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Pediatric Submersion Injuries: New Definitions And Protocols

It's a sultry summer evening in the ED when the EMS radio commands your attention. You overhear the charge nurse taking a report, describing an 18-month-old female who has fallen into a backyard swimming pool. The mother apparently answered a phone call leaving the child unattended. The outdoor pool is reported to be at ambient summer temperature, about 90° F. The submersion time is not known, but mother estimates "only a minute or two." The paramedics found the child with a weak and thready pulse not breathing spontaneously. Paramedics have the child breathing by bag-valve-mask and have also achieved IV access. They report noisy breath sounds, vomitus about the mask, feeble spontaneous motions of both upper and lower extremities, and some spontaneous respiratory efforts. The paramedics report an ETA of "about 2 minutes." You pull out your Broselow tape and ask yourself: Should I request the patient be placed in spinal precautions? Should the patient be intubated? Will steroids be helpful? Should I suspect child abuse?

MUCH of our experience with resuscitation of pediatric patients including cardiopulmonary arrest in children is a direct result of children's ventures into the water. The resuscitation of those who have been submerged and the prevention of drowning has been an important part of both medical literature and folklore for ages.[1] We found the likelihood of recovery was directly related to the rapidity and effectiveness of the resuscitation. Classical methods, taught for years to Boy and Girl Scouts, such as the Sylvester backpressure arm-lift and the Schaeffer chest pressure methods of artificial ventilation supplanted earlier techniques with little scientific basis. These techniques were all developed primarily to handle the patient who had suffered a submersion accident. For those involved in modern pediatric emergency care, knowledge of the pathophysiology and treatment of submersion injury is critical, since we are involved in providing the initial care for most of these patients.

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CME Objectives

Upon completing this article you should be able to:
1. Define drowning and submersion injury;
2. Discuss submersion injury pathophysiology;
3. Describe risk factors for sequelae of submersion; and
4. Discuss the management of children following a submersion.

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There is no doubt about the lethality of pediatric submersion accidents. Death from submersion incidents is the second leading cause of accidental death in children with one-third of all survivors sustaining significant neurological damage.[2, 3, 4] The main confusion concerns the exact percentage of the vast numbers of minor submersion incidents that result in a lethal outcome. While statistics on the incidence of drowning deaths are readily available for most nations, there are no precise data for drownings that do not result in mortality.[5] A 1977 study in South Carolina reported that > 15% of school children had at least one submersion incident during the prior year.[6] With a reported drowning rate of 7.4 per 100,000 in that state, the authors calculated that at least a half million incidents per year occurred, which presented a serious risk of drowning in South Carolina alone.

Although submersion injury is unique in some respects, it is a well studied and common cause of asphyxial injury. It can serve as a model for understanding many of the prognostic, pathophysiological, and therapeutic aspects of all types of asphyxial injury in the pediatric patient. In this issue of *Pediatric Emergency Medicine Practice*, an organized review of the drowning literature with specific attention to management and treatment of children will be presented.

Critical Appraisal Of The Literature

MEDLINE®, BestBETs (Best Evidence Topics), Google Scholar, and Google were all searched using the terms drowning, pediatrics, children, near drowning, submersion, immersion, and suffocation. The terms were used in Boolean combination and separately in each database as appropriate. A simple Google search for "drowning" gave 26,400,000 hits. The Safe Kids Coalition has useful information about drowning prevention.[9] As might be expected in this disease process, there are no prospective randomized, placebo-controlled studies of any treatment. There are multiple retrospective studies, analyses of case reports, and many individual case reports and short series.

The literature describing prognostic factors is conflicting. The one factor that clearly affects outcome is immediate bystander CPR.[7,8] Other factors, including age of the patient, submersion time, water temperature and core body temperature affect outcome of nearly-drowned children but have not been found to be predictive. This lack of agreement juxtaposed with the rare, sensational recovery from prolonged submersions creates unrealistic expectations in family members and angst for the ED physician. The one thing that is clear is our currently available therapies have not improved submersion victim outcomes. A major change found in the recent literature is a new definition of the disease process to eliminate the term near-drowning.[7-9] This is more fully covered in the section on definitions that follows. The new definitions and reporting formats will markedly enhance future reporting and enable meta-analysis of reported series. This may enable prognostic studies with real value.

Abbreviations Used in this Article

ABC's – Evaluation of Airway, Breathing, and Circulation, in emergency situations
ACLS – Advanced Cardiac Life Support
ARC – American Red Cross
BLS – Basic Life Support
BET – Best Evidence Topics
CDC – Centers for Disease Control and Prevention
CPAP – Continuous Positive Airway Pressure
CPR – Cardiopulmonary Resuscitation
ED – Emergency Department
FiO_2 – Fraction of Inspired Oxygen
ICP – Intracranial Pressure (measurement)
ICU – Intensive Care Unit
ILCOR – International Liaison Committee on Resuscitation
IMV – Intermittent Mandatory Ventilation
$PaCO_2$ – Partial Pressure of Carbon Dioxide in Artery
PaO_2 – Partial Pressure of Oxygen in Artery
pCO_2 – Partial Pressure of Carbon Dioxide, in substance measured
PEEP – Positive End-Expiratory Pressure
pH – pH is a measure of the activity of hydrogen ions (H+) in a solution and, therefore, its acidity or alkalinity. The pH value is a number without units, usually between 0 and 14, that indicates whether a solution is acidic. Pure water has a pH of 7.
pO_2 – Partial Pressure of Oxygen, in substance measured
PRISM – Pediatric Risk of Mortality Score
WHO – World Health Organization
YMCA – Young Men's Christian Association

Glossary

In order to communicate the circumstances about immersion injuries, a uniform terminology is needed. In 2002, the first World Congress on Drowning was held in Amsterdam, Netherlands. During this conference, new definitions were developed to facilitate the collection of data for epidemiological purposes. These definitions have been accepted by ILCOR, WHO, and the CDC.[7-9] The new definitions are both uniform and internationally accepted. Definitions of older terms that are frequently used have been adapted from Modell and others.[10]

Drowning

Drowning is the process of experiencing respiratory impairment from submersion/immersion in a liquid. Drowning outcomes should be classified as death, morbidity, and no morbidity.[11]

A former definition used in many texts and papers: Drowning is suffocation by submersion in a fluid, whether or not the fluid is aspirated into the lungs.[10] That definition considered drowning as the cause of death if the death occurred within 24 hours of the insult.[10,12]

Near Drowning

Near drowning is another former definition. It was defined as survival beyond 24 hours after suffocation by submersion. The older definitions of near drowning and drowning are, of course, retrospective. As such, they are of little help to the emergency physician, the emergency medical technician, the paramedic, the lifeguard, or, indeed, even the parents. Near drowning implied that recovery occurred after the insult. This was termed as a submersion injury or submersion incident in some literature. The use of a classification that has outcome as part of the classification is different than that of other medical conditions and injuries and should be abandoned. Under the new WHO definitions, the term near drowning should not be used. This definition has been replaced by drowning with either mortality, morbidity or no morbidity.[11]

Secondary Drowning

Secondary drowning implies that the victim is initially resuscitated but death occurs minutes to days after the initial resuscitation. The definition of secondary drowning is a matter of controversy and the term is probably inappropriate. Secondary drowning is a misnomer because victims who develop acute respiratory distress syndrome after drowning have not had a second submersion episode. Under the new WHO definitions, the term secondary drowning should not be used.

Immersion Syndrome

The immersion syndrome is a form of drowning caused by sudden exposure to very cold water (< 20°C or 68°F) that may be due to a vagally induced dysrhythmia. The two most commonly proposed arrhythmias are asystole and ventricular fibrillation.[13,14] Ingestion of alcohol and other intoxicants is thought to be a predisposition to this syndrome.

Immersion Hypothermia

Drowning can also result from hypothermia due to prolonged immersion. When the core temperature reaches about 32° to 33°C (89.6° to 91.4°F, the victim will lose purposeful activity. At that point, swimming and other self-protective action ceases and drowning may occur. Needless to say, if the patient becomes sufficiently hypothermic, e.g., in arctic waters, then death may occur from hypothermia alone.

Epidemiology, Etiology, And Pathophysiology

Epidemiology

In 2002, there were 3,447 unintentional drownings in the United States, averaging 9 people per day.[15] This figure does not include drownings in boating-related incidents. Drowning represents the second leading cause of death due to injury in children aged 0-19 years with 1,068 pediatric deaths reported due to drowning in 2003 (automobiles were number one).[16] Forty percent of all drownings are children under 4, and boys will drown 3 times more frequently than girls at all ages.[17,18] Whether this is due to increased inquisitiveness in boys, or the well advertised "macho" overconfidence is unknown. Most drownings occur within 10 feet of safety and two-thirds of those children can not swim.[19] Boating accidents and floods are other well-known scenarios of drowning.

Adolescents (or parents) using alcohol and drugs not only are at increased risk of drowning themselves, they increase the risk of those around them.[20,21] Whether impaired judgment or loss of self-protective reflexes is at fault is moot. The use of other, more illicit drugs is thought to play a relatively major role in drownings, but, again, the true incidence is not known.

Since all water related activities increase with warm weather, the incidence of drownings will naturally increase in warmer climates and weather. Drowning is a problem in all states, including the arid desert states (and countries).[22,23] The most common sites are home swimming pools, bathtubs, and open bodies of water.

Approximately 6% of drownings may represent child abuse or neglect.[24-27] In one study, as many as 67% of bathtub near drownings were found to have a history consistent with abuse or neglect.[28] Bathtubs are the usual sites of drowning in children under 1 year of age.[28,29] It seems prudent that a medical evaluation of these patients should include a social work consultation and a search for other accompanying injuries.

Suicide and murder may also present as drownings.[30-34] Suicide may present as a drowning, either after a leap from a bridge, another high place, or as a primary drowning episode. Water has also been used as the murder weapon in countless crimes, including those involving children.[35-37]

Epilepsy has been well documented to increase the risk of drowning.[38-40] In a population-based cohort study of pediatric patients in King County, Washington, Diekema and colleagues found that children with epilepsy have a ten-fold increase in drowning when compared to non-seizure patients.[39]

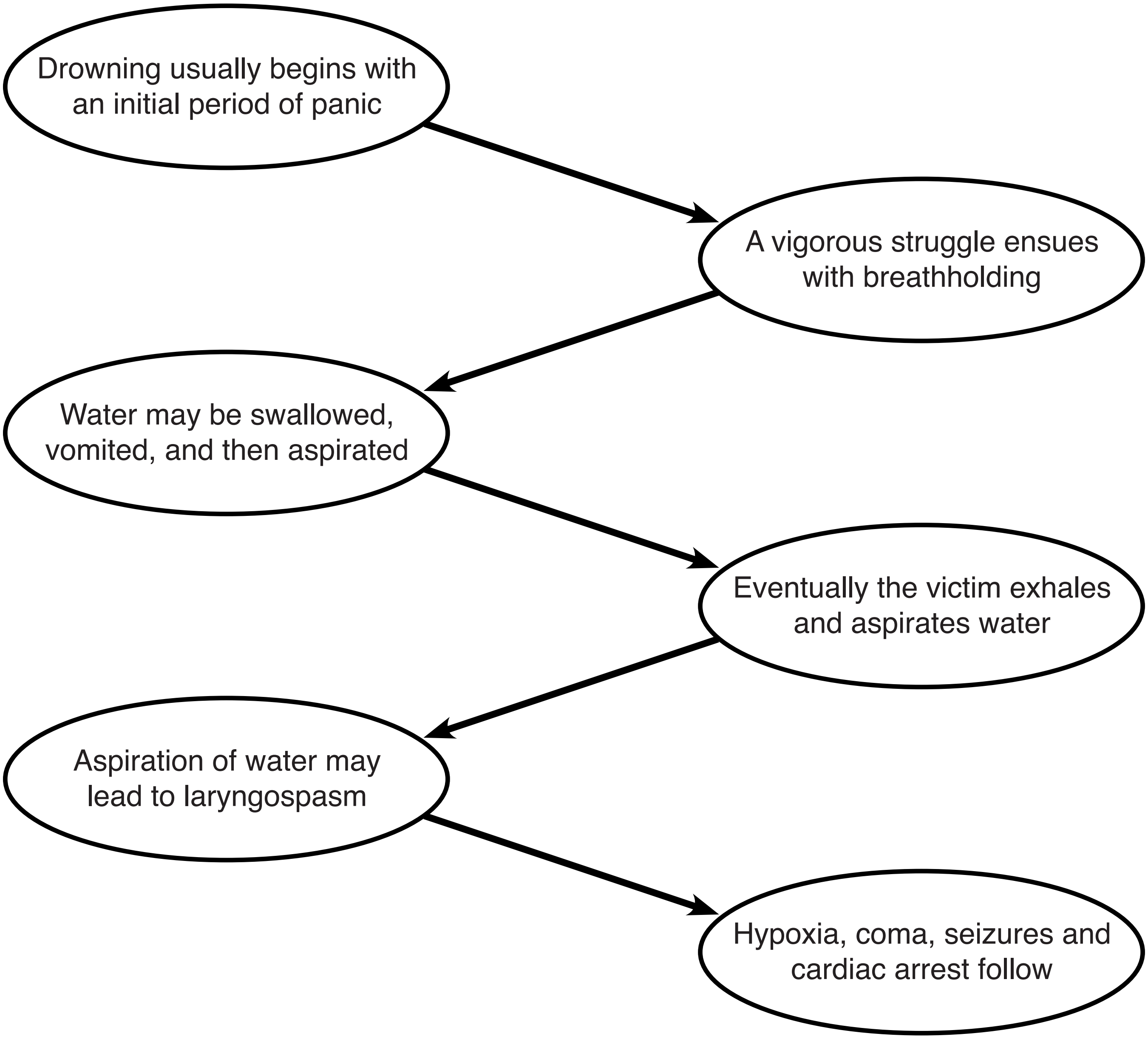
Etiology

In toddlers, submersion injuries are usually due to innocent exploration of a pool, hot tub, water bucket or an open body of water. Occasionally child abuse or neglect may present with a submersion scenario in this age group. In older children and adolescents, recreational watercraft accidents, illicit drugs, attempted suicide or murder may lead to a submersion injury (**see Table 1**).

Table 1. Risk Factors

- Age – youth (40% under 4 years old)
  (The drowning rate peaks at age 2 and again at age 16-18)[41]
- Location – home swimming pools or bathtubs
- Sex – Male 3:1 ratio[18,42]
- Drugs – particularly alcohol[21,43]
- Trauma – diving or falls
- Predisposing illnesses (particularly epilepsy)[39,40,44-46]
- Warm weather months (50% from May to August)

Figure 1: Usual Sequence of Drowning



Field Actions for Drowning Victims

1. Remove Patient From Water.
   - Ensure that you are not at jeopardy.
   - Dead Rescuers Rescue No One!
2. Ensure Ventilation - done simultaneously with #1.
3. Airway Control.
   - Endotracheal tube if patient is unconscious.
   - Supplemental oxygen at high flow.
4. Start Cardiopulmonary Resuscitation if appropriate.
5. Protect From Further Hypothermia.
6. Obtain History.
   - How long was patient submerged?
   - Age of patient.
   - Temperature of water (if available readily).
   - AMPLE history.
7. ECG and monitor for arrhythmias.
8. Adjunctive Therapy.
   - Foley catheter.
   - Nasogastric Tube.
9. Recheck The Patient For Any Associated Injuries.

Pathophysiology

Mechanism of Drowning

The sequence of events that follows submersion has been abundantly described in animal studies that have provided us with a model of drowning. In the late 1940's Swann, et al, drowned dogs and studied the terminal cardiac and biochemical events.[47-49] During a summer in Orchard Beach, Long Island, Pia filmed actual drownings that confirm some of these animal model simulations.[50]

In most drownings, a period of panic and struggling followed by exhaustion are the initial events.[50] Brouardel in France during the 1890s described this as the "stage of surprise" lasting about 5 to 10 seconds.[51] Pia noted, that this stage lasts between 20 to 60 seconds in humans. During this stage, the victim will make motions to try to reach or remain at the water's surface. Frantic hyperventilation occurs as long as the head can be held above water. Other clues that identify potential drowning victims are an open but not vocalizing mouth and a rolled back (far hyper-extended) head.

Breath-holding apnea begins with submersion and lasts about 60 seconds. The mouth is shut and respirations are voluntarily stopped. Following apnea, Brouardel then described a stage where agitation ceases, and the victim may swallow water and begin to vomit. Approximately 90% of drowning victims aspirate the water and vomitus, cough violently and then gasp involuntarily, flooding the lungs and air passages with water. Originally, clinical and experimental data, together with the finding of "dry lungs" in autopsies suggested that death could occur without significant aspiration of liquid.[52,53] Recent data show that "dry lung deaths" are found in only 2% of deaths, not the 15% described in less robust data.[54]

Brouardel then described the "second stage of respiratory arrest," where no thoracic movements occurred and the animals became unconscious. Agonal respiratory movements, cardiac arrest, and death then ensue (**see Figure 1**).

Exceptions to the Struggle

There are several exceptions to this sequence of events:

Hypothermia

As noted previously, in very cold water (< 20°C or 68°F), hypothermia may rapidly disable a victim, and little or no exhaustion, panic, or struggle may occur before the victim ceases to swim and aspirates water.

Unconsciousness

Events that render the victim unconscious, such as use of drugs or alcohol, seizures, or head trauma will also prevent a struggle and exhaustion prior to aspiration.[21,38,45,55] Children with seizure disorders have a far greater risk of drowning, particularly in a bathtub, when compared with children without seizure disorders.[38,44,46]

Voluntary Hyperventilation

Another modifying factor is hyperventilation prior to swimming underwater. By hyperventilation, swimmers can rapidly lower their $PaCO_2$ to 20 mm Hg, but the PaO will only modestly increase. As the victim exercises, their $PaCO_2$ will return to between 40 and 47 mm Hg, which is not sufficient to trigger the urge to breathe. Simultaneously, the PaO will fall to 30 to 40 mm Hg, causing unconsciousness, with subsequent drowning.[56,57]

Rapidly Moving Water

In rapidly moving water, it is unknown whether the same struggles take place. It is conceivable that the force of the moving water and objects struck underwater may cause rapid loss of consciousness due to trauma. Certainly in surf and in mountain streams, drowning is often associated with physical evidence of multiple traumas. In a similar manner, divers who sustain neck injuries may be conscious but unable to resurface.

Type of Aspirated Fluid

Aspiration of even small quantities of fluid can lead to a drastic change in PO_2. The usual differentiation between aspiration of salt or fresh water is often emphasized in some medical texts, but the toxicity of the aspirated fluid and the presence of contaminants, such as silt, mud, sewage, bacteria, and diatoms, is probably more clinically relevant. Aspiration of acidic stomach contents and other debris such as sewage, sand, mud, diatoms, or algae, contribute profoundly to the pulmonary injury with an aspiration chemical pneumonitis.

Theoretically, there should be a difference between fresh- and saltwater submersion, if a significant amount of fluid has been aspirated. Fortunately, few survivors of drowning aspirate enough water to cause any significant changes in either blood volume or serum electrolytes. Experimental studies show that if less than 20 ml/kg of body weight is aspirated, no life-threatening electrolyte abnormalities occur, and at least 11 ml/kg is necessary to cause changes in blood volume. This means that a 20 kg child must aspirate 400 ml of solution in order to have significant electrolyte disturbances. Although the lungs can hold far more than that, most adults have somewhat less than 150 ml of solution in the lungs at the time of death by drowning. The main reason for the lower volume of aspiration in human versus animal studies is thought to be the previously-described laryngospasm that is induced in humans by fluid in the posterior pharynx.

Table 2. Potential Consequences of Aspiration of Fluid

- Pulmonary edema
- Increasing shunt
- Direct toxicity of aspirated fluid
- Washout of surfactant
- Inactivation of surfactant
- Direct alveolar membrane injury

Saltwater also appears to produce a larger direct insult to the lung than freshwater.[64,65] When a significant amount of seawater is aspirated, it is intuitive that the salt diffuses into the blood with rapid elevation of the plasma sodium. Osmotic forces pull protein-rich fluid from circulation into the pulmonary interstitium. The result is a fulminant pulmonary edema with direct parenchymal damage. Clinical information on drowning patients indicates however, that there is no significant difference in serum electrolytes and hematocrit values among freshwater, saltwater, and brackish water aspiration. Following fresh- and saltwater drowning of experimental models, the ultrastructure and light microscopy findings of the lungs are remarkably similar. In patients who drown in a liquid other than freshwater or saltwater, it may be important to consider the composition of the liquid.

There are important differences in aspiration of fresh- and saltwater that do not involve electrolyte imbalance. Aspiration of saltwater is twice as lethal as freshwater per unit volume because of the impurities and bacteria it contains. Saltwater contains over 20 known pathogenic bacteria including Pseudomonas putrefactions, *Staphylococcus aureus*, and *Vibrio parahaemolyticus*.[61-63]

Immediate Sequelae of Submersion

The most important abnormality of drowning is a profound hypoxemia resulting from asphyxia. Unfortunately, the duration of the hypoxemia is unknown. The sequelae of this hypoxia may affect the brain, heart, and kidneys.

As previously noted, the most reliable data indicates 2% of patients have asphyxia from the laryngospasm without significant aspiration at the time of resuscitation. These patients recover from asphyxia rapidly if they are successfully resuscitated before cardiac arrest or irreversible brain damage occurs (**see Table 2**). Aspiration of as little as 1 to 3 ml of fluid per kg body weight results in persistently abnormal pulmonary functions from a combination of several mechanisms. Immediate vagal reflexes cause pulmonary vasoconstriction leading to pulmonary hypertension after the aspiration of the fluid. Passage of water through the alveolar epithelium, the basement membrane, and the endothelial capillary lining causes a rapid disruption of the pulmonary ultrastructure.[66,67] Loss or inactivation of pulmonary surfactant causes an alveolar collapse with a subsequent decrease in pulmonary compliance.

"Time is crucial in the management of the drowning victim."

This combination of mechanisms results in increased membrane permeability, exudation of proteinaceous material into the alveoli, and pulmonary edema. The other result of these mechanisms is a profound ventilation/perfusion mismatch and subsequent hypoxemia. These abnormalities cause a rapid elevation of the $PaCO_2$ and a fall of the PaO_2. The pulmonary blood flow and lung functions may not return to normal for days after the incident.

A case study of 10 simultaneous drowning victims reported the presence of neurogenic pulmonary edema as a significant component in the lung damage in the patients. If this has not been previously reported or evaluated, and the series is small, there may be substantial uncertainty about the contribution of neurogenic pulmonary edema to the overall lung damage in the majority of drowning fatalities.[68] However, swimming-induced pulmonary edema has been documented in young, healthy volunteers.[69]

Post-mortem examination of the lungs may reveal petechiae and seaweed, sand, mud or other bottom debris. There is a higher incidence of such bottom particulate matter aspiration in those who have died in rapidly moving water or surf. Vomitus is also frequently present in the lungs. In addition, the upper gastrointestinal tract and stomach may be filled with ingested fluid and foreign debris.

Hypothermia

In cold water, hypothermia will develop in a short time in unprotected adults.[69-72] If the water is not only cold, but also moving quickly, hypothermia may develop at an incredibly rapid rate.[73] Studies on human subjects in cold water (as low as 4.5°C) demonstrate that the maximum heat loss occurs from the head, the neck, the sides of the chest, and the groin.[72,74] Swimming and other motion enhances this loss, increasing the risks of hypothermia.[72,73]

Hypothermia complicates the management of the submersion victim. The cardiovascular complications of hypothermia include hypotension, bradycardia, conduction deficits, and ventricular fibrillation. Electrical defibrillation of the heart is difficult at low core temperatures. Drugs, such as antiarrhythmics and insulin, may be ineffective and accumulate to toxic levels due to the slowed metabolism and excretion.

The development of rapid hypothermia prior to cardiac arrest protects the brain by decreasing metabolic demands and slowing the onset of severe cerebral hypoxia. This process has been confirmed by extensive clinical experience in cardiovascular surgery. Since the late 1950's, physicians have been extending cerebral hypoxic survival times for neurosurgical and cardiovascular procedures by profound hypothermia. The problem is, that it is not possible to determine from the core body temperature upon arrival in the hospital what the patient's cerebral temperature was when the hypoxia developed.[5]

To protect the brain from hypoxic damage, it is necessary to cool the brain to at least 70°F in 10 minutes. This rate of cooling will double survival times during cerebral hypoxia and has been validated since the 1950's.[77] Unfortunately, even in children, surface cooling rates associated with immersion are too slow to cool the brain sufficiently to protect it from the anoxia from drowning.[78] If cerebral hypoxia is the mechanism for survival in protracted submersion, then an alternative metabolic method of rapid brain cooling must be evoked.

Recent canine studies suggest that swallowing and aspiration of icy water will enhance the cooling rate.[83,84] Indeed, this aspiration of cold water and rapid induction of hypothermia may play a role in cases with preservation of neurologic function despite prolonged anoxia.

It should be emphasized that the simultaneous onset of anoxia with hypothermia carries a less favorable prognosis than when the hypothermia precedes the anoxia. When cardiac arrest finally occurs, there may be only an additional 10- to 15-minute period before the brain is irreversibly damaged in the anoxic hypothermic patient. With this understanding, the prolonged periods of submersion that have a subsequent good outcome and total recovery are not quite so miraculous as they appear.

Studies of drowning victims from warmer climates show lower survival and higher morbidity. This is probably due to the loss of protective reflexes and protective hypothermia. The difference is so marked that practitioners who see more warm-water drowning patients due to geographical location have an entirely different outlook on this disease than those who deal with cold-water drowning victims, primarily in the northern states.[85] Indeed, the worst outcome appears to be in victims of hot-tub immersion accidents regardless of geographical location.

Differential Diagnosis

Since the pediatric patient has obviously been immersed in a fluid, the diagnosis should be equally obvious. However, as clinicians, we should include in our differential diagnosis those factors that can precipitate unconsciousness such as seizures, hypoglycemia, hyperventilation, hypothermia, alcohol and drug use, and trauma (accidental and intentional). Anything that causes syncope while in the water can cause drowning. As noted earlier, suicide by drowning is also a possibility.

Cardiac arrhythmias occur in a small subset of patients who are immersed in water and can occur at any age. Congenital long QT syndrome (LQTS) is a group of cardiac channel disorders characterized by delayed repolarization of the myocardium, QT prolongation, and increased clinical risk for syncope, seizures, and sudden cardiac death. In particular, these arrhythmias can be triggered by exertion and swimming.[86]

Prehospital Care

Rescue and Initial Resuscitation

Success or failure of basic life support provided at the scene has both saved and doomed many victims. It is vital that the prehospital provider understand the principles of early resuscitation of the drowning victim, including airway maintenance and various modalities of rescue breathing with a bag-valve-mask and other airway devices.

The patient should be removed from the water as soon as possible. Although rescue breathing in the water has been shown to be useful, chest compressions in the water are not effective.

Submersion Times

Time is crucial in the management of the drowning victim. Full neurologic recovery is not predicted if the victim has been submerged for longer than 60 minutes in icy water or longer than 20 minutes in cool water. In hot springs and hot tubs, successful resuscitations are unlikely, after even shorter times.[87,88] In very cold, icy water, there is one case that had a documented submersion time of 66 minutes with little or no neurological deficit.[89]

Submersion time, however, is often inaccurate and should serve only as a rough estimate. The emotional excitement at the time of submersion is so intense that few observers are able to reliably document the duration of submersion. Unless an immersion time exceeding 30 minutes in icy water is unquestionably documented, it is best to attempt resuscitation on all victims. The time of the call to the rescuers and the arrival of the rescuers are often known and in extreme cases may be used to approximate the submersion times.

Mechanisms of Injury

All patients who are involved in a boating accident, a head-first diving accident, a fall into rapidly moving water, rapids, or surf, or a fall from a height greater than 10 feet should be considered to have multiple trauma and potential cervical spine injuries.[32] The easiest and quickest splint that can be used for these critical drowning victims is the long backboard.

Dr. Heimlich, who advocates the use of the "Heimlich" maneuver to express water out of the lungs, expounds a notable exception to the policy of no "chest drainage maneuvers".[92] There are no data to support the use of a Heimlich maneuver in a drowning victim who does not have a particulate matter foreign body obstruction,[93] and recently, the case reports that served as the basis for recommendations for the use of the Heimlich maneuver, have been debunked.[94]

Care must be taken to prevent aspiration of gastric contents since vomiting is very common with this maneuver. It is imperative that no time be wasted with this or other maneuvers.

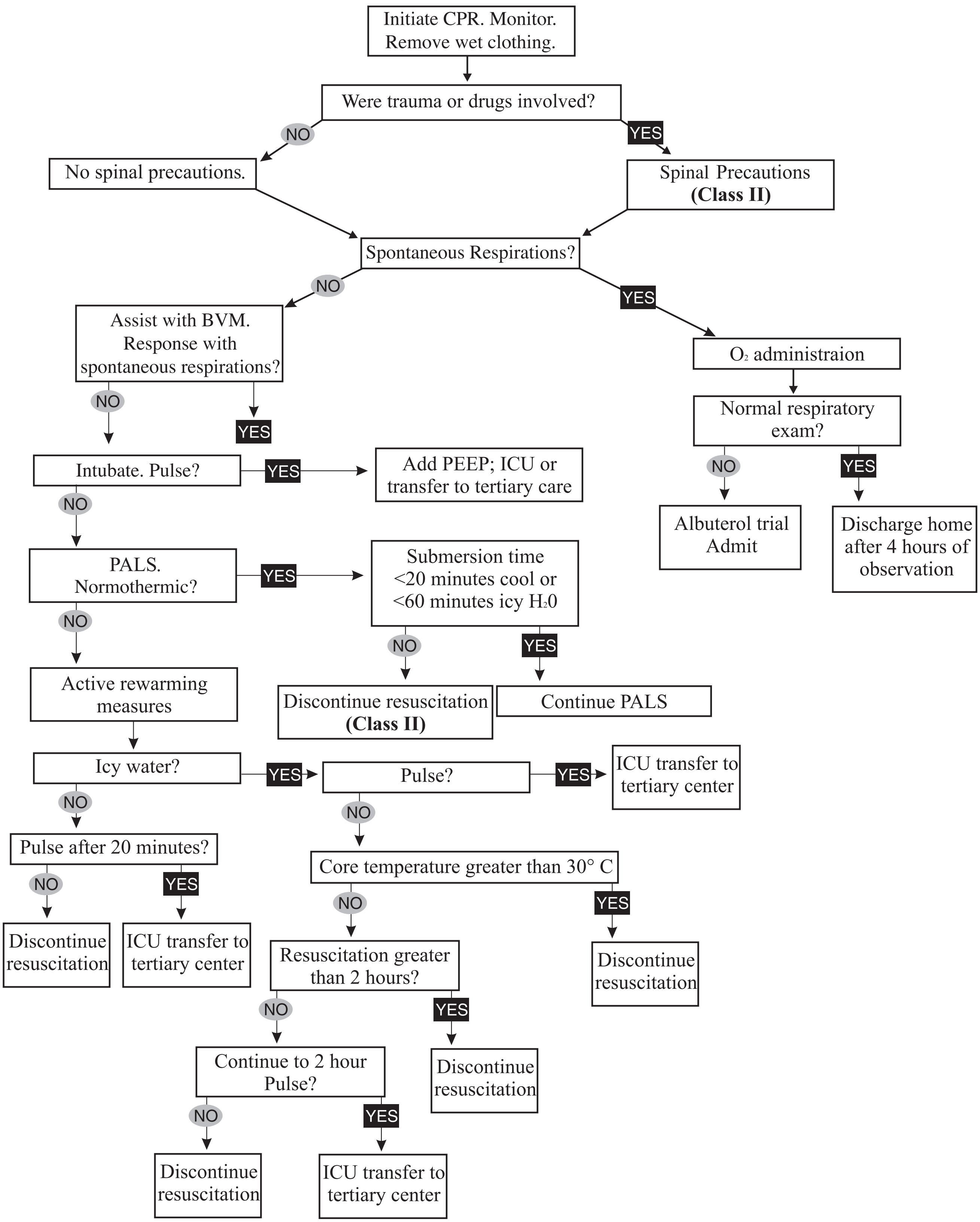
Cardiopulmonary Resuscitation

Immediate and adequate resuscitation is of paramount importance and is the single most important factor influencing survival. The immediate actions of the primary responder have the potential to significantly affect the outcome for the drowning victim.

Supplemental Oxygen

Supplemental oxygen is a mainstay in the pre-hospital care of the drowning victim. Early efforts should include 100% oxygen, administered immediately by a bag-valve-

Clinical Pathway: Pediatric Submersion Injury



This clinical pathway is intended to supplement, rather than substitute for, professional judgment and may be changed depending upon a patient's individual needs. Failure to comply with this pathway does not represent a breach of the standard of care.

mask followed by rapid intubation in the unconscious patient.

Suction

Suction equipment must be available since many of these patients will vomit or may have copious secretions from the pulmonary edema. If vomiting occurs or seems imminent, the lateral decubitus position is recommended. Early intubation of the patient will protect the patient from further aspiration and allow for both suctioning and administration of high-flow oxygen.

Post-resuscitation Management

Wet clothing should be removed, if possible, and the patient needs to be covered with blankets for warmth. Constant attention should be paid to vital signs, to the potential of vomiting, and to the possibility of deterioration of the patient during transport. Potential problems include pulmonary edema and shock from associated trauma. There is also the potential for cervical spine trauma in accidents with a suggestive mechanism.

ED Evaluation

Emergency Department Management

The "dunked" patient

The awake, alert toddler who was merely "dunked" and has not required rescue breathing or supplemental oxygen therapy may be observed for several hours and then discharged if still asymptomatic. Chest s-rays are not helpful in either predicting these patients disposition or in making clinical decisions.[95] The "secondary drowning" case series by Pearn that spawned a generation of automatic admission for any submersion incident, pre-dated pulse oximetry and, according to his own description of the patients, did not include any asymptomatic children.[111] Therefore, the asymptomatic patient with normal pulse oximetry may be safely discharged home (**see Figure 2**).

The critical patient

The asystolic patient requires intubation, rapid rewarming, volume restoration and ACLS medications. Defibrillation of the patient in ventricular fibrillation should be accomplished in the field if possible. If hypothermia is found, successful defibrillation may be possible only after core rewarming is accomplished. A cold heart is always difficult to restart, so it is important to not give up too soon. There have been reports of complete recovery after CPR times of up to 2 hours, particularly in hypothermic small children. Resuscitation efforts should be continued until circulation and respiration are re-established and the victim has been warmed, or cerebral death has occurred.[94] The rescuers and clinicians should be reminded that a dry environment is safer during attempts at defibrillation.

Rapid intubation allows both protection of the airway and administration of higher oxygen concentrations. Positive end-expiratory pressure (PEEP) or continuous positive airway pressure (CPAP) with intermittent mandatory ventilation (IMV) can be easily used on the

Preventive Strategies

Like all diseases, it is much easier to prevent a drowning, than it is to treat one.[41] Many of the major factors that contribute to a drowning are preventable, such as an inability to swim, failure to wear proper protective gear, consumption of drugs or alcohol, and stunts. Because the greatest proportion of drownings occur in non-swimmers, the protection afforded by swimming lessons is easy to support and has been known for ages.

Children require special preventative measures. It is interesting to note that a Virginia study of toddler pools found that the children who had some form of swimming lessons by 18 months of age were only half as likely to require retrieval from a pool.[128] A child with "water wings," or in a floating support, without adequate supervision immediately available, is a fatality waiting to happen. Overestimation of swimming skills and trauma associated with horseplay may contribute to a child's demise. Most parents believe their child is not susceptible to injury.[135]

Fences around pools markedly reduce the incidence of submersion injuries in those areas where it is required.[129-132] Because fencing requires no training or action on the part of the child or the parent; it deserves a very high priority in prevention efforts. The fencing should be at least 4 feet high and include self-locking gates. Immersion alarm systems for unattended pools will further decrease deaths, but should not be used as a primary means of drowning prevention.

The adult who is intoxicated not only cannot supervise a child; he or she cannot supervise personal actions. To reach the "legally drunk" 100 mg/dl level, the average 70-kg person needs to consume only 4 beers or two mixed drinks in the space of an hour. Any steps that reduce intoxication among swimmers will reduce the frequency of injury and death.

Patients with seizure disorders or other handicaps must be properly supervised, as their risk is higher.[133] For these patients, buddy swimming and proper supervision is mandatory. For parents of these children, cardiopulmonary resuscitation training should be strongly advocated.[41] ▲

intubated patient. PEEP will recruit atelectatic areas of the lung and improve ventilation. Ideally, PEEP should be started in the ED and monitored with blood gases as the patient's course progresses. Nasal CPAP may also be used in the conscious and unintubated patient with respiratory distress.[95]

In experimental drowning in pigs, 5 cm of PEEP increased arterial oxygen tension, even when instituted 20 minutes after the insult.[96] The addition of PEEP will decrease the degree of intrapulmonary shunting, decrease the V/Q mismatch, and increase the functional residual capacity. The increased PaO_2 from the use of PEEP and continuous positive airway pressure (CPAP) will occur regardless of whether the patient has suffered freshwater or saltwater submersion.

Bronchospasm may be treated with nebulized bronchodilators such as albuterol. The dosages of these agents do not change due to the insult of drowning.

Rewarming begins with removal of wet materials, followed by more active warming measures. Forced air surface rewarming has been shown to be effective in patients with body core temperatures <30°C who in one series were successfully rewarmed to >35°C.[134] Patients may require more aggressive methods using warm isotonic fluids including NG or foley catheter lavage, peritoneal lavage or thoracostomy lavage.

The medium acuity patient

The patient who required resuscitation or currently requires supplemental oxygen should have oxygen titrated to keep saturations greater than 94%. An intravenous line for medications should be started in the symptomatic patient if not already present. However, arterial blood gas determinations are not necessary in most patients. Core body temperature should be measured and actions to dry off the patient and conserve the patient's body temperature should be undertaken. Warming lights or warming blankets are always appropriate for unclothed wet children in air-conditioned areas. Monitoring is needed for patients for a minimum of 4 hours, following which a disposition decision can be made. Those that have been successfully weaned from supplemental oxygen and are asymptomatic may be discharged home.

Protection of the cervical spine

The actual incidence of traumatic injury in submersion injuries is quite low and is almost always associated with a history of boating accidents, falls from heights, diving from a high height, or vehicle crashes.[98,99] If there are any indications of trauma, or if there is a history of high velocity impact to the water, the cervical spine should be protected by a cervical collar and long spine board, and cervical spine x-rays should be obtained as soon as possible.

History

After all immediate resuscitative efforts are underway, it is appropriate to obtain available medical history, paying particular attention to those factors that will influence the prognosis and possible complications. The physician should be able to document what kind of fluid the patient was submerged in, the temperature of the solution, a rough approximation of the duration of submersion, what resuscitative efforts were made at the scene, and the response to these efforts. Use of alcohol and/or illicit drugs should be identified. Any pre-existing diseases that are known should be identified. In many cases, this data will be readily available from friends or family. If possible, while questioning the patient or those who came with the child, obtain details of the accident. The details may provide clues to cervical spine injuries, fractures, or intra-abdominal injuries that may go temporarily unrecognized during the excitement of the resuscitation.

If the victim is an infant, the possibility of child abuse must be considered.[25,100] Children may be forcibly submerged underwater as a form of punishment. Any inconsistencies in the history or other evidence of trauma or child abuse should prompt a more thorough investigation.

Physical exam

The clinical presentation of pediatric drowning victims varies greatly and ranges from completely asymptomatic to cardiopulmonary arrest. Common symptoms in survivors reflect the organ systems that may be affected by hypoxic or anoxic injury.

Most commonly, pulmonary symptoms including dyspnea, coughing or wheezing may be appreciated. The wheezing may be focal or heard throughout the lung fields and may be due to bronchospasm, pulmonary edema, or aspiration. The cardiac findings would most frequently include tachycardia, but in the more severe cases would include bradycardia or asystole. Gastrointestinal symptoms regularly include vomiting, and occasionally diarrhea.

Bruising, deformities, and lacerations may be present when there is a traumatic mechanism.

Diagnostic Studies

Arguably, the two most popular diagnostic studies in the drowning victim are the cervical spine x-ray and the chest x-ray. Likewise, the most popular laboratory test is the arterial blood gas. Other ancillary tests the practitioner may consider include: ethanol levels and drug screens, liver enzymes, coagulation studies, and a complete blood cell count. Some authorities even recommend blood and tracheal aspirate for aerobic and anaerobic cultures, feeling that this will give the practitioner early warning of potential pathogens.[5]

Chest x-ray

The initial radiograph may be normal, even in the patient with clinically obvious pulmonary edema. Conversely, the initial chest film can show early pulmonary edema in asymptomatic drowning victims.[125,136] Essentially, in neither study investigating predictive value of the chest x-ray for children with submersion incidents was it found to be useful in clinical management or prognosis.

Cervical spine x-ray

As noted above, the cervical spine should be evaluated in drowning victims who have a history of high-impact submersion or have physical signs of trauma. A routine cervical spine evaluation does not appear to be warranted without a history of trauma associated with the submersion.[98]

Arterial blood gas

Victims of drowning exhibit a combined respiratory and metabolic acidosis. The respiratory component should be corrected with prompt airway control and ventilation. Severe metabolic acidosis may require correction with 1 mEq/kg of sodium bicarbonate. In the profoundly affected submersion patient, metabolic acidosis can be further corrected with the guidance of arterial blood gas results. However, in most asymptomatic or mildly affected patients, an ABG is not warranted.

CBC/electrolytes

The routine ordering of complete blood counts and electrolytes are not beneficial. Unless the child has been submersed in a unique liquid medium coupled with significant ingestion, it is unlikely any significant abnormalities will be found. Demargination of the white blood cells as part of the physiologic stress response will make interpretation of a CBC difficult.

Head CT

Routine CT scans in patients without a clear traumatic mechanism are also of little benefit. While cerebral edema may be present in the more severe submersion patients, there is little utility for the otherwise neurologically intact patient.

Treatment

Resuscitation and the subsequent respiratory management of the drowning patient are well-established and little controversy exists. The therapeutic challenge that remains is limitation of brain damage in the survivors. Unfortunately reports of success stories abound in lay and medical literature alike, while the failures are not noted. In the absence of prospective studies, it is difficult to maintain an appropriate perspective of the morbidity of submersion injuries.

Early studies advocated the use of hypothermia, intracranial perfusion monitoring, and barbiturates to improve cerebral outcome.[102,103] There is now a general consensus that early barbiturate loading and control of ICP does not improve the overall outcome. Currently, ICP monitoring is not recommended, but if it is done, an elevated ICP bodes a poor prognosis for the patient.

Recent evidence for controlled hypothermia as a neuroprotective therapy has been published in a study that assessed its benefits in treating an out-of-hospital cardiac arrest.[104] Based on the favorable outcome of this and similar studies, the 2002 World Congress on Drowning in Amsterdam, recommended this therapy for drowning victims who have restoration of circulation and remain comatose.[105] A recent International Liaison Committee on Resuscitation advisory statement also suggested that hypothermia may be beneficial for cardiac arrest in drowning.[106] Since only anecdotal evidence is currently available about this therapy in drowning patients, hypothermia remains an experimental therapy modality until significant studies have been performed.[107]

The evaluation and treatment of hypothermia regardless of etiology is essentially the same.[113,114] The most basic method of prevention of heat loss should be used from the very start of the resuscitation; the patient should be dried. Evaporation causes rapid heat losses, and wet clothes rarely protect sufficiently from heat losses. Wet clothing should be removed as soon as possible in the resuscitation, and the patient should be covered with warmed, dry blankets.

For the conscious patient without significant respiratory embarrassment, active external heating may suffice. Although heated moistened oxygen and warmed intravenous fluids do not contribute significant heat calories to the resuscitation; this form of adjunctive warming will often balance heat losses.

Water baths for rewarming are dangerous to both patient and staff if cardiovascular monitoring is employed. Other methods such as peritoneal dialysis and hemodialysis, also allow invasive monitoring and rapid rewarming of the core simultaneously.

The rewarming method of choice in the hypothermic non-breathing drowning victim is forced air rewarming, along with warm lavage in the stomach, bladder, peritoneal space, and chest. For asystolic drowning victims from an icy submersion, the preferred rewarming method is probably cardiopulmonary bypass with a in-line heat exchanger. This method has the very practical advantage of rewarming the core and oxygenating the brain at the same time. Extracorporeal rewarming potentially plays an important role in treating significantly hypothermic patients and probably should not be transported to a hospital that lacks these facilities if other alternatives exist.[75,76]

Adjuvant Theory

Fluid replacement and inotropic support

Intravascular volume depletion is common. It appears to be secondary to pulmonary edema, and is generally independent of the type of fluid aspirated. Volume expansion may be indicated. Isotonic crystalloid (20 mL per kilogram) is recommended as a first-line therapy. This may be followed with inotropic support using either dopamine or dobutamine.

Antibiotics

The mortality of drowning-associated pneumonia is 60%.[63] There is little evidence for, and substantial logic against the use of prophylactic antibiotics.[63] In one study where 21 patients were given prophylactic antibiotics, 16 developed pneumonia from an organism resistant to the antibiotic used.[108] No reduction in pneumonia or mortality was noted when prophylactic antibiotics have been used.

Less controversy exists over the use of prophylactic antibiotics when the patient aspirates grossly contaminated water from sewers or septic tanks. With such contamination of the lungs, most authorities recommend antibiotics.

The decision to start antibiotic therapy is a difficult one. Antibiotics should obviously be given to those patients who exhibit signs of infection or sepsis. If the patient develops a new fever, pulmonary infiltrate, or systemic signs of infection, then empiric therapy should be started. Unfortunately, many of these drowning victims will have signs and symptoms of pneumonia, such as leukocytosis and fever.

Many clinicians advocate culture of a tracheal aspirate and treatment with appropriate antibiotics for that culture; only if there is clinical evidence of an infection.

Glucose

Hypothermia and alcohol, alone or in combination, may cause hypoglycemia, and drowning victims may benefit from dextrose. Toddlers also have little glycogen reserves, and may become hypoglycemic secondary to the physiologic stress.

Steroids

Corticosteroid therapy for pulmonary injury of drowning has not been demonstrated to be helpful in either canine or human studies.[94,109] In one meta-analysis of 33 papers, the authors found no prospective studies and only 5 retrospective studies.[110] There were 9 case reports or small series described in the meta-analysis. The authors of the meta-analysis felt that there was very little evidence for the value of intravenous steroids in the treatment of drowning. They should probably not be used for treatment of the pulmonary injury.[110] Obviously, studies exist which show beneficial effects for the treatment of cerebral edema. In this case, steroids may be helpful.

Surfactant

Surfactant is washed out or destroyed by both saltwater and freshwater aspiration. Addition of artificial surfactant will theoretically improve the gas exchange in drowning survivors. Artificial surfactant has been used in the treatment of drowning victims with some success.[111,112]

Table 3. Factors Affecting Prognosis

- Duration of the submersion
- Duration and degree of hypothermia (water temperature)
- Age of the patient
- Water contaminants
- Duration of respiratory arrest
- Duration of cardiac arrest
- Rapidity and effectiveness of resuscitation

*Without controlled studies, it is difficult to determine which factors have the greatest effect on the outcome of the patient after a drowning.

Animal studies have conflicting results, and this method will need substantial study before it can be routinely recommended.

Special Circumstances

Profound electrolyte changes can be found in Dead Sea drowning victims and survivors alike, even with aspiration of only modest amounts of fluid.[58,59] One might expect similar results for drowning victims from the Great Salt Lake, but no cases have been reported in the literature. The hypernatremia seen in these instances is thought to be due to swallowed water rather than aspiration.[60]

Fiberoptic or rigid bronchoscopy may be indicated in patients who have aspirated particulate matter or contaminated fluids. Particularly noteworthy is the high percentage of patients who have had silt or sand in the trachea and lungs after falling in rapidly moving streams or in surfing accidents. These densities may be seen as 'sand bronchograms' on plain films of the chest.[97] Chest CT may be indicated for patients who have possible aspiration of sand or other particulate matter. Imaging of the sinuses may also be indicated to assess possible nasal inhalation of foreign material.

The cessation of resuscitation

Without prospective studies, any time recommendations for determining futility of resuscitation are conjecture. Initially the emergency physician should generally treat ***all*** patients as survivable casualties, unless there is an obvious injury that is incompatible with life. Only after documented submersion times are greater than 20 minutes in cool water, or 1 hour in icy water, should the ED consider that the patient is non-rescuscitatable. These times may be shortened if the water was hot.

After rescue, the victim may appear to be clinically dead, either because a true cardiac arrest has occurred or because the bradycardic weak pulse is not palpable. Bedside ultrasound is a useful modality in confirming lack of ventricular activity. It is emphasized that the development of immersion hypothermia prior to the anoxic insult is protective for the brain. This has been confirmed by a considerable amount of clinical experience with deliberate hypothermia in cardiovascular surgery. Therefore, all drowning victims should have a trial of resuscitation with immediate ventilation and closed chest massage. Brain death is difficult to determine at lower body temperatures, so rewarming the patient to at least 30°C is required before abandoning CPR. CPR exceeding 2 hours has been successful, and victims have survived submersion times as long as 66 minutes.

Controversies/Cutting Edge

The most important controversy in treating the child who has been immersed in water is when to stop. The advisability of continuing CPR efforts and the length of these efforts is a perplexing dilemma for the emergency physician. Although no one would want to stop resuscitation for a child who has an opportunity for recovery, the possibility of resuscitating the drowning victim to the level of a persistent vegetative state is real. Despite multiple attempts to develop prognostic criteria that would allow the emergency physician to effectively manage this issue, there simply isn't any consensus in the literature regarding prognostic scores or indices that would predict either meaningful survival or no possibility of return to an acceptable mental status.

The use of surfactant intuitively would seem beneficial, but has met with mixed results clinically. While research continues with this modality, at this time, it does not seem as promising as once thought.

Extracorporeal membrane oxygenation has been life-saving for submersion patients, but is technologically challenging and available only at tertiary care facilities. Continuing efforts to successfully utilize this modality for submersion victims will need to focus on these practical logistical issues.

Disposition

Intensive care admission/transfer

A prognosis of the patient with drowning may be difficult to estimate, but current data justifies guarded optimism. If the patient has made a first respiratory effort within 30 minutes of rescue, the prognosis is good.[115] The patient who arrives at the hospital with a beating heart has a good chance of recovery of all neurologic function. Those patients with progressive neurologic deterioration appear to have a uniform incidence of prior deterioration of pulmonary status. Survival after the drowning event appears to depend upon a number of interrelated factors (**see Table 3**).

In warm water submersion, a clinical picture that includes one or more of the following features will imply a severe neurologic impairment or mortality, even in children[116-118] (**see Table 4**).

Table 5. Good Prognostic Factors in Drowning

- Alert and awake on arrival to ED
- Icy freshwater
- Short submersion
- Older child or young adults
- On scene ACLS/BLS
- Healthy

These indicators are not absolutely reliable, and the prognostic criteria should be always regarded with skepticism.[122] Prognostic systems can never predict outcome with 100% specificity, so a high severity score does not always indicate impossibility of survival or presence of severe neurologic impairment. As knowledge of pediatric cardiopulmonary resuscitation is refined, more children will survive submersion incidents. An unfortunate consequence is that a higher percentage of survivors will be severely neurologically impaired. This makes for difficult decisions for the pediatric emergency provider.

No combination of available variables has been able to prospectively differentiate all intact survivors from those with poor outcome. Most of these predictive rules are more appropriately applied in the ICU after initial resuscitation than in the ED. An interesting exception would be for a tool designed for the ICU—the Pediatric Risk of Mortality Score (PRISM).[119] This tool appeared to be more effective when used in the ED than in the ICU, but still has drawbacks.[2]

In the absence of any unusual circumstance, such as icy-water immersion or barbiturate use, a reasonable guideline is to continue resuscitation for 30 to 40 minutes. After that time, consider stopping all efforts, if no effective

Table 4. Prognostic Indicators

Favorable Prognostic Indicators	*Unfavorable Prognostic Indicators*
• Age > 3 years	• Age ≤ 3 years
• Female	• Male
• Cold water submersion (<10° C)	• Warm water submersion (≥ 10° C)
• Duration of submersion < 5 minutes	• Duration of submersion ≥ 5 minutes
• No aspiration	• Aspiration
• Prompt initiation of resuscitation (within 10 minutes of submersion)	• Delayed initiation of resuscitation (more than 10 minutes after submersion)
• Spontaneous circulation on arrival in ED	• Pulseless on arrival in ED
• Blood pH ≥ 7.1 on arrival in ED	• Blood pH < 7.1 on arrival in ED
• Awake on arrival in ED	• Comatose on arrival in ED
• Reactive pupils	• Fixed and dilated pupils
• No requirement for epinephrine administration	• Epinephrine administration in the pre-hospital setting or ED
• Normal chest radiograph	• Abnormal chest radiograph
• Initial blood glucose < 200 mg/dL	• Initial blood glucose ≥ 200 mg/dL

cardiac activity has been restored.

The same prognostic factors cannot be applied to submersion in icy water. As has been noted before, there is a profound protective effect of hypothermia on cerebral survival. In very warm water, prognosis becomes guarded at best after even short periods of immersion.

Studies of drowning victims from warmer climates show lower survival and higher morbidity. This is probably due to the loss of protective reflexes and protective hypothermia. The difference is so marked that practitioners who see warm water drowning patients from the southern states have an entirely different outlook on this disease than Northerners who deal with cold water drowning. Indeed, the worst outcome appears to be in victims of hot-tub immersion accidents.

Hyperkalemia in severely-hypothermic patients is usually indicative of asphyxial cardiac arrest before significant cooling has occurred. A potassium concentration greater than 10 mmol/dl is not compatible with successful resuscitation.[123,124] (**see Table 5**).

Ensure that all patients who have respiratory symptoms, altered oxygenation by pulse oximetry, or any potential victim of non-accidental trauma is admitted to the hospital.

Summary

Between 6,000 and 8,000 drownings occur each year in the United States, and there are a like number of non-fatal submersion injuries that are reported. There is not a mandate to report drownings, so the actual number may be far higher.

The single most important factor in recovery of the patient is the time from submersion until definitive ventilatory support and airway care. Rapid delivery of advanced cardiac life support procedures provides this airway care and allows correction of complications of both aspiration and asphyxia.

The shorter the submersion time and the more quickly the patient receives CPR, the better the prognosis for long-term survival. Those who are submersed in hot tubs have the worst prognosis. All patients deserve a full and aggressive resuscitation, with only a very few exceptions. Unfortunately, there is no good way to predict which person will survive intact, which will die, or which will suffer damage that leaves only vegetative functions intact.

Survivors of drowning incidents may require psychiatric counseling for post-trauma stress.[127] Those who have attempted suicide will require appropriate counseling and therapy.

Finally, the best treatment for this disease is prevention. Bodies of water—whether a pool, canal, or lake—should be given the same respect as an open mine shaft in the backyard. Age-specific swimming lessons, water safety, and adequate supervision should be stressed for children. Liquor and other intoxicants should be banned from swimming areas. Seizure patients should be carefully supervised if swimming.[46] ▲

Ten Pitfalls to Avoid

1. **She looked so good, was awake and in no distress. The only clue that I had was her oxygen saturation of 91%. She'd only been submerged a few minutes, quickly regained consciousness and wasn't in any distress. I didn't even consider a chest x-ray. How could I know that she would crash?**

   The finding of a low oxygen saturation in a submersion victim isn't quite ominous. It should call for significant monitoring and admission, at least overnight. These children can decompensate rapidly.

2. **The 14-year-old girl was waterskiing and crashed. They said that she went down and just didn't come up. Her friends pulled her from the water, did CPR and got her breathing. Now she's paralyzed.**

   Head trauma can lead to unconsciousness and drowning without a struggle. Cervical spine trauma can make it impossible for the victim to struggle. In every case of trauma, you should assume that the patient may have a cervical spine injury and use cervical spine precautions.

3. **The 4-year-old was only under water for about 3 minutes in the hot tub. The hot tub temperature was 103ºF. I thought that AHA said that it takes about 4 minutes to develop brain damage.**

   The figure of 4 minutes is both an average and assumes that the patient is normothermic. Since the rate of metabolism increases about 13% for each degree centigrade rise, a hot tub will markedly decrease that anoxic time before brain damage ensues. Hot tubs can be lethal places to drown, no matter what age you are.

4. **The child was submerged for 15 minutes in icy water. The bystanders noted that the child had fallen through the thin ice and it took 15 minutes to locate the child's body underwater. The**

paramedics found no respirations and no pulse. They have started CPR at mother's insistence. They want you to pronounce the child dead at scene.

This is a potential problem. This child deserves resuscitation—at least until warm and dead. You need to re-orient the EMS crew, after you finish resuscitation of the child. It may be futile; they may be right, but you won't know until you have tried. The literature is full of anecdotal evidence of intact neurological survival in children in cold water immersion.

5. **The child was submerged for 30 minutes in ice-cold water. You have managed CPR, intubated the patient, and have continued the resuscitation as lab trickles back in. The child's potassium is 14.9. You want to call the code. Do you have sufficient evidence?**

   A potassium of above 10 should make your decision. In cases of hypothermia that didn't involve submersion, marked elevation of potassium was associated with 100% mortality.

6. **You are taking care of a child who has fallen into a septic tank with a short period of submersion. The child is rapidly resuscitated and is doing well. Your intern feels that the child should be started on antibiotics. You read that antibiotics should generally not be started on drowning victims. Who is correct?**

   In this case, your intern is probably correct. Although antibiotics are generally NOT recommended for initial therapy for drowning victims, certain exceptions apply. Septic tank submersion with the massive bacterial contamination that can ensue is probably an outstanding example of the exception to the no-antibiotics philosophy.

7. **The intern wants to complete the picture above by starting the child on steroids. Do you agree in this patient with probable aspiration of significantly contaminated fluid?**

   Unlike the use of antibiotics in the case of serious pulmonary contaminants, there isn't a similar analogue for the use of steroids. Steroids may be helpful in patients with underlying asthma or other bronchospasm or in cases of cerebral edema, but there isn't any evidence supporting their use in patients who have been submerged.

8. **Your patient has been rescued by the pool lifeguard. He was trying to cross the pool and return underwater. He had been observed hyperventilating by the lifeguard. The very alert lifeguard pulled him from the water almost as soon as he stopped trying to swim. The child is now awake and alert, he has a slight cough. Oxygen saturation is now 98%. Your intern wants to admit the child to the intensive care unit and arrange for cardiac electrophysiological studies, looking for an arrhythmia as the source of the unconsciousness. Do you agree?**

   This is a relatively a classic case of hyperventilation, followed by anoxia. The child lowered his CO_2, worked hard swimming and burned up his oxygen supplies before the rise in CO_2 could trigger the urge to breathe. He became anoxic and lost consciousness while swimming. This child may need observation for his cough and questionable aspiration of pool water, but probably doesn't need electrophysiological studies based on this history.

9. **You are involved in the resuscitation of a child who drowned in the surf. The submersion time was relatively short. The 15-year-old surfer was placed in cervical precautions, intubated, and is now spontaneously breathing. He is making spontaneous movements. You notice some sand in the endotracheal tube. What is your next step?**

   This patient deserves either bronchoscopy or chest CT looking for sand and other particulate matter. Surfing accidents are noteworthy as sources of silt and sand in the airway.

10. **You are taking care of three victims of a motor vehicle accident where the SUV ran off the road and into a canal. The oldest victim, the mother, escaped from the vehicle and is asymptomatic. A passerby leaped into the water and pulled out 2 children. The oldest is pulseless, apneic, and flaccid. She was in the water for about 10 minutes. The youngest is coughing, moving all extremities, and breathing spontaneously. Mother appears quite calm and collected. Should you be suspicious?**

    Child abuse and murder by submersion are not terribly unusual. A mother that is not acting appropriately should always arouse your suspicions of abuse or deliberate homicide. This situation needs more investigation than you can do in the ED department. You will need to contact your local authorities or ensure that the police do this. ▲

References

Evidence-based medicine requires a critical appraisal of the literature based upon study methodology and number of subjects. Not all references are equally robust. The findings of a large, prospective, randomized, and blinded trial should carry more weight than a case report.

To help the reader judge the strength of each reference, pertinent information about the study, such as the type of study and the number of patients in the study, will be included in bold type following the reference, where available. In addition, the most informative references cited in the paper, as determined by the authors, will be noted by an asterisk (*) next to the number of the reference.

1. Liss HP. A history of resuscitation. Ann Emerg Med 1986;15(1):65-72. **[Historical review]**
2. Zuckerman GB, Gregory PM, Santos-Damiani SM. Predictors of death and neurologic impairment in pediatric submersion injuries. The Pediatric Risk of Mortalilty Score. Arch Ped Adolesc Med 1998;152(2):134-140. **[Retrospective review]**
3. Orlowski JP. Drowning, near-drowning, and ice-water drowning. JAMA 1988;260(3):390-391. **[Review article]**

*4. Quan L, Kinder D. Pediatric submersions: prehospital predictors of outcome. Pediatrics 1992;90(6):909-913. **[Retrospective review; 77 patients.]**

5. Golden F, Tipton MJ, Scott RC. Immersion, near-drowning and drowning. Br J Anaesth 1997;79:214-225. **[Review]**
6. Schuman SH, Rowe J, R., Glaxer HM, et al. Risk of drowning: an iceberg phenomenon. J Am Coll Emerg Phys 1977;6(6):139-143. **[Prospective and retrospective review; 909 drownings and 9420 prospective questionaires.]**
7. Anonymous. Nonfatal and Fatal Drownings in Recreational Water Settings–United States, 2001-2002. JAMA 2004;292(2):164-166. **[Fact sheet]**
8. Anonymous. World Health Organization Drowning Fact Sheet, 2003. Found at: http://www.who.int/violence_injury_prevention/publications/other_injury/en/drowning_factsheet.pdf. Date accessed: 27 February 2006 **[Fact sheet]**
9. Idris AH, Berg RA, Bierens J, et al. Recommended guidelines for uniform reporting of data from drowning: the "Utstein style". Circulation 2003;108(20):2565-2574. **[Consensus guideline]**
10. Modell JH. Drown versus near-drown: a discussion of definitions. Crit Care Med 1981;9(4):351-352. **[Editorial; definitions used in drowning.]**

*11. van Beeck EF, Branche CM, Szpilman D, et al. A new definition of drowning: towards documentation and prevention of a global public health problem. Bull World Health Organ, 2005;83(11):853-856. **[Fact sheet]**

12. Modell JH. Drowning. N Engl J Med 1993;328(4):253-256. **[Review article]**
13. Duffin J, Miller R, Romet TT, et al. Sudden cold water immersion. Respir Physiol 1975;23(3):301-310. **[Prospective study; 8 subjects]**
14. Keatinge WR, Hayward MG. Sudden Death in cold water and ventricular arrhythmia. J Forensic Sci 1981;26(3):459-461. **[Review article]**
15. Anonymous. Centers for Disease Control and Prevention Water-Related Injuries: Fact Sheet 2006. Found at: http://www.cdc.gov/ncipc/factsheets/drown.htm. Date accessed: 27 February 2006 **[Fact sheet]**
16. Anonymous. Centers for Disease Control and Prevention, National Center for Injury Prevention and Control Database of Injury Deaths, 2003. Found at: http://www.cdc.gov/ncipc/wisqars. Date accessed: 27 February 2006 **[Online Database Access at CDC]**
17. Joseph MM, King WD. Epidemiology of hospitalization for near-drowning. South Med J 1998;91(3):253-255. **[Retrospective review; 53 patients]**
18. Howland J, Hingson R, Mangione TW, et al. Why are most drowning victims men? Sex differences in aquatic skills and behaviors. Am J Public Health 1996;86(1):93-96. **[Retrospective review, household survey]**
19. Smith DS. Sudden drowning syndrome. Physician Sportsmed 1980;8:76-83. **[Review]**
20. Driscoll TR, Harrison JA, Steenkamp M. Review of the role of alcohol in drowning associated with recreational aquatic activity. Inj Prev 2004;10(2):107-113. **[Review article]**
21. Lincoln JM, Perkins R, Melton F, et al. Drowning in Alaskan waters. Public Health Rep 1996;111(6):531-535. **[Retrospective review]**
22. Davis S, Ledman J, Kilgore J. Drownings of children and youth in a desert state. West J Med 1985;143(2):196-201. **[Retrospective review]**
23. Al-Mofadda SM, Nassar A, Al-Turki A, et al. Pediatric near drowning: The experience of King Khalid University Hospital. Annals of Saudi Med 2001;21(5-6):300-303. **[Retrospective case series]**
24. Orlowski JP. Prognostic factors in pediatric cases of drowning and near-drowning. JACEP 1979;8(5):176-179. **[Retrospective review; 93 patients]**
25. Gillenwater JM, Quan L, Feldman KW. Inflicted submersion in childhood. Arch Pediatr Adolesc Med 1996;150(3):298-303. **[Retrospective case series]**
26. Quan L, Cummings P. Characteristics of drowning by different age groups. Inj Prev 2003;9(2):163-168. **[Retrospective review]**
27. Schmidt P, Madea B. Death in the bathtub involving children. Forensic Sci Int 1995;72(2):147-155. **[Retrospective case series]**
28. Lavelle JM, Shaw KN, Seidl T,et al. Ten-year review of pediatric bathtub near-drownings: evaluation for child abuse and neglect. Ann Emerg Med 1995;25(3):344-348. **[Retrospective review; 21 patients.]**
29. Castiglia PT. Drowning. J Pediatr Health Care 1995;9(4):185-186. **[Review article]**
30. Seiden RH. Where are they now? A follow-up study of suicide attempters from the Golden Gate Bridge. Suicide Life Threat Behav 1978;8(4):203-216. **[Retrospective review]**
31. Lafave M, LaPorta AJ, Hutton J, et al. History of high-velocity impact water trauma at Letterman Army Medical Center: a 54-year experience with the Golden Gate Bridge. Mil Med 1995;160(4):197-199. **[Retrospective review]**
32. Lukas GM, Hutton JE Jr, Lim RC, et al. Injuries sustained from high velocity impact with water: an experience from the Golden Gate Bridge. J Trauma 1981;21(8):612-618. **[Retrospective review]**
33. Fanton L, Miras A, Tilhet-Coartet S, et al. The Perfect Crime: myth or reality? Am J Forensic Med Pathol 1998;19(3):290-293. **[Retrospective review]**
34. Bennett AT, Collins KA. Elderly suicide: a 10-year retrospective study. Am J Forensic Med Pathol 2001;22(2):169-172. **[Retrospective review]**
35. Schmidt P, Madea B. Death in the bathtub involving children. Forensic Sci Int 1995;72(2):147-155. **[Retrospective review]**
36. Pollanen MS. Diatoms and homicide. Forensic Sci Int 1998;91(1):29-34. **[Review]**
37. Schmidt P, Madea B. Homicide in the bathtub. Forensic Sci Int 1995;72(2):135-146. **[Retrospective review]**
38. Orlowski JP, Rothner AD, Lueders H. Submersion accidents in children with epilepsy. Am J Dis Child 1982;136(9):777-780. **[Retrospective review]**
39. Diekema DS, Quan L, Holt V. Epilepsy as a risk factor for submersion injury in children. Pediatrics 1993;91(3):612-616. **[Retrospective review; 336 victims]**
40. Strauss D, Shavelle R, Anderson TW, et al. External Causes of death among persons with developmental disability: the effect of residential placement. Am J Epidemiol 1998;147(9):855-862. **[Retrospective review; 520 patients]**
41. O'Flaherty JE, Pirie PL. Prevention of pediatric drowning and near-drowning: a survey of members of the American Academy of Pediatrics. Pediatrics 1997;99(2):169-174. **[Membership survey]**
42. Ibsen LM, Koch T. Submersion and asphyxial injury. Crit Care Med 2002;30(11 Suppl):S402-408. **[Review]**
43. Cummings P, Quan L. Trends in unintentional drowning: the role of alcohol and medical care. JAMA 1999;281(23):2198-2202. **[Retrospective review]**
44. Wirrell EC, Camfield PR, Camfield CS, et al. Accidental injury is a serious risk in children with typical absence epilepsy. Arch Neurol 1996;53(9):929-932. **[Retrospective review]**
45. Spitz MC. Injuries and Death as a consequence of seizures in people with epilepsy. Epilepsia 1998;39(8):904-907. **[Retrospective review]**
46. Besag. Tonic seizures are a particular risk factor for drowning in people with epilepsy. Br Med J 2001;321:975-976. **[Editorial]**
47. Swann HG, Brucer M. The cardiorespiratory and biochemical events during rapid anoxic death; fresh water and sea water drowning. Tex Rep Biol Med 1949;7(4):604-618. **[Historical animal study]**
48. Swann HG, Brucer M, Moore C. Fresh water and sea water drowning: A study of terminal cardiac events. Tex Rep Biol Med 1947;5:423-437. **[Historical animal study]**
49. Swann HG, Spafford NR. Body salt and water changes during fresh and sea water drowning. Tex Rep Biol Med 1951;9(2):356-382. **[Historical animal study]**
50. Suzuki T. Suffocation and related problems. Forensic Sci Int 1996;80(1-2):71-78. **[Animal study]**
51. Hermann LK. Drowning, a common tragedy. Rocky Mt Med J 1979;76(4):169-173. **[Historical review article]**
52. Modell JH, Keck EJ, Ruiz BC. Effect of intravenous vs. aspirated distilled water on serum electrolytes and blood gas tensions. J Appl Physiol 1972;32:579-584. **[Animal study]**
53. Modell JH, Graves SA, Ketover A. Clinical course of 91 consecutive near-drowning victims. Chest 1976;70(2):231-238. **[Retrospective review: historical]**
54. Lunetta P, Modell JH, Sajantila A. What is the incidence and significance of "dry-lungs" in bodies found in water? Am J Forensic Med Pathol 2004;25(4):291-301. **[0195-7910 (Print) Journal Article]**
55. Franks CM, Golden FS, Hampton IF, et al. The effect of blood alcohol on the initial responses to cold water immersion in humans. Eur J of Appl Physiol Occup Physiol 1997;75(3):279-281. **[Human study; 16 subjects]**
56. Craig AB, Jr. Causes of loss of consciousness during underwater

swimming. J Appl Physiol 1961;16(4):583-586. **[Human trial: Historical]**
57. Craig AB, Jr. Summary of 58 cases of loss of consciousness during underwater swimming and diving. Med Sci Sports 1976;8(3):171-175. **[Human trial: Historical]**
58. Yagil Y, Stalnikowicz R, Michaeli J, et al. Near drowning in the Dead Sea. Electrolyte imbalances and therapeutic implications. Arch Intern Med 1985;145(1):50-53. **[Retrospective review; 8 patients]**
59. Saidel-Odes LR, Almog Y. Near-drowning in the Dead Sea: a retrospective observational analysis of 69 patients. Isr Med Assoc J 2003;5(12):856-858. **[Retrospective review]**
60. Ellis RJ. Severe hypernatremia from sea water ingestion during near-drowning in a hurricane. West J Med 1997;167(6):430-433. **[Case report]**
61. Sims JK, Enomoto PI, Frankel RI, et al. Marine bacteria complicating seawater near-drowning and marine wounds: a hypothesis. Ann Emerg Med 1983;12(4):212-216. **[Retrospective literature review]**
62. Chaney S, Gopalan R, Berggren RE. Pulmonary Pseudallescheria boydii infection with cutaneous zygomycosis after near drowning. South Med J 2004;97(7):683-687. **[Case report; literature review]**
63. Ender PT, Dolan MJ. Pneumonia associated with near-drowning. Clin Infect Dis 1997;25(4):896-907. **[Review]**
64. Karch SB. Pathology of the lung in near-drowning. Am J Emerg Med 1986;4(1):4-9. **[Animal study]**
65. Gu MN, Xiao JF, Huang YR, et al. Study of direct lung injury by seawater in canine models. Di Yi Jun Yi Da Xue Bao 2003;23(3):201-205. **[Animal study]**
66. Pearn J. Pathophysiology of drowning. Med J Aust 1985;142(11):586-588. **[Editorial]**
67. Nopanitaya W, Gambill TG, Brinkhous KM. Fresh water drowning. Pulmonary ultrastructure and systemic fibrinolysis. Arch Pathol 1974;98(6):361-366. **[Animal study]**
68. Rumbak MJ. The etiology of pulmonary edema in fresh water near-drowning. Am J Emerg Med 1996;14(2):176-179. **[Retrospective review; 10 patients]**
69. Steinman AM, Hayward JS, Nemiroff MJ, et al. Immersion hypothermia: comparative protection of anti-exposure garments in calm versus rough seas. Aviat Space Environ Med 1987;58(6):550-558. **[Human study]**
70. Steinman AM, Parris L. Immersion hypothermia. Emerg Med Serv 1977;6(4):22, 24-25. **[Review article]**
71. Stewart CE. Drowning. In: Stewart CE, ed. Environmental Emergencies. Baltimore: Williams and Wilkins, 1990. **[Review Chapter]**
72. Tipton MJ. The initial responses to cold-water immersion in man. Clin Sci (Lond) 1989;77(6):581-588. **[Review]**
73. Whittmers LE, Jr. Pathophysiology of Cold Exposure, 2001. Found at: http://www.mnmed.org/publications/MnMed2001/November/Whittmers.html. Date accessed: 1 March 2006 **[Review Article]**
74. Collis ML. Survival behavior in cold water immersion. Proceedings of the cold water symposium 1976, Toronto, Ontario. **[Review article]**
75. Harries M. Near drowning. BMJ 2003;327(7427):1336-1338. **[Review]**
76. Wollenek G, Honarwar N, Golej J, et al. Cold water submersion and cardiac arrest in treatment of severe hypothermia with cardiopulmonary bypass. Resuscitation 2002;52(3):255-263. **[Case series; 12 patients]**
77. Hunter AR. Neurosurgical anesthesia. 2nd ed. Oxford, England: Blackwell Scientific Publications, 1975. **[Review Chapter: Historical]**
78. Suominen PK, Korpela RE, Silfvast TG, et al. Does water temperature affect outcome of nearly drowned children. Resuscitation 1997;35(2):111-115. **[Retrospective review]**
79. Andersson JP, Runow E, Schagatay EKA. Diving response and arterial oxygen saturation during apnea and exercise in breath-hold divers. J Appl Physiol 2002;93(3):882-886. **[Volunteer human study; 8 subjects]**
80. Andersson J, Liner MH, Frested A, et al. Cardiovascular and respiratory responses to apneas with and without face immersion in exercising humans. J Appl Physiol 2004;96(3):1005-1010. **[Human study; 15 subjects]**
81. Tipton MJ, Kelleher PC, Golden FS. Supraventricular arrhythmias following breath-hold submersions in cold water. Undersea Hyperb Med 1994;21(3):305-313. **[Human study; 12 subjects]**
82. Tipton M. The effect of clothing on "diving bradycardia" in man during submersion in cold water. Eur J Appl Physiol Occup Physiol 1989;59(5):360-364. **[Human study; 18 subjects]**
83. Conn AW, Miyasaka K, Katayama M, et al. A canine study of cold water drowning in fresh versus salt water. Crit Care Med 1995;23(12):2029-2037. **[Animal study]**
*84. Golden F. Mechanisms of body cooling in submersed victims. Resuscitation 1997;35(2):107-109. **[Editorial, Review - This is an excellent review of the mechanisms of cooling in submersion.]**
85. Modell JH, Idris AH, Pineda JA, et al. Immersion in fresh water and survival. Chest 2004;126:2027-2029. **[Letter]**
86. Tester DJ, Kopplin LJ, Creighton W, et al. Pathogenesis of unexplained drowning: new insights from a molecular autopsy. Mayo Clin Proc 2005;80(5):596-600. **[Case report]**
87. Tron VA, Baldwin VJ, Pirie GE. Hot tub drownings. Pediatrics 1985;75(4):789-790. **[Case report]**
88. Anonymous. Consumer Product Safety Commission: "Spas, Hot Tubs, and Whirlpools", 2001. Found at: http://www.cpsc.gov/cpscpub/pubs/5112.html. Date accessed: 1 March 2006
89. Chochinov AH, Baydock BM, Bristow GK, et al. Recovery of a 62-year-old man from prolonged cold water submersion. Ann Emerg Med 1998;31(1):127-131. **[Case report]**
90. Orlowski JP. "Heimlich maneuver" for near-drowning questioned. Ann Emerg Med 1982;11(2):111-113. **[Letter]**
91. Wilder RJ, Wedro BC. "Heimlich maneuver" for near-drowning questioned. Ann Emerg Med 1982;11(2):111-113. **[Letter]**
92. Heimlich HJ. Subdiaphragmatic pressure to expel water from the lungs of drowning persons. Ann Emerg Med 1981;10(9):476-480. **[Review]**
93. Ornato JP. The resuscitation of near-drowning victims. JAMA 1986;256(1):75-77. **[Review]**
94. Orlowski JP. Drowning, near-drowning, and ice-water submersions. Pediatr Clin North Am 1987;34(1):75-92. **[Review]**
95. Dottorini M, Eslami A, Baglioni S, et al. Nasal-continuous positive airway pressure in the treatment of near-drowning in freshwater. Chest 1996;110(4):1122-1124. **[Case report; 2 patients]**
96. Lindner KH, Dick W, Lotz P. The delayed use of positive end-expiratory pressure (PEEP) during respiratory resuscitation following near drowning with fresh or salt water. Resuscitation 1983;10(3):197-211. **[Animal study]**
97. Dunagan DP, Cox JE, Chang MC, et al. Sand aspiration with near-drowning. Radiographic and bronchoscopic findings. Am J Respir Crit Care Med 1997;156(1):292-295. **[Case report]**
*98. Huang U, Shofe F, Durbin DR, et al. Prevalence of traumatic injuries in drowning and near drowning in children and adolescents. Arch Pediatr Adolesc Med 2003;157(1):50-53. **[Retrospective review; 143 patients]**
99. Watson RS, Cummings P, Quan L, et al. Cervical spine injuries among submersion victims. J Trauma 2001;51(4): 658-662. **[Retrospective review: 2,244 patients]**
100. Rouge-Maillart C, Jousset N, Gaudin A, et al. Women who kill their children. Am J Forensic Med Pathol 2005;26(4):320-326. **[Retrospective review]**
101. Fandel I, Bancalari E. Near-drowning in children: clinical aspects. Pediatrics 1976;58(4): 573-579. **[Retrospective review]**
102. Nussbaum E, Galant SP. Intracranial pressure monitoring as a guide to prognosis in the nearly drowned, severely comatose child. J Pediatr 1983;102(2):215-218. **[Randomized controlled study; 21 subjects]**
103. Dean JM, McComb JG. Intracranial pressure monitoring in severe pediatric near-drowning. Neurosurgery 1981;9(6):627-630. **[Case series; 20 patients]**
104. Bernard SA, Gray TW, Jones BM, et al. Treatment of comatose survivors of out -of- hospital cardiac arrest with induced hypothermia. N Engl J Med 2002;346: 557-563. **[Randomized controlled trial; 77 patients]**
105. Bierens JJ, Knape JT, Gelissen HP. Drowning. Curr Opin Crit Care 2002;8(6):578-586. **[Review]**
106. Nolan JP, Morley PT, Hoek TL, et al. Therapeutic hypothermia after cardiac arrest. An advisory statement by the Advanced Life Support Task Force of the International Liaison Committee on Resuscitation. Resuscitation 2003;57(3):231-235. **[Guideline statement]**
107. Williamson JP, Illing R, Gertler P, et al. Near-drowning treated with therapeutic hypothermia. Med J Aust 2004;181(9):468-469. **[Case report]**
108. Oakes DD, Sherck JP, Maloney JR, et al. Prognosis and management of victims of near-drowning. J Trauma 1982;22(7):544-549. **[Retrospective review; 40 patients]**
109. Calderwood HW, Modell JH, Ruiz BC. The ineffectiveness of steroid therapy for treatment of fresh-water near-drowning. Anesthesiology 1975;43(6):642-650. **[Animal study]**
110. Foex BA, Boyd R. Corticosteroids in the management of near-drowning. Emerg Med J 2001; 18(6):465-466. **[Case report and literature review]**
111. McBrien M, Katumba JJ, Mukhtar AI. Artificial surfactant in the treatment of near drowning. Lancet 1993; 342(8885): 1485-1486. **[Case report]**
112. Staudinger T, Bankier A, Strohmaier W, et al. Exogenous surfactant therapy in a patient with adult respiratory distress syndrome after near drowning. Resuscitation 1997; 35(2):179-182. **[Case report]**
113. Samuelson T, Doolittle W, Hayward J, et al. Hypothermia and cold water near drowning: treatment guidelines. Alaska Med 1982;24(6):106-111. **[Treatment guidelines]**
114. Anonymous. Part 10.4: Hypothermia. Circulation 2005; 112 (24_suppl): IV-136-138. **[Treatment guideline]**
115. Pearn J. The management of near drowning. Br Med J (Clin Res Ed) 1985;291(6507): 1447-1452. **[Review]**
116. Danzl D. Pediatric near-drowning: aggressive CPR is best. Patient Care 1987(August 15): 14-16. **[Review]**
117. Robinson MD, Seward PN. Submersion injury in children. Pediatr Emerg Care 1987;3(1): 44-49. **[Review]**
118. Graf WD, Cummings P, Quan L, et al. Predicting outcome in pediatric submersion victims. Ann Emerg Med 1995;26(3):312-319. **[Retrospective cohort matched study 194 children]**
119. Pollack MM, Getson PR, Ruttimann UE. Pediatric risk of mortality (PRISM) score. Crit Care Med 1988;16(11):1110-1116. **[Retrospective review]**
120. Christensen DW, Jansen P, Perkin RM. Outcome and acute care hospital costs after warm water near drowning in children. Pediatrics

1997;99(5):715-721. **[Retrospective chart review; 274 patients.]**
*121. Habib DM, Tecklenburg FW, Webb SA, et al. Prediction of childhood drowning and near-drowning morbidity and mortality. Pediatr Emerg Care 1996;12(4):255-258. **[Retrospective review; 93 patients]**
122. Opdahl H. Survival put to the acid test: extreme arterial blood acidosis (pH 6.33) after near drowning. Crit Care Med 1997;25(8):1431-1436. **[Case report]**
123. Hauty MG, Esrig BC, Hill JG, et al. Prognostic factors in severe accidental hypothermia: experience from the Mt. Hood tragedy. J. Trauma 1987;10 1107-1112. **[Case series; 10 patients]**
124. Schaller MD, Fischer AP, Perret CH. Hyperkalemia. A prognostic factor during acute severe hypothermia. JAMA 1990;264(14):1842-1845. **[Case report: Retrospective study]**
*125. Noonan L, Howrey R, Ginsburg CM. Freshwater submersion injuries in children: a retrospective review of seventy-five hospitalized patients. Pediatrics 1996;98(3 Pt 1):368-371. **[Retrospective review; 75 patients]**
126. van Berkel M, Bierens JJ, Lie RL, et al. Pulmonary oedema, pneumonia and mortality in submersion victims; a retrospective study in 125 patients. Intensive Care Med 1996;22(2): 101-107. **[Retrospective review]**
127. Ness G, Macaskill N. Near drowning: self therapy in situ. Br Med J 2000;321(7276):1604-1606. **[Case report]**
128. Spyker DA. Submersion injury. Epidemiology, prevention, and management. Pediatr Clin North Am 1985;32(1):113-125. **[Review]**
129. Pearn J, Brown J, 3rd, Hsia EY. Swimming pool drownings and near-drownings involving children. A total population study from Hawaii. Mil Med 1980;145(1):15-18. **[Retrospective epidemiologic review]**
130. DeNicola LK, Falk JL, Swanson ME, et al. Submersion injuries in children and adults. Crit Care Clin 1997;13(3):477-502. **[Review]**
131. Rivara FP, Grossman DC, Cummings P. Injury prevention. Second of two parts. N Engl J Med 1997;337(9):613-618. **[Review]**
132. Fisher KJ, Balanda KP. Caregiver factors and pool fencing: an exploratory analysis. Inj Prevention 1997;3(4)257-261. **[Retrospective review, statistical analysis of database]**
133. Rivara FP. Pediatricinjury control in 1999: where do we go from here? Pediatrics 1999; 103(4 Pt 2): 883-888. **[Editorial]**
134. Kornberger E, Schwarz B, Linder KH, et al. Forced air rewarming in patients with severe accidental hypothermia. Resuscitation 1999;41(2):105-111. **[Retrospective; 15 patients]**
135. Morrongiello BA, Kiriakou S. Mothers' home-safety practices for preventing six types of childhood injuries: what do they do, and why? J Pediatric Psych 2004;29(4):285-297.
*136. Causey AL, Tilelli JA, Swanson ME. Predicting discharge in uncomplicated near-drowning. Am J Emerg Med 2000;18(1):9-11. **[Retrospective cohort study; 48 patients]**

Physician CME Questions

49. Factors that contribute to drowning incidents include:
A. Use of alcohol
B. Lack of supervision.
C. Age
D. Co-existing seizure disorder
E. All the above

50. In the hospitalized drowning patient, evidence of respiratory distress may be found:
A. Within 4 hours
B. Within 6 hours
C. Within 8 hours
D. Within 12 hours
E. Within 24 hours

51. Which of the following is true regarding drowning?
A. 75% of victims are 0 to 4 years old.
B. Boys are 10 times more likely to drown than girls.
C. Drowning is the 5th leading cause of unintentional traumatic death among children.
D. Most victims drown in the ocean.
E. Near drowning is an obsolete term.

52. Drowning patients commonly experience which of these problems?
A. Premature ventricular contractions
B. Ventricular fibrillation
C. Bradycardia
D. Atrial fibrillation
E. All the above

53. Common metabolic derangements in drowning include which of the following?
A. Hypoxemia
B. Hypocapnia
C. Alkalosis
D. Hypoglycemia

54. Positive end-expiratory pressure (PEEP) improves ventilation in the non-compliant lung by which of the following mechanisms?
A. Improve vital capacity
B. Recruitment of atelectatic areas
C. Providing better alveolar ventilation and decrease of capillary blood flow
D. Shifting the interstitial pulmonary fluid into the capillaries
E. Increasing the diameter of the airway (both large and small airways) to improve ventilation

55. Which of the following factors are important in the prognosis of the pediatric drowning patient?
A. Presence of pulse in the ED
B. Temperature of the water
C. Immediate bystander CPR
D. Submersion time
E. All the above

56. When should you NOT give cardiopulmonary resuscitation to a submerged patient?
A. When the water temperature is below 32ºC.
B. When the patient has a core temperature of 28ºC.
C. When the patient has been immersed for longer than 6 minutes.
D. When the patient has been mortally injured.

57. Which of the following are true?
A. Only drowning victims that have been involved in a diving accident will have any significant chance of cervical spine injury.
B. If a child is involved in a bathtub submersion incident, it is not child abuse.
C. The water temperature will rarely influence the management of the drowning victim.
D. Caregivers should document the temperature and type of fluid in which the submersion incident occurred.
E. Drowning victims frequently experience neurogenic shock.

58. Regarding pulmonary edema in the drowning patient:

A. It takes at least three days to manifest.
B. It may be clinically apparent within minutes.
C. As many as 50% of deaths may occur due to pulmonary edema.
D. It becomes more common in salt water.

59. **Although somewhat controversial, most authorities would agree that the physician should:**
A. Give steroids, since they decrease the chances of a gram-negative pneumonia.
B. Give careful airway management and adequate pulmonary toilet.
C. Administer antibiotics based on a Gram's stain of the edema fluid obtained at the time of endotracheal intubation.
D. Administer prophylactic antibiotics.
E. Employ transtracheal instillation of normal saline and antibiotics to decrease the chances of infection.

60. **Which of the following factors is least likely to influence prognosis in the survival of a drowning victim?**
A. Patient's weight
B. Submersion time
C. Temperature of the water
D. Associated injuries
E. Bystander CPR

61. **The patient's core body temperature is the most reliable predictor of recovery in the drowning patient who is only mildly symptomatic.**
A. True
B. False

62. **Which treatments are potentially given to a drowning victim?**
A. Warm blankets
B. Bronchodilators
C. Inotropic agents
D. Fluids
E. All the above

63. **Treatment of pulmonary edema can include high flow oxygen, bronchodilators, PEEP or BiPAP, and mechanical ventilation.**
A. True
B. False

64. **If defibrillation of a hypothermic asystolic drowning victim is not immediately successful, you can give up fairly quickly.**
A. True
B. False

Physician CME Answers

49. Answer: E. All of the answers are correct. Toddlers, in particular, need appropriate supervision or their explorations will get them into trouble. Co-existing seizure disorders or the use of alcohol are both factors associated with greater incidence of water-related accidents.

50. Answer: A. Normally, patients who require hospitalization will show signs of respiratory distress within 4 hours. Indeed, most of them will have immediate distress.

51. Answer: E. Only 40-50% of victims are 0 to 4 years old. Boys are three times more likely to drown than girls, and drowning is the second leading cause of unintentional traumatic death among children. Most victims drown in freshwater. Near drowning is an obsolete term that is no longer used to describe survival of the patient for at least 24 hours.

52. Answer: E. Ventricular fibrillation and multiple PVC's are quite common. Bradycardia is common, particularly if the patient is hypothermic. Atrial dysrhythmias are also quite common.

53. Answer: A. The submersion victim is likely to be acidotic, *hyper*capnic, and hypoxic. Hypoglycemia may occur in cases involving alcohol or with toddlers, but is not very common.

54. Answer: B. The major effect of PEEP is to recruit atelectatic areas of lung and improve the ventilation.

55. Answer: E. All of these are important prognostic factors.

56. Answer: D. You will not start CPR if the patient has a mortal injury, such as decapitation.

57. Answer: D. A cervical spine film will be surely necessary for any boating accident and any time that the victim has been submerged in rapidly moving water. An icy-water temperature will certainly influence the management of the patient's ED and hospital course. Submersion patients do not experience neurogenic shock.

58. Answer: B. Pulmonary edema may form within minutes. In particular, respiratory complications are just as common with freshwater as with saltwater.

59. Answer: B. Most authorities would not agree with the use of prophylactic antibiotics in any form. Steroids are controversial, but haven't been shown to help at all in controlled studies. Careful pulmonary toilet is indicated.

60. Answer: A. This should be easy. The patient's weight is the least likely factor to influence prognosis—assuming that we don't have a 300-pound 6-year-old who has drowned.

61. Answer: B. The most important prognostic factor is hypoxia—even in the patient who has few symptoms on arrival. Generally speaking, the mildly-symptomatic patient's temperature will not be the most important factor in the patient's prognosis.

62. Answer: E. There is a role for each of these treatment modalities.

63. Answer: A. Any of these treatments may be appropriate for submersion patients.

64. Answer: B. Successful defibrillation may be possible only after core rewarming is accomplished. There have been reports of complete recovery after CPR times of up to 2 hours.

Class Of Evidence Definitions

Each action in the clinical pathways section of *Pediatric Emergency Medicine Practice* receives a score based on the following definitions.

Class I
- Always acceptable, safe
- Definitely useful
- Proven in both efficacy and effectiveness

Level of Evidence:
- One or more large prospective studies are present (with rare exceptions)
- High-quality meta-analyses
- Study results consistently positive and compelling

Class II
- Safe, acceptable
- Probably useful

Level of Evidence:
- Generally higher levels of evidence
- Non-randomized or retrospective studies: historic, cohort, or case-
- control studies
- Less robust RCTs
- Results consistently positive

Class III
- May be acceptable
- Possibly useful
- Considered optional or alternative treatments

Level of Evidence:
- Generally lower or intermediate levels of evidence
- Case series, animal studies, consensus panels
- Occasionally positive results

Indeterminate
- Continuing area of research
- No recommendations until further research

Level of Evidence:
- Evidence not available
- Higher studies in progress
- Results inconsistent, contradictory
- Results not compelling

Significantly modified from: The Emergency Cardiovascular Care Committees of the American Heart Association and representatives from the resuscitation councils of ILCOR: How to Develop Evidence-Based Guidelines for Emergency Cardiac Care: Quality of Evidence and Classes of Recommendations; also: Anonymous. Guidelines for cardiopulmonary resuscitation and emergency cardiac care. Emergency Cardiac Care Committee and Subcommittees, American Heart Association. Part IX. Ensuring effectiveness of community-wide emergency cardiac care. *JAMA* 1992;268(16):2289-2295.

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