TRAUMA REPORTS

Practical, Evidence-Based Reviews in Trauma Care

MAY/JUNE 2015 VOL. 16, NO. 3

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AHC Media

Submersion and Drowning Injuries

Unfortunately, drowning remains a too frequent event in the pediatric population. Survival depends on a coordinated effort to minimize the interval between airway compromise and ventilatory efforts. Children younger than 4 years of age and between 15 and 19 years of age are at highest risk. Certain medical conditions, including epilepsy, cardiac disease, and predisposition to cardiac dysrhythmias (for example, prolonged QT syndrome), increase a child's risk of drowning. The authors review the critical aspects for the evaluation and management of a child who has sustained a drowning injury.

—Ann M. Dietrich, MD, Editor

Introduction

The purpose of this article is to review the definitions, epidemiology, pathophysiology, prehospital management, emergency department management, and advanced treatment modalities in patients who suffer submersion and drowning injuries. This article will review risk factors for drowning, pathophysiology of drowning, and management guidelines. We will present a systematic approach for both prehospital care and definitive care once the patient arrives in the

Figure 1. Reach, Throw, Row, Go

Figure 2. ABC Stabilization of Drowning Victim

EXECUTIVE SUMMARY

- Drowning is a process of primary respiratory impairment from submersion or immersion in a liquid medium in which the airway is covered by liquid.
- Drowning causes a large burden of disease and injury, with more than 500,000 deaths worldwide. Drowning is the second leading cause of unintentional pediatric deaths in the United States. These numbers are likely underreported.
- Patient rescue and immediate resuscitation improve outcomes in drowning victims. Survival trends correlate with the time interval between initial airway compromise and ventilatory efforts.
- The critically ill drowning victim may develop acute respiratory distress syndrome (ARDS), hypotension, and acidemia. Advanced treatment modalities such as NIPPV, intubation, bronchoscopy, post-arrest cooling, and ECMO may be necessary.

emergency department. Finally, we will present common pitfalls in evaluating a suspected drowning patient, and will make recommendations regarding the initial evaluation and the ultimate disposition of these patients.

Definitions

Drowning. For the past 40 years, multiple entities and authors have tried to define the medical phenomena that follow a submersion injury.[1] A publication by the International Liaison Committee on Resuscitation (ILCOR) highlighted this as they discussed confusion around "delayed death subsequent to near drowning, drowning without aspiration, near drowning without aspiration, near drowning with aspiration, dry drowning, wet drowning, silent drowning, active drowning, passive drowning, and secondary drowning."[2] Confusing terminology and inconsistencies in the literature have stymied efforts to track and characterize the efficacy of therapeutic interventions and to study the epidemiology of disease.

At the World Congress on Drowning, held in Amsterdam in 2002, participants came together and agreed upon a common definition for the medical sequelae surrounding submersion injuries. At this conference, drowning was defined as "a process resulting in primary respiratory impairment from submersion/immersion in a liquid medium. Implicit in this definition is that a liquid/air interface is present at the entrance of the victim's airway, preventing the victim from breathing air."[2]

The ILCOR recommends that the terms dry and wet drowning, active and passive drowning, near drowning, and secondary drowning no longer be used as they are confusing and not clinically relevant. Instead, a simpler, more uniform "Utstein" style of terminology should be used.[2]

In accordance with the ILCOR guidelines, patients should be referred to as drowning victims if they have suffered a suspected respiratory injury following submersion in a liquid medium, regardless of their clinical status, which may vary from essentially asymptomatic to severely ill at time of presentation. Additional descriptors such as whether there was a precipitating event that led to drowning or whether the drowning was witnessed may be used as necessary. The primary outcome of a drowning episode is either death or survival. Adopting this clinical nomenclature will allow future studies to better characterize, study, and risk stratify drowning victims.

Immersion. To be immersed is for a body part to be covered in a liquid medium; it does not require the entire body to be underwater. For an immersion victim to drown, the oral and nasal airways must be under water or other liquid medium, limiting the victim's ability to breath.

Submersion. To be submersed is for the entire body to be covered in a liquid medium. Explicit in this definition is that the airway, in its entirety, is under the liquid medium.

Interval Time. Survival trends directly correlate with the time between initial airway compromise and ventilatory efforts by either the victim, spontaneously, or through the rescuer through basic life support.[3-5] This time difference is known as the interval time.

Epidemiology

Drowning accounts for more than 500,000 deaths worldwide each year. Despite this staggering number, drowning deaths are thought to be underreported, due in part to the confusing nomenclature used to classify these deaths.[1,6] Ninety-seven percent of deaths from drowning occur in low- and middle-income countries, and in many regions of the world drowning is either the first or second leading cause of death in the pediatric population.[7,8]

Table 1. United States Risk Factors for Drowning by Age Group[9,11,12]

Infants and Toddlers
- Unsupervised bath time
- Bath seats
- Caucasian ethnicity
- Residential pools
- Low and middle income families

Children and Adolescents
- Underlying medical conditions
- Access to open bodies of water
- Unsupervised swimming
- African-American ethnicity
- Male sex
- Autism spectrum disorders

Teenagers and Adults
- Underlying medical conditions
- Intoxication
- Trauma
- Tourism
- Swimming alone

All Ages
- Cardiac arrhythmia syndromes
- Epilepsy

Although the incidence of pediatric death due to drowning in the United States has significantly decreased over the past 30 years (2.68 per 100,000 children to 1.96 per 100,000), it is still a frequently encountered injury pattern and an area in which physicians should be well versed.[9]

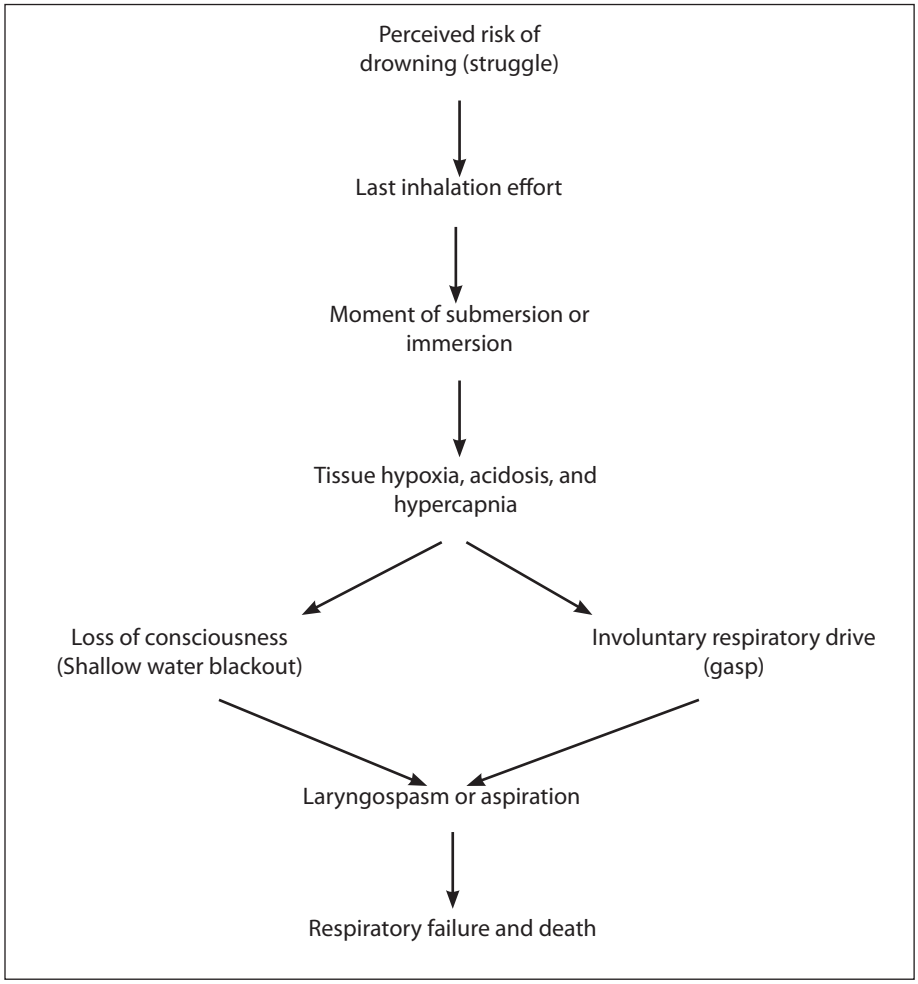
The leading cause of death in the United States between 2006-2010 among children (1-18 years of age) was unintentional injuries.[10] In the Center for Disease Control's database on all-cause mortality, drowning was responsible for roughly 4500 deaths during this time period, which equates to roughly 12% of all pediatric deaths. This is second only to motor vehicle crashes. To put this into perspective, more children died from drowning in the United States between 2006 and 2010 than from sepsis, chronic lung disease, influenza, and pneumonia combined. For all age groups, there were more than 17,000 U.S. deaths from drowning during this same time period.[10]

A study by Burford et al. showed that age, gender, and ethnicity are all independent risk factors for drowning in the United States.[11] There is a bimodal distribution of drowning deaths, with children having the highest risk between 0-4 years of age and 15-19 years of age. Males are at higher risk of death from drowning than females in all age groups. Overall, African-American children are more likely to suffer a drowning-related death than Caucasian children, except between 0-4 years of age. In this age group, Caucasian children are more likely to drown than their African-American counterparts. This is thought to be due to greater access to residential pools for Caucasians in this age group.

The location of drowning, particularly pediatric drowning, has been well studied.[9,12-14] In the United States, children younger than the age of 1 year most often drown in bathtubs, buckets, and toilets, while children ages 1 to 4 are more likely to drown in a pool. It is often underappreciated that young children can drown in as little as 5 cm of water.[9] After the age of 4, children and adolescents are more likely to drown in open water. Almost 50% of all fatalities occur in open water.[10,14]

Additional risk factors associated with drowning of infants and toddlers are unsupervised bath/pool time and the use of bath seats while in the bathtub.[9] In the adolescent population, the majority of drownings are related to risky behavior, such as the use of alcohol or illicit drugs, or diving-related trauma.[15,16] In all age groups, medical conditions such as epilepsy, cardiac disease, and predisposition to cardiac arrhythmias (e.g., prolonged QT syndrome) increase the risk of drowning. (*See Table 1.*)

Figure 3. The Drowning Process[22-25]



Pathophysiology of the Drowning Process

The Drowning Process. The "drowning process" is the stepwise progression of events leading to respiratory failure, hypoxia, and death.[17-19] (*See Figure 3.*) When the human body is submersed, there is an unconscious drive to breath-hold. Breath holding occurs when the victim closes the larynx to prevent air from being inhaled or exhaled. Once submersed, the victim will quickly deplete oxygen stores. As the drowning process continues, the victim becomes progressively acidotic, hypoxic, and hypercapnic. Hypercapnia is the primary stimulus of the respiratory drive.[20] If the victim hyperventilates prior to the incident, there may be a loss of consciousness from cerebral hypoxia prior to feeling the hypercapnic drive to breathe, a phenomenon referred to as "shallow water blackout."[21] This phenomenon is sometimes seen in swimming competitions and in military training. Without hyperventilation, the victim will swallow water due to involuntary inspiration caused by the hypercapnic respiratory drive. In rare cases of laryngospasm, no initial

Figure 4. Chest Radiograph Following Drowning Event

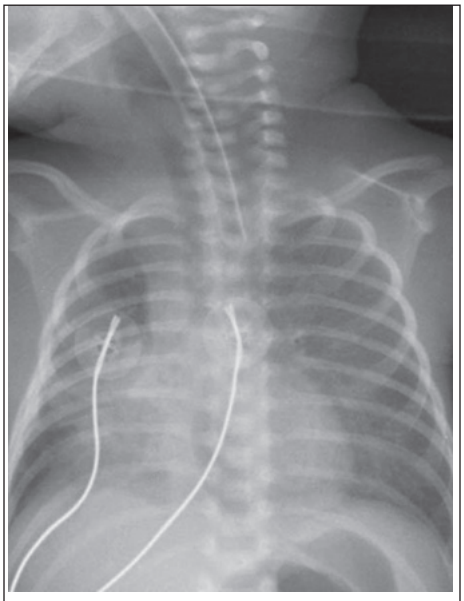


Image courtesy of Ann M. Dietrich, MD

Table 2. Prognostic Factors in Drowning Victims[5,6,52-57]

Poor Prognostic Indicators

- Submersion > 5 minutes
- No resuscitation for > 10 minutes
- Fixed and dilated pupils
- GCS < 5 (comatose)
- pH < 7.1

Good Prognostic Indicators

- Age < 14
- CPR in the field
- CPR < 25 min
- Detectable pulse on arrival
- T Core < 35°C (mixed results; some studies support this, some show no effect)

aspiration of water will occur. However, eventually there is a relaxation of the laryngospasm, likely due to both cerebral hypoxia and tissue fatigue, and the victim usually aspirates.

The amount of fluid ingested during the drowning process varies among victims, but ingestion of water is thought to be the main contributing factor to the vomiting seen in the majority of drowning victims.[2,22]

Please see the simplified flow diagram for the progression of the drowning process and prognostic factors in drowning victims. (*See Figure 3.*)

Cardiovascular and Pulmonary Systems. The cardiovascular system undergoes a variety of changes prior to and during the drowning process. Starting from the first moment of immersion, there is an increase in systemic venous return from compressive forces on the upper and lower extremities and, in cold water, from peripheral vasoconstriction. These processes result in central hypervolemia. This causes an elevation in sensed circulatory volume that results in increased myocardial stretch, increased pulmonary artery pressure, and an increase in stroke volume, leading to increased cardiac output.[23] In patients with pre-existing illness, such as congestive heart failure or pulmonary hypertension, central hypervolemia can be lethal.

The pulmonary system undergoes tremendous changes following a submersion event and drowning. As little as 1-3 mL/kg of water may be sufficient to compromise surfactant in the alveoli, leading to alveolar collapse, shunting, and V/Q mismatch. This damage can lead to profound hypoxia, tachypnea, acid/base disturbances, and, ultimately, acute respiratory distress syndrome (ARDS). In addition, as fluid enters the lung, there is a potential osmotic shift between the alveoli and the systemic circulation, worsening the alveolar collapse. Finally, the aspirated medium may carry debris and infectious organisms, which can promote lung infections.[24] Following a significant aspiration event, there is often early evidence of intra-alveolar consolidation. It can be very difficult to differentiate infection from aspiration pneumonitis in the acute setting. (*See Figure 4.*)

Renal System. The kidney plays an important role in the regulation of hemodynamic stability and fluid balance during and after the drowning process. As discussed above, following a submersion event, the victim may experience shunting of blood to the core, known as "central hypervolemia."[25,26] The increase in circulatory pressure in the thorax and abdomen promotes natriuresis and diuresis through a rapid and elegant series of neuroendocrine feedback systems. Atrial natriuretic peptide, an endocrine hormone released from the myocardium due to increased myofibril stretching, causes increased glomerular blood flow, decreased free water reabsorption, and decreased vasopressin release from the hypothalamus.[25,27-29] Combined, these effects will result in an overall free water deficit and dehydration over time.

Central Nervous System. In drowning, the primary mechanisms of injury to the central nervous system are tissue hypoxia and ischemia. Over the past half-century, numerous clinicians and researchers have attempted to enhance cerebral perfusion in hopes of promoting a favorable neurological outcome after a drowning event. Even after creating an ideal environment for the brain to heal (i.e., normal intracranial pressures, normal glucose levels, permissive hypothermia for the first 12-24 hours after the incident, normal arterial oxygen concentrations, and sufficient cerebral perfusion pressures), there has been no improvement in outcomes. The biggest determinants of outcome and long-term neurologic sequelae are the duration of submersion and the interval time between drowning and ventilation efforts.[30] (*See Table 2.*)

Evaluation and Treatment

Prehospital Care. In the management of the drowning victim, scene safety, rapid extraction, and prompt

basic life support are the keys to improve survival.

Rescue and Extrication. Submersion and drowning incidents often occur in bodies of water that pose a potential danger to the rescuers. Prehospital care must be attuned to scene safety to ensure that rescuers are not injured.[31] Scene safety is a key concept of wilderness and remote medicine practice. The National Fire Protection Association (NFPA) and other swift water rescue training programs teach the adage "Reach, Throw, Row, Go."[32] These are the four steps in water rescue with "progressively more risk to the rescuer." Rescuers should start by reaching for the victim with an object, such as a paddle or branch. If this fails, rescuers should throw a flotation device such as a throwbag or personal flotation device (PFD) to the victim. If necessary, rescuers should proceed to take a boat to the victim. As a last resort, rescuers should enter the water to rescue the victim. The U.S. Corps of Army Engineers (USACE) advocates "Reach, Throw, Row, Go for help," to emphasize that only those trained in water rescue should enter the water and that all others should go for help. (*See Figure 1.*)

Regardless of the method, rapid, safe extrication of victims from the water is crucial to decrease morbidity and mortality. Rescue and immediate resuscitation by bystanders improve outcomes.[33] The reported incidence of cervical spine injury in drowning victims is very low. The American Heart Association (AHA) recommends against routine spinal immobilization during water extrication.[34] Unnecessary spinal precautions can delay extrication.[35] However, if there are clinical signs of a spine injury or if there is a mechanism of injury that could have damaged the spinal column, such as diving, surfing, or high-speed boating, spine stabilization should be considered during the extrication and rescue, if possible. Airway, breathing, and circulation should always take precedence over stabilization of the spine. (*See Figure 2.*)

Basic Life Support. As soon as is feasible in a water rescue, the patient's airway should be opened and rescue breathing started. If there is a delay in accessing the shore or a rescue boat, in-water basic life support consisting of ventilations only should be considered.[36] In-water chest compressions are futile. Once on a stable surface, CPR for drowning victims should use the traditional A-B-C approach with emphasis on ventilating the patient.[35] Rescuers should give two rescue breaths before proceeding to check the pulse and to give chest compressions if the patient is pulseless. Often, with simply opening the airway and giving breaths, the patient will start breathing spontaneously. One caveat is that victims of drowning often swallow water during the initial gasping and struggle. Vomiting is common during resuscitation whether the victim is conscious, apneic, or pulseless.[37] Prehospital providers should watch for vomiting and should perform appropriate airway clearance and spine-safe rolls as needed. The use of portable suction and barrier devices such as a mask with valve or a bag valve mask (BVM) is strongly recommended.

It was once thought rescuers could effectively "drain fluid from the lungs" through actions such as the Heimlich maneuver, abdominal thrusts, or suspending the patient with the head down. These practices have been abandoned. Current AHA Basic and Advanced Cardiac Life Support (BLS and ACLS) algorithms call for standard chest compressions and ventilations for a pulseless drowning victim with the adjunct of suctioning if available.[35]

For the unconscious drowning victim, the EMS system should be activated. For a patient in cardiopulmonary arrest, an automatic external defibrillator (AED) should be applied as soon as possible and BLS/ACLS algorithms should be followed. In order to avoid endangering rescuers or bystanders, a drowning victim should be removed from the water before attempting defibrillation. Wet clothes should be removed and the chest dried as much as possible before AED pads are placed.[31] For all victims of cardiopulmonary arrest, resuscitation should be started as soon as possible at the scene. Patients

Table 3. Submersion and Drowning Treatment Summary

Asymptomatic

- Full vital signs, including temperature and pulse oximetry
- Chest X-ray
- Discharge with precautions or observe 4-6 hours

Mild Symptoms

- Full vital signs, temperature, oxygen prn
- Bronchodilator
- Chest X-ray, electrolytes
- Treat mild hypothermia
- Observe 6-24 hours

Moderate to Severe Symptoms

- Full vital signs, temperature, oxygen prn, telemetry
- Chest X-ray, electrolytes, CBC, coagulation studies
- Consider NIPPV or intubation with PEEP
- Volume support, treat hypothermia
- Supportive care and admission

Cardiopulmonary Arrest

- ACLS
- Post-arrest temperature management
- Consider ECMO

Figure 5. Chest Radiograph with Atelectasis

Image courtesy of Ann M. Dietrich, MD

should be transported to the emergency department (ED) unless there are obvious signs of death (e.g., rigor mortis, dependent lividity, decomposition, decapitation, etc.).[35] There have been case reports of successful resuscitation and full neurologic recovery after prolonged submersions, especially in icy water.[38-40] According to the 2010 AHA ACLS Guidelines, all victims of drowning who require any form of resuscitation (including rescue breathing) need to be transported to a hospital for evaluation and monitoring, even if they appear well following the event.[35]

EMS personnel should do a primary survey on all drowning victims, including aggressive airway management and restoration of adequate oxygenation and ventilation.[36] If oxygen saturations are less than 92%, supplemental high-flow oxygen should be provided. In patients with persistent hypoxia or respiratory difficulty, positive pressure ventilation, such as continuous positive airway pressure (CPAP) ventilation, should be started. EMS should consider intubation or supraglottic airway devices in patients with decreased level of responsiveness or persistent hypoxia despite high-flow oxygen or CPAP.[36] Victims of drowning are at risk for hypothermia, and active external rewarming should be initiated on hypothermic patients as they are transported to the hospital. If there is concern for cervical spine injury, either by mechanism of injury or by exam, the cervical spine should be stabilized.

Emergency Department Care

On arrival in the ED, resuscitation, including ACLS algorithms, should be continued as appropriate. In general victims of drowning will fall onto one of three categories: the asymptomatic patient, the symptomatic patient, and the severely symptomatic patient or patient in cardiopulmonary arrest. (*See Table 3.*)

The Asymptomatic Patient. Much of the confusion with drowning terminology and classification concerned the asymptomatic or mildly symptomatic patient. By current consensus, a patient who was immersed in a liquid and suffered any sort of respiratory event suffered a drowning. The respiratory compromise may have been subtle, such as coughing or aspirating a small amount of water. Simply being submersed and breath holding does not constitute a drowning event if no respiratory compromise occurred. Sometimes this subtle distinction between drowning and submersion without respiratory compromise is difficult or impossible for the patient or the provider to distinguish. In these cases, a conservative approach and the assumption that a drowning occurred is prudent.

Asymptomatic patients who have suffered a drowning incident have no cough or dyspnea. Their vital signs are normal, without hypoxia or tachypnea, and their chest exam is normal, without crackles or wheezes. There is limited evidence regarding management of these patients. A reasonable approach is to take a complete set of vital signs, including temperature and pulse oximetry, to do a full physical exam, and to look for evidence of pulmonary or traumatic injury.[43] A chest X-ray is recommended to look for early evidence of aspiration. While most pulmonary signs and symptoms develop almost immediately after drowning, respiratory symptoms can develop up to 24 hours after the event.[42] Most symptoms, however, will develop early. A review of 75 pediatric patients who suffered a drowning in fresh water found that all symptoms developed within seven hours of the event.[44]

Emergency physicians may choose to discharge asymptomatic drowning victims after they have been evaluated in the ED. This practice is supported by a 1997 paper by Szpilman et al. that proposed a classification system based on 1,831 drowning victims seen over a 20-year period in Brazil. This system

risk stratifies patients to very low risk (grade 1) if they had no dyspnea and had normal pulmonary auscultation with or without cough. None of these 1,189 grade 1 patients died in the study follow-up.[41] While this grading system has not been prospectively validated, it is reasonable to discharge asymptomatic drowning victims from the ED as long as they receive education and good return precautions. Emergency physicians may also choose a more cautious approach and observe asymptomatic patients for 4-6 hours after the drowning event. This practice is supported by a handful of studies showing that patients with normal exams and normal room air oxygen saturations at 4-6 hours after the drowning event do not deteriorate.[43,45]

The Symptomatic Patient. The management of mildly to moderately symptomatic victims of drowning is challenging. These patients present with respiratory compromise such as cough, sore throat, or dyspnea. On exam, they may have subtle wheezes or crackles. In these patients, standard ACLS and Advanced Trauma Life Support (ATLS) protocols should be followed with a focus on airway, breathing, circulation, and spinal stabilization as indicated. A full set of vital signs should be taken, including temperature. Oxygen should be given to maintain an oxygen saturation of greater than 92%. Wet clothing should be removed and rewarming should be started on any hypothermic patient. Patients should be placed on telemetry to monitor for dysrhythmias. A chest X-ray should be performed to look for evidence of aspiration, pneumonitis, atelectasis (*see Figure 5*), pulmonary edema, and inhaled foreign bodies (*see Figure 6*).

It is not uncommon for drowning victims to suffer aspiration pneumonitis. This is a chemical pneumonitis. Antibiotics can be held unless the patient develops clinical signs of pneumonia such as fever, leukocytosis, new or persistent consolidation on X-ray, or a new oxygen requirement.[46] Only a small percentage of drowning victims will develop a clinical pneumonia. There is no evidence to support the routine use of prophylactic antibiotics for patients who drowned in clean water. Because of the risk of bacterial lung infections, antibiotics should be given to patients who were submersed in grossly contaminated water (e.g., water containing sewage or manure).[47] Empiric steroids are thought to be ineffective for drowning victims, but inhaled bronchodilators should be considered for the bronchospasm that is often seen in non-fatal drowning.[19]

Figure 6. Chest Radiograph of Foreign Body (See Unilateral Hyperinflation Classic for a Foreign Body)

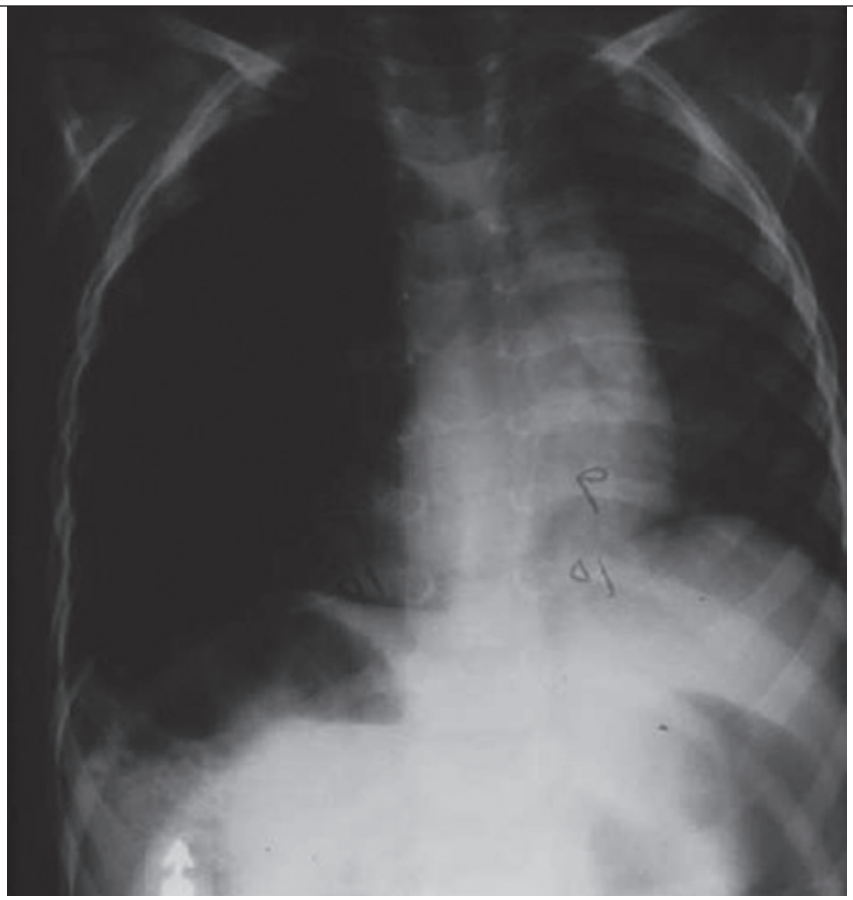


Image courtesy of Ann M. Dietrich, MD

Basic labs, including electrolytes and coagulation panels, should be sent on drowning victims who are symptomatic. As stated earlier, prolonged submersion and drowning events may cause intravascular volume changes and may promote diuresis and dehydration. In addition there is a theoretical risk of electrolyte changes and coagulopathies from inhaling or swallowing large amounts of fresh or salt water. While electrolyte shifts have been seen in animal models with large volume aspirations,[20,48,49] such shifts have not been found in human studies.[50]

Mildly to moderately symptomatic patients and patients with abnormal vital signs, including low oxygen saturation, should be admitted for observation and supportive care for at least 6-24 hours.[44,46] The length of admission depends on clinical status. Patients should not be discharged until symptoms have resolved.

Severely Symptomatic/ Cardiopulmonary Arrest Patients. When a severely symptomatic victim of drowning arrives in the emergency department, ACLS, ATLS, and emergency stabilization guidelines should be followed with a focus on prompt correction of hypoxemia and acidosis.

Adequate ventilation and oxygen support are essential. Initially supplemental oxygen should be given by nonrebreather facemask with 100% oxygen. The FiO_2 can be titrated down once the patient is stabilized. Aspiration of water and solutes may result in alveolar

Figure 7. Chest Radiograph of Intubated Drowning Victim

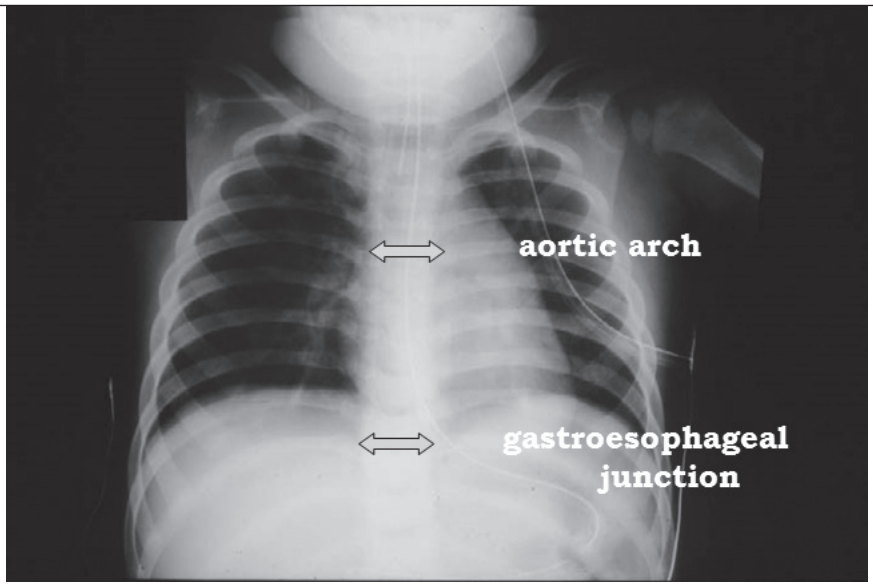


Image courtesy of Ann M. Dietrich, MD

Figure 8. Dilated Stomach of Drowning Victim

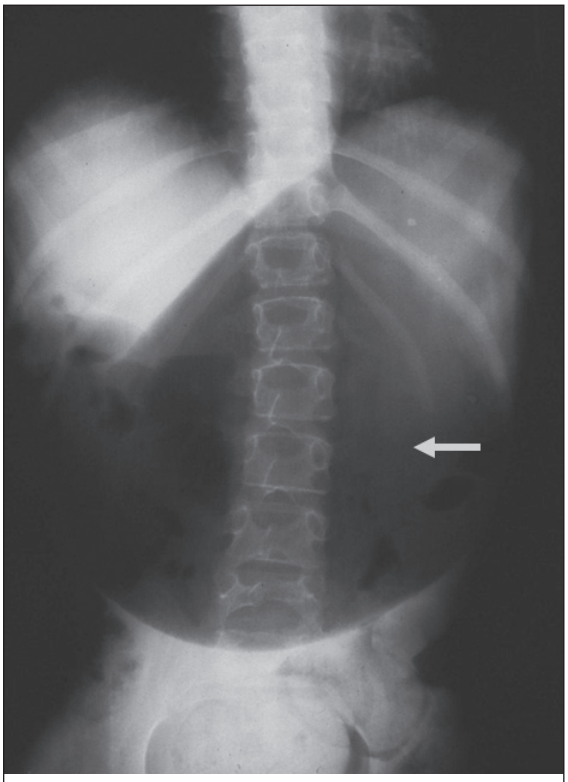


Image courtesy of Ann M. Dietrich, MD

collapse, a significant A-a gradient, and difficulty with oxygenation. In addition, a decrease in lung compliance and an increase in airway resistance may lead to difficulty with ventilation. Trials of non-invasive positive pressure ventilation (NIPPV) may overcome these challenges and should be considered.[19] In patients with persistent poor ventilation, poor oxygenation, or depressed mental status, intubation and positive end-expiratory pressure (PEEP) may be necessary.[19] (*See Figure 7.*) As stated earlier, drowning victims can develop ARDS requiring ventilatory support and ICU admission. Bronchoscopy to clear aspirated debris (sand, organic material, vomit) may be necessary. An orogastric or nasogastric tube should be placed to decompress the stomach and to remove any water and debris that may have been ingested. (*See Figure 8.*) Chest X-ray or chest CT should be obtained to assess for consolidations, atelectasis, and inhaled foreign bodies.

Severely symptomatic drowning victims will often present in critical condition with evidence of hypoxemia, hypothermia, dysrhythmias, and altered mental status. Full vital signs, including a core temperature, should be measured. In addition to blood chemistries, a complete blood count and coagulation studies are recommended. Hypothermic drowning victims can experience a "cold diuresis," resulting in hypovolemia, hypotension, and renal dysfunction.[29] Supportive care including appropriate volume resuscitation with normal saline and rewarming of patients is appropriate.

Some drowning victims will present in cardiopulmonary arrest. ACLS and ATLS algorithms should be followed with a focus on oxygenation, ventilation, volume support, and correction of acidosis. Some patients with prolonged submersion in cold water may appear "cold and dead." In these severely hypothermic patients, resuscitation and warming should be continued until the core temperature reaches 32°C-35°C.[51] If the patient is still in cardiopulmonary arrest following rewarming, resuscitation can be terminated.

Hypothermic drowning victims who have ROSC after cardiopulmonary arrest should not be rewarmed completely. Instead, therapeutic hypothermia or targeted temperature management should be maintained for 12-24 hours.[52] While hospital guidelines may vary, recent literature suggests that there is no significant outcome difference between a targeted core temperature of 33°C or 36°C for post-arrest victims.[53]

Advanced Care Management

Many submersion and drowning victims will present to community hospitals that lack specialized intensive care units and the ability to manage post-arrest or critically ill patients. Following initial evaluation, stabilization, and treatment, patients who are critically ill should be transferred expeditiously to a facility that offers intensive care appropriate to the age and condition of the patient. Restoration of normal physiology offers the best prognosis. Aggressive intervention may be warranted.[30]

Therapeutic hypothermia or targeted temperature management should be considered in drowning victims for the first 12-24 hours following an arrest. Previous

guidelines recommended a targeted core temperature between 32°C-34°C, however a recent study on targeted temperature management for victims of cardiac arrest suggests a temperature of 36°C may be equivalent.[60,61,51] This initial window of temperature control below normal core temperature is thought to decrease the metabolic demands of the body and may help reduce the production of radical oxygen species, which are responsible for significant cellular damage. Targeted temperature management has been studied in patients with normothermic cardiac arrests and the benefit in hypothermic drowning victims is speculative.

If the victim has suffered a significant aspiration event that has progressed to ARDS, that patient may benefit from a lung-protective ventilatory strategy such as the ARDSNet Protocol, which uses lower tidal volumes, PEEP, and low plateau pressures to prevent barotrauma while increasing oxygenation.[62] A small percentage of patients may continue to decline clinically despite pressor support, fluid resuscitation, and mechanical ventilation. These patients may benefit from extracorporeal membrane oxygenation (ECMO).[62,63] Good evidence supporting the use of ECMO is lacking. Over the past three decades, there have been several case reports of successful resuscitations in which ECMO was used. Access to ECMO is often limited, and may require transfer to a quaternary health care center.[40,65,66]

Special Consideration: Cold-Water Drowning

Although cold-water drowning is often considered to be neuro-protective (i.e., offering a higher likelihood of good neurological outcome), the data are mixed. There have been several case reports suggesting better outcomes if hypothermia is present.[54,66] Other studies have shown no benefit of accidental hypothermia with regard to morbidity and mortality after drowning when compared to case controls.[7,57] The mixed results likely reflect the fact that accidental hypothermia is an uncontrolled, unmonitored event that is different than induced therapeutic hypothermia. The apparent protective effects of environmental hypothermia in drowning, based on case reports, may occur when hypothermia happens quickly, preceding the asphyxia of drowning.[57]

Conclusion

Drowning pathophysiology and management are important topics for the emergency practitioner. Drowning is a process in which there is respiratory impairment after submersion or immersion in liquid. Old terms, such as wet and dry drowning, as well as active and passive drowning, should be abandoned to simplify the definitions and to gather more accurate data regarding epidemiology and treatment. Drowning causes significant morbidity and mortality worldwide, especially among high-risk groups such as children and people with underlying medical conditions. While the drowning process affects many physiologic systems, the final common pathway is respiratory failure and resultant hypoxia either from aspirated fluid or from laryngospasm. The morbidity and mortality associated with drowning are due to direct pulmonary injury and to brain ischemia.

In the prehospital management of the drowning victim, there should be an emphasis on scene safety followed by immediate resuscitation. Initial BLS should focus on opening the airway and on high quality ventilation. In the emergency department, asymptomatic patients can usually be discharged. Symptomatic patients often need chest X-rays, blood work, telemetry, warming, and supplemental oxygen. They may need admission for supportive care. In the severely symptomatic patient, consider a trial of non-invasive positive pressure ventilation, intubation with PEEP, bronchoscopy, and gastric decompression. For drowning victims who have suffered cardiopulmonary arrest, consider targeted temperature management and transfer to a center that can perform extracorporeal membrane oxygenation.

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CME/CNE Questions

1. The most accurate definition of drowning is:
   A. death following a submersion event
   B. a process resulting in primary respiratory impairment from submersion/immersion in a liquid

C. a process in which a liquid is aspirated into the lungs
D. a process in which one's entire body is submersed in liquid

2. Survival trends from drowning correlate directly with:
   A. the age of the victim
   B. the cleanliness of the water
   C. the temperature of the water
   D. the time between initial airway compromise and ventilatory effort

3. The final common pathway of drowning is:
   A. cardiac arrhythmia
   B. cerebral ischemia
   C. cold water diuresis and hypotension
   D. hypoxia
   E. renal failure and electrolyte abnormalities

4. Cervical spine precautions are necessary in most extrications of drowning victims.
   A. true
   B. false

5. In asymptomatic drowning victims with no dyspnea or respiratory distress, normal chest auscultation, and normal oxygen saturations, it is reasonable to:
   A. Discharge the patient from the emergency department and give strict precautions to return if delayed symptoms develop.
   B. Observe for 4-6 hours in the emergency department.
   C. Admit to PICU for 24 hours of observation.
   D. A or B
   E. B or C

6. Which of the following statements is true?
   A. Approximately 50% of drowning victims will develop clinical pneumonia.
   B. Aspiration pneumonitis is a chemical pneumonitis and antibiotics are not needed unless signs of clinical pneumonia develop.
   C. Empiric steroids are effective in treating drowning victims who have suffered an aspiration event.
   D. Prophylactic antibiotics are effective in preventing progression from pneumonitis to pneumonia.

7. Drowning victims who are persistently symptomatic or who have abnormal vital signs should be admitted for observation and supportive care.
   A. true
   B. false

8. All of the following are reasonable interventions for a drowning victim who has suffered a cardiopulmonary arrest and has return of spontaneous circulation, *except*:
   A. extracorporeal membrane oxygenation (ECMO)
   B. lung protective ventilator strategies
   C. positive pressure ventilation
   D. systemic steroids
   E. therapeutic hypothermia or targeted temperature management

9. Which of the following are poor prognostic indicators for a drowning victim?
   A. submersion > 5 minutes
   B. no resuscitation for > 10 minutes
   C. fixed and dilated pupils
   D. GCS < 5 (comatose)
   E. all of the above

10. Which of the following is *not* part of the ARDSNet Protocol?
   A. lower tidal volumes
   B. PEEP
   C. higher tidal volumes
   D. low plateau pressures to prevent barotrauma while increasing oxygenation

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- describe the various modalities used to identify different traumatic conditions;
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- identify possible complications that may occur with traumatic injuries.

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Editorial & Continuing Education Director: Lee Landenberger

Executive Editor: Shelly Morrow Mark

GST Registration No.: R128870672

Periodicals Postage Paid at Atlanta, GA 30304 and at additional mailing offices.

POSTMASTER: Send address changes to ***Trauma Reports,*** P.O. Box 550669, Atlanta, GA 30355.

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