years.

This vast majority of submersion injuries are in fresh water with most accidents occurring in private swimming pools and natural bodies of water close to home. Ocean drowning are uncommon.

The distribution of submersion injury changes with age. Children less than 1 year of age most frequently drown in bathtubs and buckets. Children 1 to 4 years of age most often drown in private swimming pools. Older children and adolescents most frequently drown in lakes, ponds, rivers, and pools. This variation is also dependent on geographical region, season, race/ethnicity, and economic status.

Salt water drowning is very uncommon, probably because of the better surveillance and rescue systems available at ocean beaches. Most diving-related submersion accidents occur in salt water.

## TERMS AND DEFINITIONS

*Drowning* is defined as death resulting from suffocation within 24 hours of submersion in water. *Near-drowning* implies successful resuscitation with survival for at least 24 hours. The victim that subsequently dies of the submersion injury is termed *near-drowning with delayed death*.

*Submersion injury* is preferred among injury prevention specialists.

Emergency physicians provide the initial medical care for the overwhelming majority of submersion victims.

Although the major pathophysiologic phenomena in all submersions are asphyxiation and hypoxemia, submersion involves many interrelated factors that all have an effect on the clinical outcome of the submersion victim. There are pulmonary, neurologic, cardiac, hypothermic, metabolic, traumatic, and toxicologic consequences that have to be assessed and treated.

Death is usually a result of the pulmonary or cerebral insult.

**PULMONARY**

Victims of unexpected submersion typically exhibit panic and a period of intense struggling and breath-holding before hypoxia leads to unconsciousness. After which, the gag reflex, the breath-holding ability, and protection of the airway are lost. The victim aspirates a small amount of water which leads immediately to laryngospasm which lasts for as long as two minutes. In addition, the victim may begin to swallow water into the stomach.

One of two courses follow. Eighty to 90 percent of victims experience what is called a *wet drowning*, where the laryngospasm relaxes secondary to hypoxia, and they then aspirate large volumes of water. Ten to 20 percent of victims experience a *dry drowning* and aspirate little or no water. These victims have either no pulmonary damage, or if they develop pulmonary edema, it is due to hypoxia and is not secondary to aspiration. In both courses the lethal common denominator is hypoxia.

Both fresh and salt water damage alveoli, destroy surfactant, and result in pulmonary edema of the non-cardiogenic or respiratory distress syndrome variety. However, they do so by different mechanisms.

Fresh water is hypotonic and is very damaging to the surfactant that lines the alveoli and to the basement membrane. This results in pulmonary edema with alveolitis and transudation of proteinaceous material into the alveolar space.

Salt water has 3 to 4 times greater osmolality than plasma. When it enters the alveolar space, it also destroys surfactant and damages the alveolar basement membrane and moves water from the intravascular space into the alveolus.

The end result in both fresh and salt water submersions is the same: ventilation-perfusion mismatch; right-to-left intrapulmonic shunting; and decreased compliance. These effects all lead to hypoxia.
Initial clinical findings can include tachypnea, rales, rhonchi, and wheezing.

Radiographic findings will initially show perihilar, localized or diffuse pulmonary infiltrates, but may initially underestimate the degree of pulmonary injury.

Severe pulmonary infection and non-cardiogenic pulmonary edema (ARDS) are associated with aspiration. These secondary injuries (from aspirated chemical irritants, or vomited gastric contents) are frequently delayed after the initial insult.

Regardless of how benign the initial clinical presentation appears, patients with aspiration of chemicals, contaminated water, or gastric contents should be observed and carefully evaluated for impending respiratory insufficiency.

**NEUROLOGIC**

Submersion victims fall into four clinically distinct long-term outcome groups: neurologically normal survivors; survivors with mild anoxic encephalopathy; survivors with severe anoxic encephalopathy; and death. Severe anoxic encephalopathy is characterized by permanent vegetative state with no self help-skills and little or no meaningful interaction. Mild encephalopathy is characterized as ataxia and/or spasticity, but with normal or near normal cognitive functions.

Diffuse cerebral edema with elevated intracerebral pressure may develop after circulation is restored, but is rare and late in the course.

Patients with known epilepsy have a 4 to 5 times increased risk of submersion. At greatest risk are patients who are poorly controlled on anticonvulsant medications, or have had recent changes in their medications.

**CARDIAC**

Combined metabolic and respiratory acidosis can be extremely severe and can lead to cardiac arrhythmias, complicating resuscitative efforts.

Hypothermia can result in bradycardia, atrial fibrillation, ventricular fibrillation, and asystole.

**HYPOTHERMIA**

In mild cases of submersion, the core temperature is around 35 $^{o}$C. In more severe cases, the core temperature is closer to 32 or 33 $^{o}$C. In cold weather climates, the core temp can be below 30 $^{o}$C.

*Immersion syndrome* is defined as sudden death, probably vagally mediated, due to cardiac arrest following immersion in icy water.

Rapid hypothermia in children exposed to icy water has a protective effect. The exact mechanism is unclear, but is probably a multifactorial effect.

In submersion hypothermia, as in non-submersion hypothermia, you are not dead until you're warm and dead.

**METABOLIC**

Metabolic acidosis is an important consequence of submersion. This is partly due to the increased muscle activity associated with struggling which generates lactic acid.

The electrolyte and hemoglobin alterations in fresh and salt water drowning are minimal and usually not of clinical significance. Typically, coagulopathies and DIC are not seen in even severe submersion episodes.

In fresh water submersions, a transient increase in intravascular volume occurs. The body rapidly corrects for the increased volume by redistribution and diuresis. In salt water submersions, there may be a transient intravascular volume decrease, but the body usually compensates in a relatively brief period.

**TRAUMA**

Intracranial and cervical spine injury must be considered in any submersion victim with a history of trauma, diving into the water, or head injury.

Head trauma and C-spine injuries are typically found in the older age groups, whereas child abuse is typically seen in the younger age group, particularly if the submersion accident involves a bath tub. Cervical spine and head injuries are frequently the precipitating event of the submersion.

Air embolism, decompression sickness, and other types of barotrauma must be considered in any submersion victim engaged in scuba driving activities.

With boating accidents or falls from height into water, internal injuries to the chest and abdomen should be considered.

## INTOXICATION

Adolescent and young adult victims of submersion are frequently intoxicated with ethanol. In an extensive long-term study in Australia, 35 percent of all males over 15 years old had elevated blood alcohol levels. Other studies have shown an even higher percentage.

## PRE-HOSPITAL MANAGEMENT

The most important consequence of submersion injury is hypoxemia and its effect on the brain. Since hypoxemia increases rapidly during apnea, even a few minutes of delay in commencing treatment may be critical to recovery of normal brain function. The single most important step in the treatment of submersion accident is the immediate institution of resuscitative measures at the earliest opportunity.

Mouth-to-mouth resuscitation should begin as soon as the rescuer reaches the victim, even if still in the water. External cardiac massage should be instituted if the patient is pulseless. External cardiac compressions, however, cannot effectively be performed in the water and so must be delayed until the victim is out of the water.
The Heimlich maneuver has limited application and should be restricted to airway obstruction.

## EMERGENCY DEPARTMENT MANAGEMENT

Oxygen is the first line of therapy for submersion victims. Hypoxia is the primary insulting event. Do not waste time trying to figure out fluid and electrolyte derangements. The main objective is to reverse hypoxemia and acidemia to preserve brain cells. If the patient is in respiratory insufficiency, this will require assisted ventilation.

With the aspiration of water and subsequent destruction of surfactant and marked decrease of pulmonary compliance, the apneic victim will obviously need mechanical ventilatory support, which necessitates intubation of the patient and PEEP ventilation to decrease the degree of intrapulmonary shunting.

Intubation not only insures an adequate airway and provides needed positive airway pressure, it enables good bronchial-pulmonary hygiene and removal of secretions and debris.

In small children, it is extremely easy to intubate the right mainstem bronchus.

PEEP should be started at 5 cm $H_20$ and then increased by increments of

2 to 3 cm $H_20$ until the desired oxygenation ($Pa0_2$ 90 to 100 torr) is achieved and maintained for 24 to 48 hours before attempting to decrease it in order to allow adequate surfactant regeneration.

The Fi02 should be reduced to <.50 as soon as possible in order to avoid oxygen toxicity.

Sedation and paralysis may be needed.

Beta-adrenergic aerosols are useful in the management of bronchospasm.

Prophylactic antibiotics are controversial and probably indicated only if the patient has aspirated gastric contents or grossly contaminated water.

Steroids have not been shown to improve survival outcome.

Placement of an ICP monitor is not indicated. Increased ICP seldom occurs, and when it does it is late in the course, after irreversible brain damage has occurred.

Barbiturate coma and induced hypothermia are unproven therapies.

Diuretics may be beneficial in mobilizing interstitial pulmonary edema, but must be given cautiously to hemodynamically unstable patients.

Nasogastric tube decompression of gastric dilatation can reduce the risk of regurgitation and improve ventilation.

Metabolic acidosis is very common and should be treated with adequate ventilation and administration of bicarbonate (1 mEq/kg of $NaHCO_3$).

Check for other signs of child abuse such as contusions, bruising, burns, and retinal hemorrhages ("shaken baby syndrome"), and consider obtaining a CT of the head and trauma -series X-rays of the body to rule out intracranial hemorrhage and old fractures.

In the majority of submersion cases, at least one parent is at the scene of a submersion accident. Often there is a tremendous feeling of guilt and negligence about the child's condition.

Admission is indicated for any significant submersion injury. However, patients that have a GCS of 15 and are also without respiratory symptoms, significant aspiration, or metabolic derangement may be discharged home after six hours of observation.

**FACTORS AFFECTING OUTCOME**

There are multiple factors that affect outcome. It is impossible to reliably predict the outcome of individual victims. Overall, patients arriving in the ED with spontaneous cardiac activity are likely to survive without residual neurologic impairment. Cardiac arrest in the ED greatly decreases the likelihood of full recovery, but does not make it hopeless. Therefore, all submersion victims must be aggressively resuscitated.

Prolonged submersion is strongly associated with a poor outcome. However, since most submersion events were not witnessed, actual reported times of submersion are estimates at best. Often, these estimates are based on the time period the child was lost to attention. In addition, estimates of elapsed time during frantic search and rescue efforts by family and friends are subject to recall bias.

Although accurate determination of the duration of submersion is difficult, the strength of the association between prolonged submersion and poor clinical outcome suggest that at some period of time, death or severe anoxic encephalopathy is inevitable.

Hypothermia is also associated with poor clinical outcome. This factor, however, is closely related to the duration of submersion. The protective effect of icy (<5 $^{o}$C) water on pediatric victims with prolonged (greater than 30 minutes) submersion is well documented.

Age and gender are not predictive of outcome.

Immediate resuscitation prior to the arrival of paramedical personnel is associated with a better neurological outcome in patients hospitalized with submersion injury. Many victims of submersion injury can have improved clinical outcomes with simple, rapid, and effective artificial respiration which should be taught to all parents, siblings, and caretakers of children.

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