**Chapter 17
Submersion injuries/drowning**

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**Epidemiology**

Drowning remains a leading cause of unintentional death and unintentional injury [1]. The Centers for Disease Control (CDC) place the incidence of non-fatal drowning at between 4,000 and 7,000 cases per year [1–5]. Fatalities range from 3,200 and 6,000 cases per year [1,4,5]. The incidence of non-fatal drownings ranges from one to four times that of fatal drownings [3]. Over 50% of all non-fatal drownings require hospitalization [1].

Drowning and near drowning are the second most common unintentional injuries for ages 1–4 and 15–19 [2,6]. In infants less than 1 year old, most drownings occur in the bathtub [7]. For children less than 4 years old, most drownings occur in private pools. For age greater than 15 years the predominant drowning locations include natural water settings such as beaches and lakes [8]. Fatalities are higher for victims less than 4 years old. Compared with females, males have twice the rate of non-fatal and five times the rate of fatal drowning [1]. Over half of adolescent and adult drownings involve alcohol or illicit substance use [8,9]. Approximately 35% of persons who drown under the age of 20 are classified as accomplished swimmers [10]. Preexisting medical conditions may play a role as well, as noted in children with seizures having a four-fold increase in risk compared to the general population [3].

Drowning accidents involving children commonly result from lapses in adult supervision. In the majority of child drownings, the child was under the care of one or both parents and was “out of sight” for less than 5 minutes [9]. While surveyed pool owners favor cardiopulmonary resuscitation (CPR) requirements, less than half of these households actually have a CPR-qualified individual. Of pool owners favoring isolation fencing around pools, only one-third had their pool fenced. The risk of drowning or near drowning is 3–4 times higher in unfenced than fenced pools [5].

Epidemiological and public health data highlight the role of education, planning, and other community-level interventions in drowning prevention. Estimates of preventable drowning deaths are as high as 80% [3]. Many EMS systems participate in drowning prevention efforts, such as education and water safety programs.

**Pathophysiology of drowning**

Drowning is commonly defined as suffocation and death as the result of submersion in a liquid environment [5,9,10]. Historically, two types of drowning have been described: wet and dry. “Wet drowning” is the aspiration of material such as water, sand, vomitus, etc [11–13]. This material can lead to pulmonary edema, pneumonitis, and surfactant dysfunction, impairing gas exchange. “Dry drowning” involves minimal aspiration; the inhaled liquid triggers laryngospasm, resulting in suffocation. Experts have questioned the mechanisms and clinical significance of this differentiation. Some postulate that decreasing level of consciousness and increasing hypoxia will eventual break any “spasm,” allowing liquid to enter the lungs [9,14]. Submersion describes the airway opening beneath the surface of the liquid medium–air interface, while immersion is the splashing of liquid in or about the airway.

Classically, drowning begins as a period of panic and struggle, but in a minority of cases (for example, cervical trauma or seizure), this initial phase may not be present [9,12]. Death from drowning ultimately results from suffocation, tissue hypoxia, and cardiac arrest. Successful resuscitation after a drowning-induced cardiac arrest is rare.

Historically, drowning education materials have emphasized differences in fresh-water and salt-water drowning, citing the theoretical electrolyte and fluid shifts occurring with each situation. However, current practice downplays the importance of these differences [5,11]. Some consideration of the water contaminants may be clinically important in the hospital setting, and the EMS insight into those scene variables may be helpful to hospital staff.

Cerebral hypoxia plays a significant role in the functional recovery of the victim. Many drowning survivors suffer some permanent neurological damage, with up to 10% suffering severe lasting effects [13,15]. The duration of hypoxia is correlated with submersion time and is an important determinant of recovery [11,13]. Another important consideration is the neuroprotective effect of hypothermia. The medical literature and the lay press are replete with examples of survival after lengthy submersion in frigid or near freezing water. Cold-water submersion does not guarantee survival but may play a significant role in management decisions during and after the resuscitation [11,16].

The term “secondary drowning” typically refers to patients who survive the submersion injury for some period of time, yet later develop respiratory failure and death attributed to the original submersion event [5]. This deterioration may occur from hours to days later [8,13]. While the term “drowning-related death” has been proposed to describe deaths occurring more than 24 hours after a submersion, this definition is not widely used [10].

“Near drowning” is defined as immediate survival after a submersion event [13]. While most of these individuals may survive, many will deteriorate. The definition has some variability among authors and published sources, with some including asphyxia or loss of consciousness in the definition [5,9,10]. There remain ongoing efforts to better formalize definitions, including the use of the term “drowning” (defined as a process resulting in primary respiratory impairment from submersion and immersion in a liquid medium) to classify all events regardless of outcome as drowning [3]. To date, this has not been widely accepted in medicine or by the lay public. The remainder of this chapter will distinguish drowning (death) from near drowning.

**Clinical management**

**Dispatch life support**

Emergency dispatchers should provide dispatch life support, including standard respiratory and/or cardiopulmonary arrest instructions. Minimizing delays in delivering instructions is essential. DeNicola showed that 42% of children drowning in home swimming pools were rescued by bystanders but did not have CPR initiated until EMS personnel arrived [5]. The use of an automated external defibrillator (AED) is appropriate and should be included when such a device is available. A less clear area is whether dispatchers should direct callers to rescue drowning victims. All water rescues involve risk and may potentially result in additional victims.

**Scene and crowd control**

The first step in successful drowning management is rapid extraction of the victim from the water. Scene safety is paramount, especially in natural water and moving water scenarios. Rescuers not specifically trained in water rescue should not attempt extraction or rescue in moving water.

Crowd control and prevention of secondary victims are essential. Drownings are dramatic events. Depending on the setting (public pool, hotel pool, natural water setting), a large number of bystanders may be present. Bystanders acting as rescuers may inadvertently become secondary victims, especially in natural water settings or in large groups with several non-swimmers. Rescuers should liberally request and utilize crowd control resources.

**Management of the drowning victim in cardiac arrest**

The most dramatic clinical presentation of drowning is cardiopulmonary arrest. Rescuers should initiate standard BLS, ACLS, and Pediatric Advanced Life Support (PALS) protocols on drowning victims in cardiac arrest. CPR should begin as soon as practical, with some advocating initiation of CPR while the victim is still in the water [10]. Airway management should begin immediately with bag-valve-mask (BVM) ventilation [16]. Typically extrication from the water should not be delayed for more definitive airway management. Once extricated from the water, additional airway procedures consistent with cardiac arrest protocols may be considered. Rescuers should anticipate vomiting, which may occur in up to 86% of drowning victims receiving rescue breathing and chest compressions [16,17]. Maneuvers to clear water from the lungs, such as laying the patient prone and lifting the arms behind the back toward the head, are not necessary and should not be performed [5,8,12,16].

Cardiac arrest treatment algorithms do not require modification for drowning victims. While experts have historically emphasized minimizing movement in the severely hypothermic patient to avoid precipitating ventricular dysrhythmias, this recommendation seems to be based more on theory and conjecture than data. Advanced airway management is appropriate in services and personnel competent in the skill. Airway management while in the water is fraught with difficulty and risk of aspiration and delay of CPR initiation. While each scene may pose a unique risk–benefit analysis around patient access and timely egress, typically anything more than basic maneuvers should be deferred to accomplish rapid extrication and initiation of full resuscitation efforts. In the severely hypothermic patient, advanced airway placement may allow for warmed, humidified ventilation. Vascular access and drug therapy should follow standard resuscitation protocols.

Some experts have raised concerns that medications may reach toxic levels in the circulation due to decreased metabolism in the severely hypothermic patient [16]. However, little scientific evidence distinguishes drug metabolism in hypothermic versus normothermic cardiac arrest patients. Despite this concern, most guidelines recommend minor alterations of cardiac arrest protocols for patients with hypothermia [16]. Specifically, in moderate hypothermia (30–34 ºC), rescuers may increase the time interval between intravenous medications. Rescuers should also perform active external rewarming for moderate-to-severe hypothermia. For severe hypothermia (<30 ºC), current ACLS guidelines recommend providing a single defibrillation attempt and withholding intravenous medications until the core temperature is >30 ºC [18]. The determination of an accurate core temperature in the field setting is difficult, and rescuers should base their actions on the best available clinical information.

**Management of near drownings**

By definition, the near drowning patient has vital signs. Near drownings may include patients who never lost vital signs, and those successfully resuscitated. Airway management, hemodynamic stabilization, and transport are the mainstays of treatment. These individuals may be apneic, hypotensive, or hypothermic and should receive appropriate resuscitative interventions. Near drowning victims have strong potential for pulmonary injury and should receive emergency department evaluation. Over half of near drowning victims ultimately require hospital admission. Near drowning victims should be transported and evaluated, as initial presentation can progress rapidly, and refusals should be strongly discouraged [5,10].

Field management should focus on management and evaluation of oxygenation. Monitoring of pulse oximetry, cardiac rhythms, vital signs, and overall neurological status is warranted. Monitoring of end-tidal CO2 may also be helpful. Continuous positive airway pressure (CPAP) in the conscious breathing patient is being increasingly advocated [10,14]. Rapid deterioration in ventilation, oxygenation, or ability to protect the airway may require more aggressive airway management techniques consistent with medical respiratory distress protocols. Secondary aspiration from vomiting is a risk in the declining near drowning victim. Intravenous access should be established in most near drownings. Consideration should be given to potential concurrent trauma. Victims may have had concurrent medical conditions that triggered the event, such as hypoglycemia, seizures and cardiac dysrhythmias. These should be addressed and treated appropriately.

**Management of concurrent trauma**

Many drownings occur concurrently with other major trauma. For example, an individual may sustain a cervical or spinal cord injury after diving into shallow water. Swimmers in lakes have sustained traumatic brain injuries or penetrating trauma after being struck by motor boats.

The most important consideration in drowning victims is the potential for cervical spine injury. Hwang et al. [4] identified seven cervical spinal injuries in 143 pediatric drowning and near drowning patients transported to a pediatric trauma center. Watson et al. identified 11 cervical spine injuries in 2,244 drowning victims [18]. All patients in each series were identified with mechanisms of injury suggestive of trauma (diving, high-impact, or assault).

Emergency medical services rescuers should consider cervical spine injuries in all diving, high-impact (e.g. dive from a height), white water, and submersion injuries. However, the rescuers must weigh the risks and benefits of cervical immobilization. For example, cervical immobilization may be dangerous and difficult in swift water rescues [18]. Current American Heart Association guidelines state “… routine stabilization of the cervical spine is not necessary unless the circumstances leading to the submersion episode indicate that trauma is likely …” Drowning circumstances potentially linked to cervical injury include a history of diving, water slide use, concern for alcohol intoxication, or physical signs of injury [16]. The decision to initiate spine immobilization while in the water is a risk–benefit decision for the patient and rescue team. An absence of identified risk for cervical injury precludes the need for spine immobilization in or out of the water. Swimming pools in particular may be a more appropriate setting for floating backboards or baskets and application of cervical collars without undue risk to the patient or the rescue team. Swift water environments may require a more limited cervical spine control maneuver and rapid extrication to the water’s edge prior to application of rigid collars and boards. In all events, if secondary concerns for cervical injury are discovered by examination or history, cervical protection measures should be instituted.

**Rewarming of drowning victims**

Rewarming is appropriate for severely hypothermic patients. Initial thermal management begins with removal of the patient from the offending environment. The patient should be removed from the water. The resuscitation effort should continue in a warmed environment. EMS rescuers should prewarm the ambulance if possible. To prevent further heat loss, the patient’s wet clothing should be removed.

Additional rewarming techniques are commonly classified as active external rewarming and active internal rewarming. Active external rewarming includes the use of warm packs, warm water packs, forced air, thermal blankets, warmed O2, and warmed IV infusions. Care should be taken to avoid secondary thermal injury from warm packs against the native skin. Concern for a paradoxical drop in the core temperature due to vasodilation of the peripheral vasculature during rewarming has been postulated. Careful hemodynamic monitoring should be instituted [16].

Active internal rewarming includes the use of peritoneal lavage with warmed fluids, esophageal tubes for rewarming, chest lavage with warm fluids via chest tubes, and the cardiac bypass or extracorporeal circulation; these measures are typically not carried out in the prehospital environment.

Traditionally, most experts argued for rewarming by whatever means available and to do so aggressively during the resuscitation. The old adage “A victim is not dead until warm and dead” may require reconsideration. Mounting evidence has shown that induced hypothermia after return of spontaneous circulation may impart some neurological benefit for ventricular fibrillation arrest and possibly other arrhythmias. It would seem logical that a drowning victim may benefit from induced or continued hypothermia [3,10]. Additionally, ACLS guidelines now target core temperature to 32–34 °C with return of spontaneous circulation in cardiac arrest due to accidental hypothermia [16]. In the absence of specific drowning data, and the success of prehospital hypothermia in general cardiac arrest, the historic practice of aggressive rewarming is being questioned. Some in medicine are specifically calling for abandoning the practice altogether [14].

### Destination decisions

Patients in cardiac arrest should be transported to the nearest emergency facility. Patients with perfusing rhythms may benefit from transport to a specialized facility (for example, trauma or pediatric center), provided that the additional transport time is limited. While many victims have concurrent trauma, it is not clear whether transport to a trauma center is warranted for all drownings.

## Grief reactions

Drownings are unexpected events in typically young and healthy patients. Relatives and bystanders may express significant grief from these events. After the incident, attention should be paid to possible grief reactions in rescue personnel so that appropriate referral or interventions can be implemented.

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