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WILDERNESS MEDICAL SOCIETY PRACTICE GUIDELINES

Wilderness Medical Society Practice Guidelines for the Prevention and Treatment of Drowning

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The Wilderness Medical Society convened a panel to review available evidence supporting practices for the prevention and acute management of drowning in out-of-hospital and emergency medical care settings. Literature about definition and terminology, epidemiology, rescue, resuscitation, acute clinical management, disposition, and drowning prevention was reviewed. The panel graded evidence supporting practices according to the American College of Chest Physicians criteria, then made recommendations based on that evidence. Recommendations were based on the panel's collective clinical experience and judgment when published evidence was lacking.

Key words: drowning, submersion, immersion, cold water submersion, hypothermia

Introduction

With an estimated annual worldwide human mortality of approximately 372,000, the burden of drowning as a global disease is self-evident.[1] Drowning often affects the young and can have dire personal, emotional, and financial consequences for patients, their families, and society. The goal of these practice guidelines is to reduce the burden of drowning through improvements in prevention, rescue, and treatment. We present preferred drowning terminology and a review and evaluation of the literature regarding acute care for the drowning patient in out-of-hospital and emergency medical care settings, with particular focus on the wilderness context. The experience and knowledge of a panel of wilderness and emergency medicine practitioners was used to make recommendations when little or unreliable evidence was available.[2]

Methods

A panel of reviewers was convened twice in 2013. Members were selected based on clinical and research experience. The panel included 5 emergency physicians and 1 pediatric physician, all of whom have practical wilderness medical experience, and several of whom have extensive experience in drowning prevention, education, and training.

Relevant articles were identified through PubMed, MEDLINE, and Google Scholar using a keyword search appropriate to each topic. Randomized controlled trials, observational studies, case series, and review articles were reviewed, and evidence was assessed. Abstracts for which the full article could not be obtained were excluded. If no relevant studies were identified, recommendations are based on the panel's clinical experience and judgment about potential risks of the recommended intervention vs its potential benefits. Recommendations are graded using the American College of Chest Physicians classification scheme, in accordance with prior versions of the Wilderness Medical Society Practice Guidelines (Table 1).[3]

EPIDEMIOLOGY

The highest risk age group for drowning is children 1 to 4 years old in residential pools; the next highest risk group is adolescents and young adults in natural bodies of water. There were 46,419 recorded drowning deaths in the United States from 1999 to 2010, including

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Table 1. American College of Chest Physicians classification scheme for grading evidence in clinical guidelines

Grade	*Description*	*Benefits vs risks and burdens*	*Methodological quality of supporting evidence*
1A	Strong recommendation, high-quality evidence	Benefits clearly outweigh risks and burdens or vice versa	RCTs without important limitations or overwhelming evidence from observational studies
1B	Strong recommendation, moderate-quality evidence	Benefits clearly outweigh risks and burdens or vice versa	RCTs with important limitations or exceptionally strong evidence from observational studies
1C	Strong recommendation, low-quality or very low-quality evidence	Benefits clearly outweigh risks and burdens or vice versa	Observational studies or case series
2A	Weak recommendation, high-quality evidence	Benefits closely balanced with risks and burdens	RCTs without important limitations or overwhelming evidence from observational studies
2B	Weak recommendation, moderate-quality evidence	Benefits closely balanced with risks and burdens	RCTs with important limitations or exceptionally strong evidence from observational studies
2C	Weak recommendation, low-quality or very low-quality evidence	Uncertainty in the estimates of benefits, risks and burden; benefits, risk and burden may be closely balanced	Observational studies or case series

RCT, randomized, controlled trial.

boating accidents; an average of 3868 deaths per year, or about 10 per day.[4] Based on World Health Organization and Centers for Disease Control and Prevention (CDC) systems for classifying drowning statistics, these numbers exclude deaths occurring during floods and other natural disasters. In 2010, there were 12,900 emergency department (ED) visits for drowning, with 20% of patients admitted to the hospital. Drowning deaths were 48% more likely on weekends. Fifty-three percent of all male and 26% of all female drowning deaths occurred in natural bodies of water.[4,5]

TERMINOLOGY

The standard definition for drowning, as defined by the World Congress on Drowning in 2002, is "the process of experiencing respiratory impairment due to submersion or immersion in liquid." Inspired by the Utstein Style for reporting cardiac arrest data, the standard definition allows for only 3 outcomes after drowning: 1) morbidity, 2) no morbidity, and 3) mortality. The following modifier terms should *not* be used to categorize "drowning" patients and events: near, wet, dry, active, passive, saltwater, freshwater, or secondary. Although previously thought to be of physiologic relevance (salt vs fresh, wet vs dry), years of data related to human drowning pathophysiology show that these are not valid distinctions because the final common pathway is hypoxemia and eventual cardiopulmonary arrest.[2,6,7] By understanding and using the standard definition for drowning and abstaining from using outdated terminology, communication between medical practitioners, data collection agencies, researchers, and policy makers may become more consistent, thereby more accurately reflecting the true incidence, prevalence, and sequelae of drowning.

Rescue of the Drowning Patient

RESCUER SAFETY

Rescuer safety is paramount during all rescue operations; in the aquatic environment, a specific set of skills, training, and physical capabilities is required. Technical rescue in the aquatic environment can range from swift-water to ocean, lake, scuba, and ice rescue, each requiring different sets of equipment and training. Few studies objectively measure effectiveness of in-water rescue techniques, and much of the literature on this topic is based on the experiences and policies of the writer or organization authoring the text. There is evidence for a high prevalence of fatal and nonfatal drowning of untrained persons attempting to perform in-water rescues.[8–10] Hazardous water conditions that led to the initial person drowning often still exist and place a well-intentioned rescuer at risk for becoming an additional drowning patient.[11] Rescue by untrained persons should be attempted without entering hazardous conditions by reaching to the drowning patient with a paddle or branch, throwing a rope, buoy, cooler, or any floating object, or safely rowing a boat, canoe, or paddleboard to the patient. Trained rescue personnel should operate according to their level of training, expertise, equipment, and comfort level. Based on the inherent risk of performing any technical rescue without appropriate training and equipment, entering the water to effect a contact rescue should be attempted only by persons with specific training to operate in that environment.

Recommendation: Given the risks associated with in-water technical rescue, persons without formal water rescue training should only attempt rescues from a safe location by reaching, throwing, or rowing to the drowning patient. Persons with formal water rescue training should perform in-water rescues according to their level of training and with appropriate personal protective and safety equipment. (Recommendation grade: 1C)

REACHING THE PATIENT

Persons not formally trained in technical rescue in specific aquatic environments (eg, swift water, ice, open water) should avoid entering the water or making direct contact with a drowning patient and seek alternative means for accessing them. The mantra of "Reach, Throw, Row, Don't Go" should be used; these principles may include use of buoyant objects from the surrounding area or piloting a vessel to the patient. Few studies have been conducted on the effectiveness of different water safety devices (eg, rescue tubes, rescue cans, throw bags, life rings), but what has been demonstrated is that proper and effective use of these devices requires basic knowledge of their function and regular practice.[12] Any trip in which water rescue devices may be used should be preceded by competency training for all participants.

Recommendation: Persons without formal technical rescue training in aquatic environments attempting a water rescue should do so by avoiding water entry and direct patient contact, according to the mantra "Reach, Throw, Row, Don't Go." There is insufficient evidence to recommend specific rescue devices; if any specialized rescue equipment is to be used during an excursion, participants should be made familiar with the location and purpose of this equipment, and designated rescue personnel with proper training in its use should be tasked with its deployment in the case of a water rescue. (Recommendation grade: 1C)

PATIENTS IN SUBMERGED VEHICLES

Death caused by entrapment and drowning in submerged vehicles is often not classified as a drowning death, confounding attempts to accurately track the epidemiology of this type of drowning.[13] Studies suggest that 10% of drowning deaths may be caused by entrapment in submerged vehicles and that in the case of inland flooding, as many as 10% of motor vehicle crashes result in a drowning death.[14–18] There is a small body of medical and rescue literature on the topic of vehicle submersions.[16,19–23] A formal review of educational and public service information identified "three probable significant contributors to [the] high fatality rate [of drowning in submerged vehicles]: 1) 'authorities' provide an inadequate description of vehicle sinking characteristics; 2) contradictory and inadequate advice is often provided; and 3) [there is] a poor public perception of how to escape."[23] Specifically, several sources recommend questionable practices without any supporting evidence for efficacy. These include allowing the passenger compartment to fill with water so that it will be easier to open doors, waiting until the vehicle sinks to the bottom of a body of water to maintain orientation, relying on kicking out the windshield or opening doors after the vehicle has fully sunk, and relying on breathing trapped air in the passenger compartment. In a formal survey, more than half of the general public identify an option that involves staying in a vehicle while it sinks to the bottom as being the safest option when trapped in a submerging vehicle; this advice appears in the popular media.[23] However, research experiments and data derived from 35 vehicle submersions conducted in diverse locations and seasons suggest that this advice is erroneous and that the best time to escape from a submerging vehicle is immediately during the initial floating phase, ideally during the initial 30 seconds to 2 minutes after water entry when most vehicles remain partially above the surface.[23] One US-based proprietary prehospital dispatch system has created an additional card addendum to its standardized protocols instructing emergency medical dispatchers not to persist in getting a location for a caller in a submerging vehicle as would be the case for all other callers. Instead, it recommends that a caller exit the vehicle immediately if it is submerging, before using precious time to determine location.[24]

Recommendation: The safest time to escape from a submerging vehicle is immediately after it enters the water, during the initial floating phase. If it remains floating, persons should climb out and remain on top of the vehicle. If it is sinking, they should move away from the vehicle and toward safety after exiting. (Recommendation grade: 2C)

IN-WATER RESUSCITATION

The primary physiologic insult in a drowning patient is that of cerebral hypoxia; its rapid reversal is the primary objective of drowning resuscitation. There are situations in which a rescuer reaches the drowning patient in the water and is faced with the decision to extricate the patient or to initiate resuscitation while in the water. For the purpose of these guidelines, in-water resuscitation (IWR) is defined as an attempt to provide ventilations to a drowning patient who is still in the water; this does not apply to chest compressions. It is not possible to perform adequate chest compressions while in the water and they should not be attempted.[25] Successful use of IWR was first described in 1976, then verified through feasibility studies on a manikin in 1980; however, the first clinical study to show a positive patient outcome was not published until 2004.[26–28] Available outcome data for IWR with ventilations are based on a single retrospective analysis of lifeguard rescues in Brazil, and show significant improvement in survival and neurological outcome in persons receiving IWR. These rescues were performed by trained, professional lifeguards in the ocean environment. Lifeguards had helicopter backup and would frequently tow the patient beyond breaking waves and perform mouth to mouth ventilations while awaiting helicopter pickup.[28] Subsequent studies, primarily using manikins, evaluated ease of performing this task in controlled aquatic environments and found that IWR increases overall rescue time, subjective rescue difficulty, number of submersions, and water aspiration.[29,30] A single study comparing lifeguards with lay rescuers when using IWR found that lifeguards showed improved rescue times and decreased estimated pulmonary aspiration.[31] Consensus statements from the International Lifesaving Federation, United States Lifesaving Association, American Red Cross, and the Young Men's Christian Association recommend IWR by trained rescuers when a patient is rescued in shallow water or in deep water when a flotation device is present.[32,33]

Rescuer safety and prevention of communicable diseases are of utmost importance, so consideration should be given to the use of barrier devices during IWR. US Food and Drug Administration–approved, IWR-specific devices are available that use a self-purging mechanical one-way valve instead of the paper valve on standard cardiopulmonary resuscitation (CPR) masks.[34]

Recommendation: The decision to perform IWR should only be considered by a rescuer with the adequate training and ability to check for a pulse in the water and to safely perform the skill. To benefit from rescue breathing alone, the drowning patient must have a pulse and be unconscious with inadequate or absent respirations. The aquatic conditions must be sufficiently safe for the rescuer to perform IWR, and the point of extrication (boat, shore, etc) must be sufficiently distant to warrant an attempt of this technically difficult task. If conditions are too hazardous to safely perform the task, or if the patient is pulseless, rapid removal from the water is indicated without a delay for IWR. Chest compressions should not be attempted in the water; all drowning patients without a pulse should be extricated as quickly and safely as possible so that early, effective chest compressions and ventilations can be initiated. (Recommendation grade: 1C)

Initial Resuscitation

HYPOTHERMIA

Water is thermally neutral at approximately 32.8°C (91°F), and most patients will drown in water at a temperature lower than this, so concomitant hypothermia is common in drowning.[14] Reversal of hypothermia is paramount in initial resuscitation of a drowning patient. Beyond initiation of basic warming measures, the details of hypothermia treatment, including augmented advanced life support measures, are beyond the scope of these guidelines. Readers are encouraged to review the Wilderness Medical Society Practice Guidelines for the Out-of-Hospital Evaluation and Treatment of Accidental Hypothermia: 2014 Update.[35]

Recommendation: Treat hypothermia aggressively with active and passive measures dependent on patient conditions and available resources. (Recommendation grade: 1C)

CARDIOPULMONARY RESUSCITATION AND PRIORITIZATION OF AIRWAY

Because of the central role of hypoxemia in drowning, initial resuscitation should focus on establishing and maintaining a patent airway and providing oxygen. Recent updates to CPR algorithms, specifically for the lay rescuer, include recommendations for compression-only CPR and prioritization of compressions before airway maneuvers.[36,37] Owing to the underlying pathophysiology of drowning, these changes do not apply to the drowning patient. If the airway is overlooked in initial resuscitation, ongoing hypoxemia leads to decreased survival and worse neurological outcomes.

Recommendation: Interruption of the drowning process as quickly as possible by supplying oxygen to the brain is critical to successful resuscitation of the drowning patient. Establishing an airway and providing oxygen are priorities in the initial resuscitation of a drowning patient. For the patient in cardiac arrest, provide positive-pressure ventilations in addition to chest compressions using the traditional Airway-Breathing-Circulation model of resuscitation. If an advanced airway is available and properly placed, provide breaths at specified time intervals (every 6 to 8 seconds) while continuous compressions are administered. (Recommendation grade: 1C)

OXYGENATION

Few large-scale studies have evaluated different airway adjuncts applied to drowning patients. Although ideal delivery of rescue breaths includes supplemental oxygen and a positive-pressure delivery device, any amount of oxygen delivery (eg, mouth-to-mouth, bag-valve-mask [BVM] with ambient air) is better than none if supplemental oxygen is not available. As a result of direct pulmonary injury and airway edema from drowning, certain supraglottic airway devices may be difficult to use for oxygenation based on leak pressures; instead, a BVM should be used if it achieves adequate chest rise.[38]

Recent resuscitation data have brought into question the benefit of providing high oxygen concentrations in the acute setting of out-of-hospital cardiac arrest and stroke, primarily based on data correlating hyperoxia after return of spontaneous circulation (ROSC) with increased mortality. Most of these data focus on the period after ROSC in the intensive care unit setting, and no studies focus specifically on cardiac arrest associated with drowning or other primary respiratory events. A single retrospective case-control study involving arterial blood analysis during CPR provides support for using high levels of supplemental oxygen. This study showed a significant increase in survival to hospital discharge with increasing levels of arterial oxygenation, in all cardiac arrest patients, even at levels that would be considered hyperoxic.[39]

Recommendation: For resuscitation of a drowning patient, oxygen should be delivered at the highest concentration available based on the patient's tolerance and available resources or provider training. For the patient in respiratory distress or arrest, providing positive-pressure ventilations is preferred over passive ventilation. If multiple modalities are available, the method that most effectively delivers the highest concentration of oxygen should be used. If a modality or device fails, BVM or mouth-to-mouth ventilation should be attempted. (Recommendation grade: 1C)

AUTOMATED EXTERNAL DEFIBRILLATOR

Although cerebral anoxia is the primary cause of morbidity in the drowning patient, hypoxic myocardial injury may also occur. Drowning patients typically experience sinus tachycardia as a result of the initial struggle, followed by bradycardia, pulseless electrical activity, and then asystole, owing to the hypoxic nature of the event.[40] In drowning patients, ventricular fibrillation (VF) is rare, occurring in less than 10% of patients in the published literature; thus, reversal of hypoxia with ventilations and compressions should not be delayed in an attempt to apply an automated external defibrillator (AED).[40–46] Early application of an AED may be beneficial, given the possibility of a VF as the cause or result of drowning, and should be considered if available. In any drowning patient, if global myocardial hypoxia persists, attempts at defibrillation may be unsuccessful without concomitant oxygenation and ventilation.

Experimental animal models have shown that as long as AED pads are placed firmly on a patient's chest and a rescuer is not in direct contact with that patient, use of an AED in a wet environment does not pose increased risk to the patient or rescuers.[47–50] AEDs have been tested and noted to correctly detect simulated arrhythmias and deliver shocks on moving boats.[51]

Recommendation: Ventricular fibrillation is rare in drowning, so incorporation of an AED in the initial minutes of drowning resuscitation should not interfere with oxygenation and ventilation. If available, an AED should be used during resuscitation of a drowning patient, and its use is not contraindicated in a wet environment. (Recommendation grade: 1A)

HEIMLICH MANEUVER

Drowning involves water obstructing the airway, causing cerebral hypoxia; in some cases, small amounts of water are aspirated into the lungs. This can cause atelectasis, direct cellular injury, and pulmonary edema. Even after unconsciousness, reflex swallowing of water from the hypopharynx into the stomach may occur. Heimlich advocated the use of abdominal thrusts in initial treatment of the drowning patient, claiming that aspirated water must first be cleared from the airway to allow proper ventilations.[52–54] In the 30 years since his original report, a great amount of concern has been raised about this recommendation, resulting in an Institute of Medicine report and 3 systematic literature reviews by the American Red Cross.[55,56] All of these investigations failed to identify quality data to support use of the Heimlich maneuver before providing ventilations. Its use during initial resuscitation delays delivery of ventilations and prolongs hypoxemia.[55]

Recommendation: Owing to the possibility of delaying ventilations, the Heimlich maneuver is not recommended for resuscitation of the drowning patient. (Recommendation grade: 1B)

CERVICAL SPINAL IMMOBILIZATION

Retrospective studies of drowning patients found the incidence of cervical spine injuries was low (0.5%–5%) and that most injuries were related to diving from a height.[57,58] Without obvious signs of trauma or a known fall or diving event, routine cervical spine immobilization is unnecessary and may distract rescuers from the critical role of oxygenation and ventilation. In accordance with the Wilderness Medical Society Practice Guidelines for Spine Immobilization in the Austere Environment,[59] spinal immobilization should be considered in the setting of blunt trauma in association with any of the following:

1. Significant mechanism for cervical spine injury
2. Altered mental status (Glasgow Coma Scale [GCS] < 15; evidence of intoxication)
3. Focal neurological deficit
4. Significant distracting injury

Recommendation: Spinal immobilization should be considered in patients with evidence of spinal injury, such as focal neurological deficit or history of high-risk activity, and in patients who exhibit altered mental status. Spinal immobilization should not take priority over initial resuscitation of a patient with severe respiratory distress who requires aggressive airway management. (Recommendation grade: 1C)

Postresuscitation Management

VENTILATION

Mechanical ventilation

No literature is available comparing out-of-hospital or in-hospital mechanical ventilation strategies for the drowning patient. Current practice recommends a lung-protective ventilation strategy similar to that used for patients with acute respiratory distress syndrome (ARDS), on the premise that the lung injury pattern after drowning is similar.[6,60,61] This includes mechanical ventilation starting with a tidal volume (Vt) of 6 to 8 mL/kg, augmentation of Vt and respiratory rate to maintain plateau pressure less than 30 mm Hg, and augmentation of positive end-expiratory pressure (PEEP) and fraction of inspired oxygen (FIO_2) to maintain arterial partial oxygen pressure (PaO_2) at 55 to 80 mm Hg.[62]

Recommendation: Mechanical ventilation for the drowning patient should follow ARDS protocols. (Recommendation grade: 1C)

Noninvasive positive-pressure ventilation

Noninvasive positive-pressure ventilation (NIPPV) has been used successfully in the prehospital setting. There are case reports describing its successful use in drowning.[63–65] However, caution should be used with NIPPV in the drowning patient with altered mental status because there may be an increased risk of vomiting and aspiration. Drowning patients who have mild to moderate hypoxemia and are being treated in prehospital and emergency medical systems familiar with NIPPV may benefit from this therapy.

Recommendation: NIPPV may be used in the alert patient with mild to moderate respiratory symptoms. Caution should be taken with any patient displaying altered mental status or active emesis because of the potential for aspiration. (Recommendation grade: 2C)

DIAGNOSTICS

Radiologic testing

Several retrospective ED studies of drowning patients found that the initial chest radiograph did not correlate with arterial blood gas levels, outcome, or disposition.[66,67] A study of admitted drowning patients showed that those who went on to exhibit acute lung injury or ARDS had abnormal chest radiograph findings within the first few hours, but not necessarily on arrival to the ED.[60] Head computed tomography (CT) imaging has been studied in an attempt to quantify anoxic brain injury in drowning patients. Retrospective studies have found that patients with abnormal initial CT scans all went on to experience severe brain injury or die, whereas initially normal head CT scans had no prognostic value.[68]

Recommendation: Initial chest radiograph findings do not correlate with arterial blood gas measurements or outcome; chest radiographs may be useful in tracking changes in patient condition, but not for determining prognosis if obtained at the time of presentation. A normal initial head CT scan does not have prognostic value in the drowning patient. Routine use of neuroimaging in the awake and alert drowning patient is not recommended unless dictated by a change in clinical status. (Recommendation grade: 1C)

Laboratory testing

Canine studies performed in the 1960s showed clinically significant hemodilution and red blood cell lysis associated with salt, chlorine, and freshwater drowning.[69–71] These studies were based on instilling up to 44 mL/kg of fluid into the trachea of anesthetized dogs, far greater than the 1 to 3 mL/kg typically aspirated by human drowning patients. Electrolyte abnormalities and hemodilution only occurred in dogs that had 11 mL/kg or greater instilled. No studies have identified clinically significant electrolyte or hematologic abnormalities in drowning patients that help guide initial therapy or provide prognostic information. In patients with altered mental status or decreased level of consciousness, laboratory evaluation for alternative causes that may have led to the drowning event, such as hypoglycemia or intoxication, may be helpful. Arterial blood gas analysis in symptomatic patients may be used to help guide initial respiratory resuscitation.

Recommendation: Routine use of complete blood count or electrolyte testing in the drowning patient is not recommended. Arterial blood gas testing in patients with evidence of hypoxemia or respiratory distress (eg, cyanosis, low oxygen saturation, tachypnea, persistent tachycardia) may be indicated to guide respiratory interventions. For patients whose mental status fails to respond to resuscitation or in whom the initial cause of submersion is unknown, laboratory testing for causes of altered mental status should be considered. (Recommendation grade: 1C)

OTHER TREATMENTS

Antibiotics

Although microorganisms present in aspirated water may eventually cause pneumonia, no studies to date have shown benefit from empiric administration of antibiotics in drowning patients. This is related in part to the fact that microorganisms found in drowning-associated pneumonia are atypical bacteria or fungi and are often resistant to standard empiric treatments.[72–74] Aspiration of even small volumes of water can produce abnormalities on chest radiograph that may mimic pneumonia. The trauma of the drowning event and hypoxemia can cause leukocytosis from stress demargination as well as fever from inflammation and irritation caused by water in the airways, making it difficult to differentiate inflammatory from infectious pneumonitis.[75] The decision to administer antibiotics should be made after initial resuscitation and ideally be based on expectorated sputum or endotracheal aspirate bacterial culture, blood cultures, or urinary antigen tests.[72–74] As these tests are not available in the wilderness setting, treatment should be initiated for symptoms consistent with pulmonary infection (eg, fever, increased sputum, abnormal lung auscultation) that continue after initial resuscitation and treatment phases.

Recommendation: There is no evidence to support empiric antibiotic therapy in the treatment of drowning patients. After initial resuscitation, if pneumonia is present, treatment should be guided by expectorated sputum or endotracheal aspirate bacterial culture, blood cultures, or urinary antigen tests. In the absence of these tests, decision to treat should be based on clinical examination focusing on physical evidence of pulmonary or systemic infection (eg, fever, increased sputum, abnormal lung auscultation). (Recommendation grade: 1A)

Corticosteroids

Corticosteroids were historically used in drowning patients to facilitate pulmonary recovery and surfactant production. A systematic review of 35 years of literature found no randomized controlled trials regarding their use; of the pertinent studies reviewed, all but one were retrospective or case studies. Low study patient numbers and varying corticosteroid regimens further hindered comparisons. There is not sufficient evidence to support empiric corticosteroid administration for drowning patients.[76]

Recommendation: Given limited data, corticosteroids should not be routinely administered specifically for treatment of drowning patients. (Recommendation grade: 1C)

Therapeutic hypothermia

Mild therapeutic hypothermia (TH) has been shown to decrease cerebral oxygen utilization and improve neurologically intact survival in patients with witnessed VF cardiac arrest.[77] Current American Heart Association/International Liaison Committee on Resuscitation guidelines recommend that survivors of out-of hospital cardiac arrest with an initial rhythm of VF be cooled to 32°C to 34°C (90°F to 93°F) for 12 to 24 hours.[78] Many institutions have extrapolated these data to include non-VF causes of cardiac arrest.

The 2002 World Congress on Drowning provided a consensus statement recommending TH of 32°C to 34°C (90°F to 93°F) for patients achieving ROSC after cardiac arrest caused by drowning.[79] Our literature search yielded multiple case reports and retrospective reviews supporting neurologically intact survival in hypothermic patients, but several older studies showed no benefit.[80–92] There are no prospective studies comparing TH with normothermia after ROSC in drowning patients. There may be benefit to discontinuing rewarming interventions after a hypothermic drowning patient has reached TH temperature range, but this has been insufficiently studied to support an evidence-based recommendation.

Recommendation: Although current literature shows there may be benefit to TH in witnessed VF arrest, there is insufficient evidence to either support or discourage induction or maintenance of TH in drowning patients. (Recommendation grade: 2C)

Disposition in the Wilderness

DECISION TO EVACUATE

If a patient survives a drowning event in the wilderness, objective physical examination findings may assist in the decision to evacuate the patient to advanced medical care. A single large retrospective study of nearly 42,000 ocean lifeguard rescues serves as the primary evidence for on-scene decision-making.[93] This study found that patients who experienced a drowning event but had no symptoms other than mild cough and did not have abnormal lung sounds had 0% mortality. As symptoms worsened and abnormal lung sounds appeared, mortality increased. A subsequent drop in blood pressure (to systolic blood pressure < 90 mm Hg or mean arterial pressure < 60 mm Hg) accounted for the next largest increase in mortality (Table 2). In a retrospective study of children who experienced nonfatal drowning, any clinical deterioration occurred within the first 4 hours in patients presenting with mild symptoms and GCS ≥ 13.[66] These findings are similar to those from another retrospective study of pediatric patients in which new symptom development after arrival to the hospital occurred within 4.5 hours in all but 1 patient; the final patient exhibited symptoms in 7 hours and had a good outcome.[94]

Recommendation: Any patient with abnormal lung sounds, severe cough, frothy sputum, or foamy material in the airway; depressed mentation; or hypotension warrants evacuation to advanced medical care if risks of evacuation do not outweigh potential benefit. Any patient who is asymptomatic (other than a mild cough) and displays normal lung auscultation may be released on scene. If evacuation is difficult or may compromise the overall expedition, patients with mild symptoms and normal mentation should be observed for 4 to 6 hours. Any evidence of decompensation warrants prompt evacuation if the risks of evacuation do not outweigh the potential benefit. If evacuation of a mildly symptomatic patient has begun and the patient becomes asymptomatic for 4 to 6 hours, canceling further evacuation and continuing previous activity may be considered. (Recommendation grade: 1C)

CEASING WATER-BASED RESCUE AND RESUSCITATION EFFORTS

A search and rescue team may range from a small group of untrained participants with no equipment to a highly trained team with extensive resources. In the wilderness setting, available resources, risk to rescuers, and team safety must be considered when deciding how much time to search for a submerged patient. Although each drowning episode has unique patient and environmental factors, the most important predictor of outcome is duration of submersion.[46,95,96] Available evidence shows that prognosis is poor with submersion times greater than 30 minutes, regardless of water temperature.[97] There are also case reports of survival with good neurologic outcome despite prolonged submersion, predominantly in children 6 years and younger in water less than 6°C (43°F), and with use of advanced treatment modalities, such as extracorporeal membrane oxygenation.[98–103] For the purpose of these guidelines, recommendations are based on available evidence relevant to a typical drowning patient, and on the probability of neurologically intact survival in specific conditions. A literature review of 43 cases serves as the evidence for water-based rescue.[104] The report concludes that there is minimal chance of neurologically intact survival with submersion time greater than 30 minutes in water greater than 6°C (43°F), or greater than 90 minutes in water less than 6°C (43°F). It is important to note that "submersion time" was defined as beginning on arrival of emergency services personnel as total submersion time is often unknown.

If a drowning patient is removed from the water and resuscitation takes place, it may be necessary to decide when to cease resuscitation efforts if no signs of life return. Based on available evidence, primarily retrospective studies, submersion times of greater than 10 minutes appear to correlate with increased mortality or survival with severe neurological dysfunction.[46,96,105] In addition, more than 25 minutes of resuscitation or prolonged time to advanced medical care also correlate with negative outcomes, but without the statistical significance of submersion time. In a Dutch retrospective review of 160 hypothermic drowning patients younger than 16 years, 98 children received

Table 2. Prehospital management and classification of drowning patients

Grade	*Pulmonary examination*	*Cardiac examination*	*Mortality (%)*
0	Normal auscultation, - cough	Radial pulses	0
1	Normal auscultation, + cough	Radial pulses	0
2	Rales, small foam in airway	Radial pulses	0.6
3	Acute pulmonary edema	Radial pulses	5.2
4	Acute pulmonary edema	Hypotension	19
5	Respiratory arrest	Hypotension	44
6	Cardiopulmonary arrest		93

Adapted from Cushing et al.[13]

CPR for more than 30 minutes, with only 11 surviving to discharge, all of whom were neurologically devastated.[97,105–107]

Recommendation: Based on resources, it may be reasonable to cease rescue and resuscitation efforts when there is a known submersion time of greater than 30 minutes in water greater than 6°C (43°F), or greater than 90 minutes in water less than 6°C (43°F), or after 25 minutes of continuous CPR. If at any point during search and rescue efforts the safety of the rescue team becomes threatened, rescue efforts should be ceased. If resources are available and recovery team safety is maintained, body recovery efforts may continue beyond the search and rescue period with the understanding that resuscitation attempts will likely be futile. (Recommendation grade: 1C)

Disposition in the Emergency Department

Although many studies have addressed prognostic factors for neurological survival at hospital discharge, only a few have addressed the question, "Which patients can be safely discharged from the ED?" The first, a prospective study of primarily pediatric patients, included follow-up phone interviews with 33 patients who were either released on scene or discharged from the ED within 1 to 6 hours of arrival, and found that none of these patients experienced delayed effects.[108] A retrospective review of 48 pediatric drowning patients who presented to a single ED with a GCS of at least 13 studied whether factors predicting safe ED discharge could be identified.[66] Initial chest radiograph did not correlate with severity of disease, and all patients who deteriorated did so within 4 hours of ED arrival. The authors concluded that patients could be safely discharged home if normalized and there was no deterioration in respiratory function after 4 to 6 hours of observation in the ED. A retrospective review of hospitalized pediatric patients found that in all patients who were initially asymptomatic, but who went on to exhibit symptoms during their stay, these symptoms developed within 4.5 hours in all but 1 patient, and within 7 hours in the final patient.[94]

Recommendation: After an observation period of 4 to 6 hours, it is reasonable to discharge from the ED a drowning patient with normal mental status in whom respiratory function is normalized and no further deterioration in respiratory function has been observed. (Recommendation grade: 2C)

Prevention

Analogous to smoking cessation and wearing seatbelts, prevention holds the potential to save far more lives than rescue or treatment of a drowning person. A comprehensive prevention program includes participant screening for medical diseases that increase risk of drowning, swimming ability, use of safety devices, and use of safe practices when in and around water.

PARTICIPANT SCREENING

Retrospective studies have linked coronary artery disease, prolonged QT syndrome, and seizure disorders with higher than normal rates of drowning and drowning deaths.[41,109–116] Preparticipation screening should focus on uncovering any medical or physical condition that may potentially impair decision making, physical abilities, and thus, swimming ability.

Recommendation: All patients with coronary artery disease, prolonged QT syndrome, seizure disorders, or other medical and physical impairments should be counseled about their increased risk of drowning and about steps to mitigate the risk should they choose to participate in water activities. (Recommendation grade: 2C)

SWIMMING ABILITY

Common sense dictates that an adolescent or adult who is a competent swimmer and has the neurocognitive ability to make appropriate decisions about water safety has a decreased likelihood of drowning. However, the best ages to learn technique and specific swimming skills that reduce a person's chance of drowning are not well understood. Most available literature evaluates infant and pediatric populations for the effects of swimming and "infant survival" lessons on drowning and mortality.[117,118] There is concern that by providing swim lessons to young children, parents may develop a false sense of security in their child's swimming ability, which may lead to an increase in drowning incidents.[119–121]

The American Academy of Pediatrics (AAP) has always maintained that children should learn to swim at some point in their life. Previous recommendations were against formal swim lessons for all children 4 years and younger. The most recent review by the AAP acknowledges lack of evidence surrounding pediatric swimming lessons and currently does not formally recommend for or against lessons for children younger than 4 years.[117]

There is considerable debate regarding the definition of "swimming" or "survival-swimming" and what constitutes the most protective approach to swim instruction. Although the ability to swim farther distances can be perceived as increased swim ability, for the purpose of swimming as a tool for drowning prevention, the distance of 25 m (82 feet) has been adopted by international lifesaving agencies and a large population-based study in Bangladesh.[122–124]

Despite the lack of definitive evidence showing a clear benefit to formal swim lessons, panel members agree that familiarity with and, more importantly, confidence in an aquatic environment would be beneficial in the event of accidental immersion or submersion. In addition, unique aquatic environments such as whitewater should be approached only after focused instruction on swimming techniques specific to that environment.

Recommendation: All persons who participate in activities conducted in or around open water should have, at a minimum, enough experience and physical capability to maintain a floating position, tread water, and make forward progress for a distance of 25 m (82 feet). (Recommendation grade: 2C [pediatrics], panel consensus [adults])

PERSONAL FLOTATION DEVICES

Under the category of personal flotation devices, devices such as lifejackets, manually or automated inflation systems, and neoprene wetsuits are available. Currently, lifejackets are the only devices with injury prevention data available and will, therefore, be used as the prototypical model for this category. In 2013, according to US Coast Guard data, drowning was the cause of death in more than 75% of fatal boating accidents.[125] In addition, 85% of these fatalities were not wearing lifejackets. Three other retrospective studies have found an association between lifejacket use and decreased mortality in boating accidents.[126–128] One of these studies specifically compared drowning deaths before and after increased lifejacket regulations, revealing improved survival rates after regulations went into effect. These data suggest that activities in and around water, especially while boating, should include lifejacket use.[126]

Recommendation: Properly fitted lifejackets that meet local regulatory specifications should be available for participants when boating or engaging in any water sports for which lifejackets are recommended, and should always be worn while engaged in the activity. (Recommendation grade: 1C)

DROWNING PREVENTION STRATEGIES

Alcohol is a known contributing factor to drowning deaths. Data have been obtained primarily from telephone studies, and likely underrepresent the true burden of alcohol in causing drowning. In 2013, alcohol was a contributing factor to 16% of boating-related deaths.[125] A 2004 review found that 30% to 70% of drowning fatalities have a measurable blood alcohol level, with 10% to 30% of deaths being directly attributed to alcohol use.[129]

There are no specific peer-reviewed studies on the utility of lifeguards on expeditions or wilderness trips.[130] A 2001 CDC working group report recommends lifeguards for drowning prevention in open water settings. In 2013, the US Lifesaving Association reported 6,725,264 preventive actions and 68,320 rescues covering a population of 339,049,941 beachgoers. There were 23 reported drowning deaths at guarded beaches compared with 92 deaths at beaches without lifeguards.[131] Among nationally recognized lifeguard certifying agencies (Ellis & Associates, American Red Cross, Starfish Aquatics Institute, and National Aquatic Safety Company), there are no specific guidelines or recommendations for the number of lifeguards per number of participants in an event or at an aquatic facility.

Recommendation: Alcohol and other intoxicating substances should be avoided before and during water activities. Despite lack of definitive evidence, all groups operating in or near aquatic environments, regardless of size, should consider water safety during planning and execution of excursions. This includes contingencies for prevention, rescue, and treatment of drowning persons. In high-risk environments or large groups, consider including personnel with technical rescue training and appropriate rescue equipment. (Recommendation grade: 1C)

Special Situations

COLD-WATER SURVIVAL

No single recommendation can address all possible scenarios that a person may encounter in a water setting. An unintentional fall into a swiftly moving river, deep offshore ocean, inland waterways, or backyard swimming pool, or falling through the ice into static or moving water, are all treated according to the skill level, preparation, and equipment available to both patient and rescuer. Immediate attention must always be given to self-rescue and extricating oneself immediately from a hazardous environment. After immersion in cold water, a person has a limited amount of time before fatigue and incapacitation render self-rescue impossible. Likelihood of survival is increased by having appropriate gear and training and by dressing for water temperature, not just air temperature, in the event of immersion.

Extensive controlled trials of cold-water survival are lacking, and the available literature is not generalizable to all scenarios. For example, the presence of a lifejacket, sea state, weather, physical fitness, clothing, and mental preparedness all contribute to survivability in cold water.

Survival in whitewater is different from still water or in the ocean in polar regions. A single large literature review serves as the source for recommendations about cold-water survival under "ideal" conditions and must be interpreted according to the level of training, preparation, and situation presented to the patient.[132]

After immersion, the most important decisions a person must make are 1) presence of any potential immediate life threats and 2) whether to swim to safety or await rescue. Should a person choose to await rescue, preventing loss of body heat becomes paramount. By positioning the body to protect major areas of heat loss, a patient may lengthen immersion survival time. A position that has been proven in a laboratory setting to decrease heat loss is the Heat Escape Lessening Position (HELP). This position is maintained by flexing the hips and knees and hugging the knees to the chest; it is important to note that to maintain this position, a lifejacket or similar flotation device is necessary. In the event of a group immersion, a huddle formation has been recommended to lessen heat loss, assist injured or weak persons, and improve group morale. Although this position has been shown to decrease cooling in participating individuals in a controlled environment, the effort needed to assist debilitated individuals in a actual emergency may result in increased heat loss (Figures 1, 2).[133]

Swimming or treading water should be limited to minimize heat loss. Lifejackets should be worn to aid insulation and flotation. If possible, the ideal location to await rescue is out of the water, even if only partially, to reduce heat loss and delay onset of hypothermia. Prolonged cold-water exposure eventually results in cognitive and motor disabilities, which can appear within 10 minutes of immersion, making advanced maneuvers or decision making difficult. For this reason, it may be beneficial to affix one's body or clothing to a floating object using rope, or freezing clothing to icy surfaces.

Figure 1. HELP position. Reprinted from *Wilderness Medicine*, 6e, Auerbach PS (ed.), Submersion Injuries and Drowning, page 1502, Copyright 2012, with permission from Elsevier.

Figure 2. Huddle formation. Reprinted from *Wilderness Medicine*, 6e, Auerbach PS (ed.), Submersion Injuries and Drowning, page 1502, Copyright 2012, with permission from Elsevier.

Should a person decide to swim to safety, some important physiologic changes may occur. The initial cold shock, which lasts seconds to a few minutes, may prompt gasping and hyperventilation, and can have a disorienting effect, making self-rescue attempts difficult. On immersion in cold water, if no immediate life threats are present, a person should focus on remaining calm and controlling breathing. Once a person is able to obtain his or her bearings, he or she may have far less than 10 minutes of effective swimming, and up to 1 hour of consciousness, before succumbing to hypothermia. All of these statements assume the person is wearing an appropriate lifejacket. Further detailed discussion of the science behind cold-water immersion is available in Chapter 6 of *Wilderness Medicine* (6th ed) by Auerbach.[14]

Recommendation: On falling into cold water, distancing oneself from any immediate life threats (eg, fire, sinking vehicle, whitewater, hazardous waves, rocks) is paramount. An attempt should then be made to remain calm and focused. The person should then consider physical capabilities, location, resources, and chances of rescue to determine whether or not to swim to safety. If a decision is made to swim to safety, this should be done as soon as possible before physical and mental capabilities deteriorate from the effects of cold stress. If a decision is made to await rescue, an attempt should be made to remove as much of the body from the water as possible. All clothing should remain on, unless it hampers buoyancy. If the person remains immersed, the HELP position should be maintained if possible. In a group, the huddle position may be used. If prolonged rescue is expected, it would be beneficial to attach oneself to buoyant objects or to a surface out of the water to improve the chance for survival once incapacitated. (Recommendation grade: 2C)

SWIMMING-INDUCED PULMONARY EDEMA

During the past 30 years, numerous case reports and studies have described a syndrome of acute shortness of breath and bloody or pink, frothy sputum after strenuous exercise, such as military training, triathlons, and long-distance swims.[134–138] For these guidelines, we focus on this spectrum of symptoms as related to surface swimming, not scuba diving. Acute pulmonary edema secondary to surface swimming is thought to be a combination of increased cardiac output, redistribution of circulating blood volume to the central circulation and pulmonary arteries as a result of immersion and cold-water vasoconstriction, and possibly overhydration. Although the incidence of this syndrome varies greatly as cited in studies, there were few reports of severe residual disease or poor outcomes. Studies have found temporary changes in pulmonary function testing lasting up to 1 week without changes in cardiac function.[135]

Recommendation: Patients experiencing symptoms consistent with pulmonary edema after swimming should cease further strenuous activity until fully recovered and be advised of the possibility for temporary changes in lung function. Patients experiencing this syndrome usually recover well without treatment, and in the absence of severe respiratory symptoms, evacuation is not warranted. (Recommendation grade: 2C)

Conclusions

Drowning is a process with outcomes ranging from no morbidity to severe morbidity, and eventually death. As with other injuries encountered in the wilderness environment, the best treatment for drowning is prevention. This includes a multitiered approach including swim lessons, appropriate supervision, use of suitable life-jacket or personal flotation device, knowledge of water conditions and weather patterns, and avoidance of drugs and alcohol. When prevention fails, or circumstance leads to the drowning process, then the most important aspect of treatment is to reverse cerebral hypoxia by providing oxygen to the brain by whatever means available.

Conflicts of Interest

The authors wish to report the following disclosures: A.S. and J.S. are directors of Lifeguards Without Borders; S.H. is the medical director of Landmark Learning, the medical director of Starfish Aquatics Institute, the medical director of NC State Parks, owner of Hawk Ventures, the Medical Director of Burke County EMS; and the executive editor of *Wilderness Medicine*; and T.C. is a board member of the Wilderness Medical Society, and chair of the WMS Practice Guidelines Committee. A.A. and P.A. have no conflicts of interest to declare.

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