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Drowning In The Adult Population: Emergency Department Resuscitation And Treatment

Abstract

Drowning is a global problem that affects all populations. The events leading up to and the sequelae from a drowning incident vary greatly based on numerous factors, but the primary physiologic insult is always hypoxia. This is the starting point for all morbidity and mortality, and it must remain the focus of treatment. This issue discusses the initial resuscitation and treatment of adult drowning patients in the emergency department. Primary focus is placed on the key components of pathophysiology that require immediate attention. From there, evidence is presented to help guide the management of associated clinical concerns such as hypothermia, mechanical ventilation, and traumatic injuries, and to help form safe and reasonable disposition plans.

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CME Objectives

Upon completion of this article, you should be able to:

1. Describe the basic pathophysiology of drowning.
2. Identify the goals of initial resuscitation and treatment of drowning patients.
3. Develop treatment and disposition plans based on symptoms, examination findings, and response to treatment.

Prior to beginning this activity, see "Physician CME Information" on the back page. ***This article is eligible for 4 Trauma CME credits.***

Case Presentations

A 35-year-old man is brought in to your ED by EMS after being pulled out of the ocean by a lifeguard. Per EMS, the patient was initially lethargic, but he was maintaining his own airway. After 10 minutes of oxygen by nonrebreather in the ambulance, he was awake and active. He arrives in your department awake and oriented, with a mild cough. He is on nasal cannula with an SpO_2 of 100%. He says he feels well and would like to return to the beach, but you are not comfortable releasing him just yet…

A 70-year-old woman with active airway assistance is brought in to your ED by EMS. She was found by a caregiver, submerged in her bathtub. Per EMS, the woman was pulseless when they arrived. They performed CPR with bag-mask ventilation, and she regained a pulse and started breathing. Upon arrival to the ED, she has a weak pulse, normal respiratory rate on nonrebreather, and she is arousable, but lethargic. She then begins to vomit large amounts of fluid, and you wonder if you need to initiate more advanced airway maneuvers…

You finally get a day off and are sitting at the beach when you hear a woman scream and run into the water. She pulls her 5-year-old son on to the sand; he is unconscious and cyanotic. There are no lifeguards in the area, so you run to offer assistance to the woman. After asking another individual to call 911, you begin to assess the child and find no pulse or respirations. You do not have a pocket mask, but you are unsure if performing only compressions will be adequate…

Introduction

With an annual estimated global mortality of 372,000 people (not including drowning from natural disasters, water transport accidents, and suicides), drowning remains a leading cause of death around the world.[1] While fatal drownings attract a large amount of attention, nonfatal drowning injuries, with a spectrum of morbidity ranging from mild cough to persistent vegetative state, often receive very little. One reason for this may be the long-standing variability in describing exactly what drowning is, and the resulting misguided focus on drowning as a fatal endpoint instead of a process on a continuum. A 2005 systematic review covering 60 years of drowning literature found 33 different definitions for "drowning" in the peer-reviewed science literature.[2] In an effort to address this, the World Congress on Drowning met in Amsterdam in 2002 and developed what is known as the standard definition for drowning: the process of experiencing respiratory impairment due to submersion/immersion in a liquid.

From this definition, there can be 3 possible outcomes: no morbidity, morbidity, or mortality. In addition to this definition, the World Congress on Drowning also recommended against using modifiers such as near, dry, wet, active, passive, and secondary, all of which only serve to add to the confusion and take the focus away from proper treatment.[3] While this definition has been accepted by the United States Centers for Disease Control and Prevention (CDC) and the World Health Organization (WHO), the inclusion of incorrect drowning definitions and modifiers has persisted in the peer-reviewed literature.

Based on a lack of data collection in low- and middle-income countries, it is estimated that only 20% of drowning deaths are actually reported.[4] Fatal and nonfatal drowning rates vary greatly around the world based on geographic, socioeconomic, and cultural differences. In the United States, for example, the annual mortality rate is approximately 1.5/1000 people, which differs greatly from Guyana, where the annual mortality rate is 11.8/1000 people.[1] For the purposes of this review, we will focus primarily on the United States, where approximately 4000 to 5000 people die from drowning annually. In the United States, as with many countries, drowning primarily affects younger individuals. In 2010, it was the leading cause of injury death in children aged 1 to 4 years, and it was the second leading cause of injury death in children aged 5 to 9 years.[5] In adult patients, being male, engaging in high-risk activities, and consuming alcohol during water activity increase the risk of drowning.[6] Among peopled aged 18 to 84 years, the most common location of drowning is in a natural body of water, and people aged > 85 years are more likely to drown in a bathtub.

This issue of *Emergency Medicine Practice* provides guidance for both prehospital and emergency clinicians, with the primary goal of simplifying and demystifying the treatment of adult drowning patients. The inclusion of prehospital care reflects its importance in the treatment of drowning, and it is meant to provide guidance for clinicians involved with prehospital medical direction and clinicians who may respond to a drowning event while participating in activities in or near a body of water.

Critical Appraisal Of The Literature

To obtain the literature for this article, PubMed was accessed and searched using the following terms: *drowning, near-drowning, submersion*, and *submersion injury*. An attempt was made to include primarily adult literature, but, in some instances, pediatric studies provide the only available data. Additionally, guidelines established by the World Congress on Drowning and the American Heart Association, and statistical databases from the CDC and the WHO were utilized. A search of the Cochrane Library revealed no systematic reviews on drowning within the database.

The study of the global burden of drowning has continually been hampered by poor data collection. It is estimated that 91% of the world's drowning deaths occur in low- and middle-income countries, the very areas where data collection is often insufficient.[1] In 2007, the International Lifesaving Federation released a World Drowning Report, which only included data from 16 of its more than 100 member countries, primarily those in North America, Europe, and a single country in South America.[7] In addition, a 2014 article examining WHO drowning data only included 60 countries, and it did not include many of the countries known to have devastating drowning death rates.[8]

In terms of treatment and outcome data, the nature of drowning and the comparatively rare occurrence in single centers precludes many randomized controlled trials and large studies. Many basic drowning physiology studies were performed in the 1970s and were often carried out using canine models, a practice which has fallen out of favor in drowning research. For these reasons, much of the data are extrapolated from studies focusing on the sequelae of drowning, such as acute respiratory distress syndrome (ARDS) and hypothermia. Primarily, case studies serve as the data for resuscitation and treatment, with topics like therapeutic hypothermia and noninvasive positive-pressure ventilation (NIPPV) lacking high-quality support in the literature. In terms of prognosis and outcome, most of the data are from the pediatric population and are retrospective in nature. For this issue, adult studies will be the primary source of recommendations, unless only pediatric data are available, and this will be noted. Updated practice guidelines were developed by Wilderness Medical Society in 2014.

Pathophysiology

The drowning process begins when the airway drops below the surface of the water. Initially, the patient attempts to hold his or her breath, protecting the airway from aspiration. This voluntary action usually lasts 30 seconds to 1 minute and is followed by an involuntary attempt at inspiration, which may allow small volumes of water to enter the airway. Patients may experience laryngospasm due to the presence of water in the airway, but this abates as hypoxia increases. If submersion continues past this point, eventually systemic hypoxia leads to loss of consciousness.[9] It was originally thought that approximately 10% to 15% of drowning patients experienced "dry drowning," with no evidence on autopsy of aspiration, but the existence of this subgroup has been brought in to question.[10] In addition, extrapolations from early animal models led to the belief that large amounts of water are aspirated into the lungs; however, these models were based on controlled massive aspirations, and the true volume experienced during a typical drowning, while unknown, is likely much smaller. Once water enters the airway, injury can occur through direct alveolar damage and surfactant washout. Subsequent bronchospasm, atelectasis, and pulmonary edema all lead to ventilation-perfusion mismatch, resulting in hypoxia.[9] As hypoxia worsens, reversible and irreversible systemic effects begin to take place.

Neurologic Effects

Traditionally, drowning has been viewed as a process affecting the pulmonary system; however, a more accurate description of drowning includes effects on the brain. Neurologic damage secondary to hypoxia is an often devastating sequela, and minimizing this damage is the foundation of treatment. Irreversible acute neuronal injury and the resulting pathologic changes (demyelination, tissue death, edema, hemorrhage) can lead to chronic morbidity, ranging from mild cognitive impairment to a persistent vegetative state.

Cardiovascular Effects

Initially, panic and physical effort lead to sinus tachycardia. In individuals with underlying cardiac disease, this stress on the heart may lead to ischemia, infarction, and dysrhythmias. As systemic hypoxia and acidosis worsen, bradycardia and eventual cardiac arrest follow. In drowning patients who are found to be in cardiac arrest, pulseless electrical activity (PEA) and asystole are the most common arrhythmias, owing to the hypoxic nature of the injury.[9] Hypoxic myocardial dysfunction, as well as immersion diuresis, can lead to systemic hypotension, further exacerbating cardiac and neurologic injury.

A 2012 review focused the role of autonomic conflict as a possible cause of death in cold-water (< 15°C) drowning cases.[11] Autonomic conflict describes the simultaneous sympathetic (cold-shock response) and parasympathetic (mammalian-diving response) stimulation on the cardiovascular system and the resulting dysrhythmogenic effects during sudden immersion in cold water. The authors of this review suggested that the dysrhythmias occurring due to autonomic conflict, rather than drowning, could be the cause of death in cold-water submersion cases.

Pulmonary Effects

Even the small volumes of water that enter the airway can cause pulmonary injury. The initial insult can be a result of airway inflammation, surfactant washout, and direct alveolar injury. With disruption of the surfactant layer, alveolar collapse ensues, and permeability of the alveolar-capillary interface increases.[9] Much attention has been placed on the effects of water salinity on pulmonary fluids shifts, but most of the data on this topic have been derived from animal models involving massive and controlled aspirations, and the true differences in human subjects are not well understood. In addition, no definitive clinical difference has been revealed in the literature. Aspiration of debris from petroleum, sewage, sand, and organic matter contaminants can lead to further pulmonary inflammation, infection, and increased morbidity and mortality.[12] No matter the physiologic changes, the direct injury coupled with airway obstruction and bronchospasm result in ventilation-perfusion mismatch and systemic hypoxia.

Renal Effects

During immersion, peripheral vasoconstriction and surrounding hydrostatic effects may result in increased pressure sensed by the kidneys and increased urination. This effect is more prominent in cold water and may exacerbate hypotension caused by systemic hypoxia. In addition, struggle during the drowning process may lead to rhabdomyolysis, resulting in renal damage.[13]

Differential Diagnosis

Most commonly, the physical inability to maintain one's airway above the surface of the water is the primary cause of drowning. Less often, an underlying medical or traumatic condition may be the cause. The following differential diagnoses, which have all been associated with increased risk for drowning death, may be considered as causes for, or results of, the drowning event.

Intoxication

A 2004 systematic review found that alcohol was detected in 30% to 70% of patients who died from drowning associated with boating accidents.[14] While the detection of illicit drugs or alcohol may not change the overall management of these patients, it may help differentiate the cause of continued altered mental status despite reversal of systemic hypoxia, and it may guide disposition.

Cardiac Disease

In a study of autopsy findings from drowning victims, 44% of the elderly study population (77 of the 168 patients were aged ≥ 60 years) had evidence of coronary artery disease. Of the coronary artery disease group, 10% had evidence of recent myocardial infarction or thrombosis.[15] In addition, channelopathies (specifically long QT syndrome) have been associated with cases of fatal drowning, although a causal relationship has not been established. In a postmortem study evaluating myocardial biopsies of 35 unexplained drowning deaths, 8 patients were found to have mutations associated with long QT syndrome.[16] Additionally, an autopsy study of a 19-year-old who died from drowning found genetic evidence of long QT syndrome, which led to further testing and diagnosis of the syndrome in other family members.[17] While it is difficult to determine the true relationship these cardiac conditions have with drowning deaths, it seems reasonable that any condition that places the heart at an increased risk of hypoxic injury would, in turn, increase the risk of sudden cardiac death associated with drowning.

Seizures

In a 2008 meta-analysis evaluating 51 papers representing 88 drowning deaths, the authors calculated a standardized mortality ratio of 18.7 in victims with seizure disorders when compared to a general population cohort.[18] Additionally, a study by Chang et al analyzing cause-of-death data from the United States found an odds ratio of 2.56 for drowning as an external cause of mortality associated with epilepsy.[19]

Trauma

Trauma leading to drowning can occur from falls into water, impact with the bottom while diving, and boating accidents. The most pertinent and clinically significant injury associated with drowning is cervical spine injury. In 2 studies evaluating traumatic injuries in drowning victims, the overall prevalence was low. The first, analyzing 2244 drowning patients over a 22-year period, found 11 patients (0.5% of the total) with cervical spine injury. Six of these patients died before care was initiated, and the remaining 5 patients all had high-risk injuries (4 diving, 1 plane crash). All of the injured patients had obvious signs of serious trauma and an altered mental state.[20] The second study, analyzing 143 pediatric drowning patients, found 7 patients (4.9%) with traumatic injuries, all of which were cervical spine injuries and all of which had known high-risk events (6 diving, 1 assault).[21]

Suicide Or Homicide

Though not usually included in national drowning statistics, suicide and homicide by drowning are well documented in the literature. A 1999 study in Broward County, Florida found that 3% of all suicides and 7% of elderly suicides in the county involved drowning.[22] These injuries often occur in conjunction with alcohol, illicit drug use, or intentional overdose. Suspicion for homicide may be especially important for cases of pediatric drowning death, in which there is a known history of nonaccidental trauma or in which the caregivers' story is questionable (eg, a nonambulatory infant climbing into a bathtub).

Prehospital Care

Rescue

Following a drowning, the greatest chance for a treatment benefit occurs in the prehospital setting. The drowning process results in hypoxia, and the faster this is reversed, the better chance a patient has for survival with good neurologic outcome. In some instances, initiating this treatment may be preceded by the need to remove the patient from the water. Unfortunately, there is a high prevalence of rescuer death associated with individuals lacking formal water-rescue training who enter the water to enact a rescue. In 2 consecutive Turkish studies, a total of 116 drowning incidents over a 4-year period resulted in 145 rescuer deaths (some of these cases involved multiple rescuer deaths).[23,24] Another study describes 26 rescuer deaths in Australia alone over a 5-year time period.[25] As difficult as it may be for a layperson or rescue personnel to refrain from immediately entering the water to assist a victim, alternative means for reaching the victim should always be considered first.

Resuscitation

Once the patient is removed from the water, initiate a rapid evaluation of the patient's airway, breathing, and circulation (ABC) status. It should be noted that patients who are hypothermic might have very weak pulses and respiratory effort. In these patients, perform the initial evaluation for at least 30 to 60 seconds, since administering cardiopulmonary resuscitation (CPR) on a hypothermic patient who still has organized cardiac activity may trigger a life-threatening dysrhythmia. For any patient who is found to be in cardiac arrest, initiate CPR (using ventilations and compressions) and arrange rapid transport to advanced care. Given the hypoxic nature of drowning, PEA and asystole are the most common life-threatening arrhythmias found. A minority of patients may be in ventricular fibrillation, and an automated external defibrillator (AED) or manual defibrillator may be utilized, though the reversal of the dysrhythmia will likely not occur unless the underlying hypoxia is improved.

If the patient has a pulse but is in respiratory distress or arrest, establish and maintain a patent airway and provide positive-pressure ventilations with 100% oxygen during transport. Any stable patient displaying symptoms (foam in the airway, cough, emesis) should be transported as well, with the understanding that these mild to moderate cases may experience clinical deterioration over the following 4 to 8 hours. During transport, initiate bolus intravenous fluid administration in hypotensive patients. No other medications, including bicarbonate, steroids, or diuretics, have been found to improve outcome in drowning patients.[9]

As previously mentioned, hypothermic patients require additional considerations. These patients may be hypothermic from falling into cold water, or from prolonged exposure to any temperature of water. Any movement must be gentle in nature, to avoid inciting dysrhythmias in the vulnerable hypothermic myocardium. The priority of treatment remains airway stabilization and ventilation support, but cessation and reversal of systemic hypothermia must also begin in the prehospital setting. The rewarming method should be based on the patient's condition and available resources. For the mildly hypothermic patient (32°C-34°C) who is still shivering, removal from the cold environment, removal of wet clothing, and the application of insulating materials for transport to the hospital is sufficient. In patients with moderate to severe hypothermia (< 32°C) or in patients who have lost their shivering mechanism, utilize active rewarming techniques (such as warmed inhaled oxygen, warmed intravenous fluids (40°C-44°C), and forced-air blankets), and expedite transportation to advanced care.[26,27] Consider transferring patients with severe hypothermia to centers capable of extracorporeal membrane oxygenation (ECMO), as studies have shown ECMO to be beneficial in such cases.[28] (See the "Extracorporeal Membrane Oxygenation" section on page 11.)

Prehospital Outcome Data

Currently, a single study out of Brazil provides the best evidence for outcomes associated with prehospital physical examination findings and outcomes after drowning. This 1997 study included 1831 cases over a 19-year span, all of which were evaluated in the prehospital setting by a physician in a "near-drowning resuscitation center." Of the cases analyzed, 195 (10.6%) died, with 166 dying before transportation to the hospital. From this data, a drowning classification system correlating physical examination findings with mortality rates was created.[29] **(See Table 1.)**

Table 1. Szpilman Classification For Drowning[29]

Grade	Examination Findings	Mortality (%)
1	Mild or no cough Lungs clear	0
2	Cough Rales in some lung fields	0.6
3	Foam in airway Rales in all lung fields	5.2
4	Foam in airway Rales in all lung fields Hypotension	19.4
5	Respiratory arrest	44
6	Cardiac arrest	93

Emergency Department Evaluation

All patients presenting to the emergency department (ED) following a drowning event should receive rapid triage and evaluation. The initial approach includes evaluating and stabilizing the patient's ABCs, determining the patient's mental status, obtaining initial vital signs, and evaluating the patient for associated trauma following the Advanced Trauma Life Support® (ATLS®) protocols or a similarly structured approach. Attend to any abnormal findings which may result in clinical decompensation before moving on with the rest of the examination. Once the initial examination is complete, perform a more thorough secondary survey, evaluating for detailed neurological findings (pupils, cranial nerves, extremity strength) as well as evidence of trauma. If there is suspicion for cervical spine injury, based on history or examination, and the patient cannot cooperate with the examination, maintain inline stabilization and place a cervical collar.

In addition to the patient evaluation, document any scene information obtained by prehospital caregivers or witnesses. **Table 2** provides information on the relevant historical findings that may assist in long-term treatment and prognosis.

Diagnostic Testing

Laboratory Studies

Patients with mild symptoms and normal oxygen saturation do not warrant specific laboratory testing. Early studies on canines found electrolyte abnormalities and hemodilution, but this was in the context of controlled massive fluid aspiration.[30] No study, to date, has found clinically significant electrolyte changes or hemodilution due to drowning, except in cases of drowning in the Dead Sea, in which hypercalcemia and hypermagnesemia have been documented.[31] In addition, obtaining arterial blood gas levels is unnecessary in well-appearing, normoxic, asymptomatic patients.

Patients displaying moderate to severe symptoms, or patients for whom a detailed history cannot be obtained may benefit from laboratory testing to further evaluate continued altered mental status, cardiac disease, rhabdomyolysis, and other conditions affected by or related to the drowning incident. **See Table 3** for tests that may aid in further evaluation of sequelae from the drowning event.

Table 2. Relevant History In Drowning Events

- Submersion time (estimated from bystanders)
- Estimated water temperature
- Witnessed events (water activity, fall from height, seizure, evidence of cardiac event)
- Bystander interventions
- Initial prehospital examination findings (ABCs, Glasgow Coma Scale score)
- Prehospital interventions

Abbreviation: ABCs, airway, breathing, and circulation.

Imaging

Chest X-Rays

ED and inpatient studies have found little correlation between initial chest x-rays and clinical course, arterial blood gases, or outcome.[32] One study of admitted patients found that patients who developed acute lung injury or ARDS often had abnormal x-rays in the first few hours, although not necessarily on arrival to the ED.[33] Obtain a chest x-ray in cases of respiratory distress or arrest, hypoxia, history of trauma, or worsening altered mental status. In addition, when observing a patient with mild symptoms, obtain an x-ray if new symptoms develop during the observation period.

Head Computed Tomography

The existing literature has found little correlation between a normal initial head computed tomography (CT) scan and long-term prognosis following a drowning event.[34] In addition, multiple studies have found that an abnormal head CT in the first 24 to 36 hours portends a poor prognosis. In 1 pediatric study analyzing 156 drowning patients who all received head CT within 24 hours of admission, all patients with an abnormal initial head CT died, and all but 1 patient with a normal initial CT but an abnormal follow-up head CT, died.[35] Similar results were found in a different study, which analyzed 14 patients who were comatose following asphyxial injuries (3 pediatric drownings).[36]

Table 3. Diagnostic Tests To Consider For Patients With Moderate To Severe Symptoms After A Drowning Event

Symptoms	Laboratory Testing
Altered mental status	• Arterial blood gas • Blood glucose • Serum ethanol
Cardiac disease	• Cardiac enzymes • Electrocardiogram
Rhabdomyolysis	• Creatine kinase • Potassium • Serum creatinine • Electrocardiogram
Trauma	• Complete blood count • Basic metabolic panel • Coagulation panel • Type and screen

Based on the best available evidence, a head CT is only recommended in cases in which a traumatic brain injury is suspected in patients with an altered mental status, and in patients with a focal neurologic deficit. Clinical decision tools, such as the Canadian CT Head Rule, should be utilized to aid in risk stratifying patients.[37] In a patient displaying continued altered mentation with a normal initial CT in the ED, further prognosis will require subsequent clinical evaluation and radiologic study in the inpatient setting.

Cervical Spine Imaging

As previously discussed, the overall prevalence of cervical spine injury in drowning patients is small, and routine imaging for all patients is unnecessary. In patients who are known to have been involved in high-risk activities and who are unable to participate in a focused cervical spine examination, imaging of the cervical spine is indicated, as long as it does not impede initial resuscitation and ventilation. Clinical decision tools, such as the National Emergency X-Radiography Utilization Study (NEXUS) and the Canadian C-spine Rule (CCR), should be used to aid in risk stratifying patients. In patients who are alert, who can cooperate with the evaluation, and who do not meet any high-risk criteria as defined by NEXUS or CCR, cervical spine imaging is unnecessary. Current guidelines recommend CT as the imaging modality of choice if cervical spine injury is suspected.[38]

Treatment

Initial Resuscitation

The primary goal in the management of drowning patients is reversal of systemic hypoxia. The initial ED evaluation and treatment focuses on establishing and maintaining a patent airway, along with delivery of oxygen. For patients with mild symptoms, place a nonrebreather mask or nasal cannula to keep oxygen saturation > 90%. If patients have evidence of bronchospasm, nebulized beta agonists may be administered as well. Successful use of NIPPV has been described in a case report that included 2 moderately to severely ill drowning patients (aged 13 and 19 years).[39] In these patients, endotracheal intubation was avoided. However, consider the risk of aspiration when using NIPPV in altered patients who are prone to emesis following a drowning event. If less-invasive methods of oxygenation fail or if the patient continues to experience worsening respiratory symptoms, altered mentation, or emesis, consider performing endotracheal intubation to protect the airway. For any patient who presents in respiratory distress and is unable to protect his or her airway, prioritize intubation as soon as possible and place the patient on mechanical ventilation.

Oxygen Delivery

Concern has been raised over providing high levels of oxygen (ie, hyperoxia) following cardiac arrest due to evidence that this may cause neuronal injury and lead to decreased survival to discharge. A 2012 study evaluated 10 controlled animal studies, all of which compared neurologic outcome after varying levels of oxygenation, based on either a neurological deficit score or histological assessment of neuronal death.[40] The authors of the study concluded that there is evidence that administration of 100% oxygen following the return of spontaneous circulation (ROSC) may lead to increased neuronal damage and worsen neurologic outcome; however, the actual generalizability to humans remains unknown.

In 2014, Wang et al published a systematic review and meta-analysis evaluating 14 human observational trials.[41] From the articles analyzed, these authors concluded that hyperoxia correlates with increased inhospital mortality, though the number of articles was small, no controlled trials were included, and there was significant heterogenicity among study parameters. The most important weakness of these studies when used to guide the treatment of a drowning patient is that they likely do not reflect the unique pathophysiology of asphyxial cardiac arrest. In all but 1 of the animal studies, cardiac arrest was induced using electrical or chemical means, and in the majority of human studies, the initial rhythm was unknown. Additionally, these studies all focus on the post-ROSC phase of resuscitation.

A 2013 prehospital study utilizing arterial blood gas measurements during active CPR in 145 patients found a significant increase in survival to hospital admission with increasing partial pressure of oxygen (PaO_2).[42] During the resuscitation of a drowning patient, utilize the most concentrated and effective means of oxygen delivery in light of the hypoxic nature of the injury. Given the possibility of increased neuronal injury, the lack of confirmed benefit to hyperoxia, and the possibility of hyperoxic lung injury, after initial resuscitation and airway stabilization, titrate oxygen concentration to keep oxygen saturation (SaO_2) at 90% to 95%.

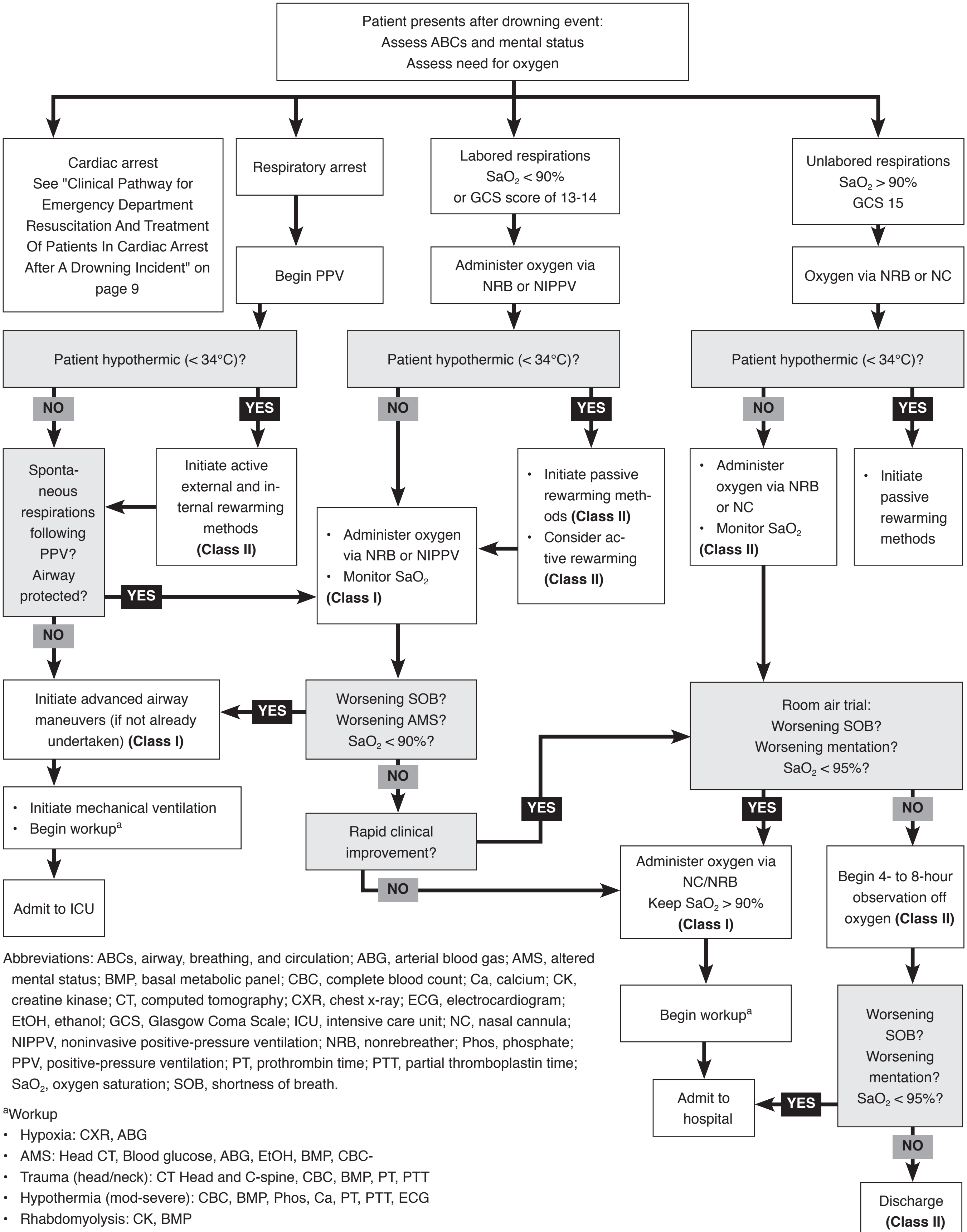
Hypotension

Systemic hypoxia and urinary losses during the drowning process can lead to hypotension. Upon arrival to the ED, aggressively treat hypotension with intravenous crystalloids. Reversal of systemic hypoxia and administration of intravenous fluids should improve perfusion, but hypotension refractory to these measures may require vasopressors. No specific agent is preferred or has been proven to be more beneficial than another.

Accidental Hypothermia And Advanced Cardiac Life Support Controversy

There are many case studies reporting the normal neurologic outcome of hypothermic patients follow-

Clinical Pathway For Emergency Department Resuscitation And Treatment Of Patients Involved In A Drowning Event



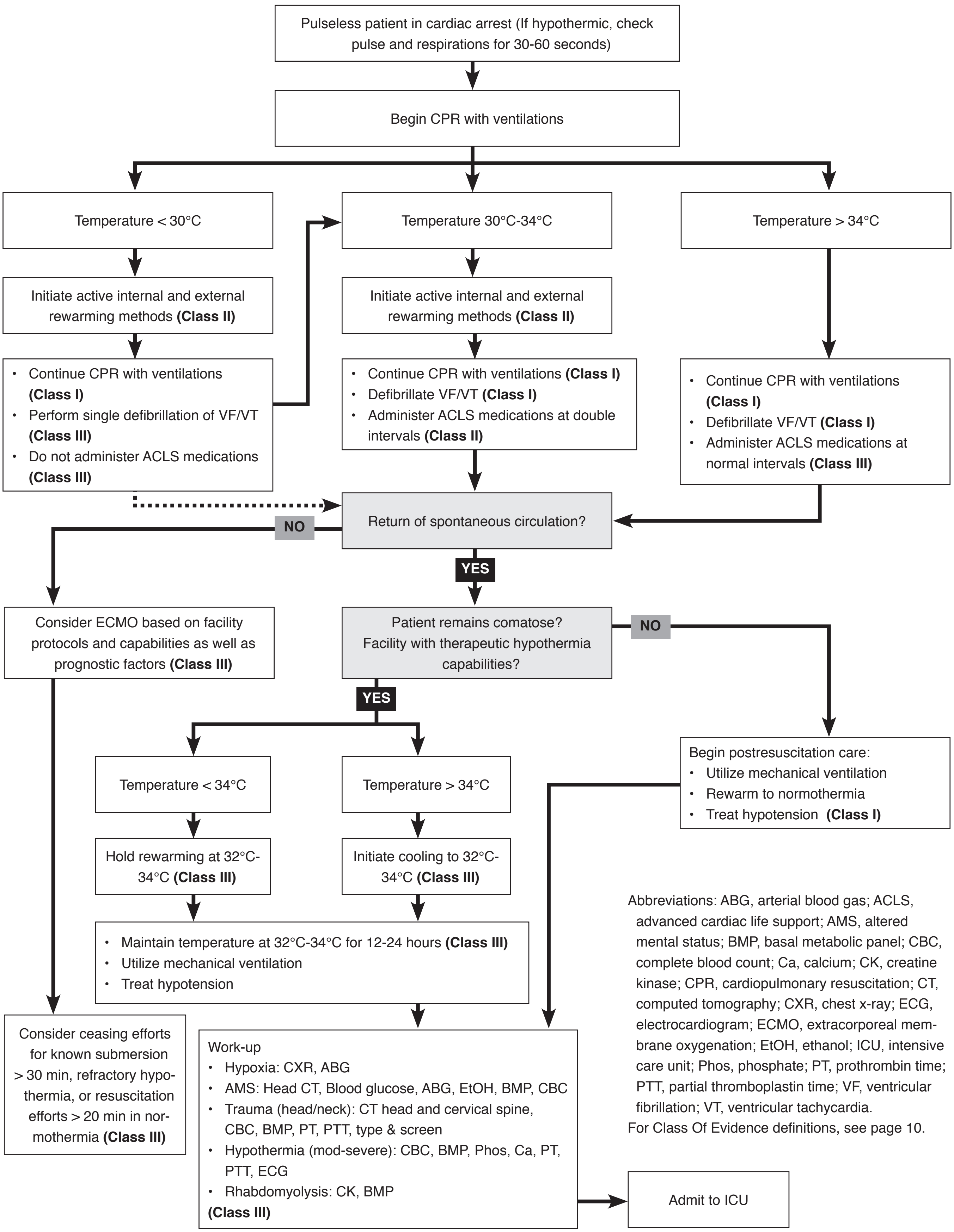
Abbreviations: ABCs, airway, breathing, and circulation; ABG, arterial blood gas; AMS, altered mental status; BMP, basal metabolic panel; CBC, complete blood count; Ca, calcium; CK, creatine kinase; CT, computed tomography; CXR, chest x-ray; ECG, electrocardiogram; EtOH, ethanol; GCS, Glasgow Coma Scale; ICU, intensive care unit; NC, nasal cannula; NIPPV, noninvasive positive-pressure ventilation; NRB, nonrebreather; Phos, phosphate; PPV, positive-pressure ventilation; PT, prothrombin time; PTT, partial thromboplastin time; SaO_2, oxygen saturation; SOB, shortness of breath.

[a]Workup
- Hypoxia: CXR, ABG
- AMS: Head CT, Blood glucose, ABG, EtOH, BMP, CBC-
- Trauma (head/neck): CT Head and C-spine, CBC, BMP, PT, PTT
- Hypothermia (mod-severe): CBC, BMP, Phos, Ca, PT, PTT, ECG
- Rhabdomyolysis: CK, BMP

(Class III)

For Class Of Evidence definitions, see page 10.

Clinical Pathway For Emergency Department Resuscitation And Treatment Of Patients In Cardiac Arrest After A Drowning Incident



Abbreviations: ABG, arterial blood gas; ACLS, advanced cardiac life support; AMS, altered mental status; BMP, basal metabolic panel; CBC, complete blood count; Ca, calcium; CK, creatine kinase; CPR, cardiopulmonary resuscitation; CT, computed tomography; CXR, chest x-ray; ECG, electrocardiogram; ECMO, extracorporeal membrane oxygenation; EtOH, ethanol; ICU, intensive care unit; Phos, phosphate; PT, prothrombin time; PTT, partial thromboplastin time; VF, ventricular fibrillation; VT, ventricular tachycardia.

For Class Of Evidence definitions, see page 10.

ing prolonged submersion (most often children with rapid immersion in very cold water [< 5°C]), but these cases are rare. In general, accidental hypothermia in a drowning patient signifies a prolonged submersion and portends a poor prognosis. In the initial resuscitation of any hypothermic drowning patient, begin rewarming the core early. For patients in cardiopulmonary arrest, initiate active rewarming techniques during the initial resuscitation. **(See Table 4, page 11.)**

Defibrillation and medication administration in the case of severe hypothermia (≤ 30°C) continues to be an area of contention. The theoretical concern that the hypothermic myocardium will likely not respond to these treatments and the possibility of toxic serum levels of medications due to decreased metabolism has led to recommendations for withholding medications until the patient's body temperature reaches 30°C, restricting defibrillation to a maximum of 3 attempts, and doubling medication administration intervals for temperatures ranging from 30°C to 34°C.[43] Recent animal models have shown possible benefit to standard treatments despite severe hypothermia, but human data are lacking. Currently, the American Heart Association cites a possible benefit to the use of vasopressors during severe hypothermia, while the European Resuscitation Council continues to recommend withholding medications.[44] In addition, the recent Wilderness Medical Society practice guidelines withhold medication recommendations given the limited evidence, and call for a single defibrillation attempt until warming is initiated.[26] Based on the paucity of high-quality data and heterogeneity of guidelines, no formal recommendations can be made other than continuing active rewarming during the resuscitation phase, with the knowledge that this will likely improve the chances for ROSC no matter what regimen is followed.

While there is no standard duration of resuscitation or goal core temperature, it is generally accepted that attempts should be made to increase core temperature to 32°C to 34°C before ceasing resuscitative efforts. If a patient is successfully resuscitated and remains comatose, consider maintaining core temperature at 32°C to 34°C and initiating therapeutic hypothermia measures, if your facility, resources, and training allow.

For an otherwise healthy patient with mild hypothermia and an intact shivering mechanism, remove any remaining wet clothing, dry the patient's skin, and place the patient under insulating blankets in a warm room. The patient's innate heat-producing mechanisms should be sufficient as long as further heat loss is minimized. For moderate to severe hypothermia, or for mildly hypothermic patients who are elderly, have multiple comorbidities, or who cannot produce a shivering mechanism, initiate active rewarming techniques, with a goal of normothermia.

Mechanical Ventilation

No standard ventilation strategy has been universally accepted for drowning patients. Most recent reviews and recommendations call for an ARDS-focused strategy, due to the similar pulmonary disease pattern that critically ill drowning patients often develop, although given the temporary nature of the inciting event, resolution of pulmonary injury is often faster than with ARDS following sepsis.[9] **(See Table 5, page 11.)** This strategy incorporates a lung-protective approach based on utilizing low tidal volumes, augmenting positive end-expiratory pressure (PEEP) and fraction of inspired oxygen (FiO_2) to optimize oxygenation, and avoiding increased plateau pressures.[45]

If hypoxia is refractory to initial ventilation strategies, salvage strategies, such as prone positioning and airway pressure release ventilation, have been recommended, but few cases exist in the literature. These strategies may be considered in consultation with a pulmonary critical care team. For additional information on mechanical ventilation strategies, see the September/October 2014 *EM Critical Care* issue titled "Ventilator Management And Troubleshooting In The Emergency Department," available at: http://www.ebmedicine.net/ventilatortroubleshooting.

Class Of Evidence Definitions

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

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

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

Class II
- Safe, acceptable
- Probably useful

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

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

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

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

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

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

Therapeutic Hypothermia

While the literature suggesting a neuroprotective benefit to therapeutic hypothermia primarily deals with out-of-hospital cardiac arrest from nonasphyxial causes, a growing number of cases describing its use in drowning patients are being reported. In 2002, the World Congress on Drowning released recommendations on the use of therapeutic hypothermia in drowning patients who remain comatose after initial resuscitation. In addition, the recommendations called for suspending rewarming techniques in patients found to be hypothermic, once core temperature reaches 32°C to 34°C.[3] These recommendations were extrapolated from the out-of-hospital cardiac arrest data. To date, most of the data specific to drowning patients are in the form of single-patient case studies.[46] In a study of 20 drowning patients, all of whom underwent therapeutic hypothermia, the authors concluded that therapeutic hypothermia did not improve survival with good neurologic outcome, although the study population was small and no control group was used.[47]

Another study evaluated the use of therapeutic hypothermia in 14 patients who were found to be comatose following asphyxial injuries (hanging, drowning, and carbon monoxide or methane exposure). In this study, all 3 drowning patients were children, and the authors were unable to provide evidence showing a clear benefit from therapeutic hypothermia in this patient population.[36] Recently, a Korean study evaluated patients who underwent therapeutic hypothermia following asphyxial cardiac arrest due to foreign body ingestion, asthma/chronic obstructive pulmonary disease/pneumonia, or confinement in a low-oxygen environment, but none due to drowning. In this generally older population (average age 65 years), survival with good neurologic outcome was low (5%), and no control group was included.[48]

While there are no controlled studies confirming a benefit to therapeutic hypothermia use in drowning patients, no studies, to date, have shown any harm to patients by using this treatment modality. Given the importance of neuroprotective strategies following cerebral anoxia and the evidence of benefit in nonasphyxial out-of-hospital cardiac arrest, it may be reasonable to initiate therapeutic hypothermia in patients who remain unresponsive after initial resuscitation following cardiac arrest due to drowning, as long as this treatment takes place in a facility with the experience, training, and resources to efficiently initiate and maintain this treatment for 12 to 24 hours. Additionally, in patients who are initially hypothermic, consider holding rewarming efforts once core temperature reaches 32°C to 34°C, and maintain this temperature for the specified duration, with the understanding that, given the paucity of evidence, this treatment should not impede basic resuscitation of the patient.

Extracorporeal Membrane Oxygenation

The use of ECMO in the treatment of drowning has become more prevalent in the last decade. The data for its use following drowning are primarily in the form of case reports and small series, as this is often used as a salvage treatment for refractory hypoxia and hypothermia.[49] Its protocolized use in the acute resuscitation of drowning cardiac arrest has been reported in the literature. The most impressive case series involved the treatment of 7 pediatric and adult patients following a boating accident. All 7 patients were placed on ECMO within 178 to 241 minutes of the incident, and all 7 survived to discharge (6 with mild to moderate neurologic deficits and 1 with severe deficits).[28] While reports like this do tend to spark conversation about the ethics of resuscitating individuals who have a high likelihood of chronic neurologic sequelae, they show promise

Table 4. Active Rewarming Techniques

Active External Rewarming
- Forced-air warming blankets
- Radiant heaters
- Warm water bath
- Warming mattress

Active Internal Rewarming
- Warmed intravenous fluids
- Warmed inhaled oxygen
- Warmed bladder irrigation
- Peritoneal lavage
- Thoracic lavage
- Hemodialysis
- Extracorporeal membrane oxygenation
- Cardiopulmonary bypass

Table 5. Acute Respiratory Distress Syndrome Ventilation Strategy[45]

Initial Settings	
1	Set initial tidal volume (V_T) = 8 mL/kg (predicted body weight)
2	Set initial rate (RR) to deliver expected minute ventilation (7-9 L/min) [max RR of 35 breaths/min]
3	Set initial PEEP = 5 cm H_2O
4	Set initial FiO_2 = 100%
Oxygenation Goal (PaO_2 = 55-80 mm Hg or SpO_2 = 88%-95%)	
1	Titrate FiO_2 < 70% when feasible
2	Utilize increased PEEP to meet goals
Plateau Pressure (P_{PLAT}) goal (≤ 30 cm H_2O) If P_{PLAT} > 30 cm H_2O, decrease V_T by 1 mL/kg increments (minimum = 4 mL/kg)	

Abbreviations: FiO_2, fraction of inspired oxygen; H_2O, water; PEEP, peak end-expiratory pressure; P_{PLAT}, plateau pressure; RR, respiratory rate; VT, tidal volume.

for protocol-based systems that can provide access to this treatment rapidly with hope for improved inclusion criteria to optimize outcome.

Two recent adult studies have been published evaluating the use of ECMO in the initial resuscitation phase of drowning and in severely hypothermic patients. The first included 20 patients over an 11-year period and followed a protocolized ECMO resuscitation. All patients were in asystole on arrival to the hospital. In this study, only 4 patients survived to 24 hours, 2 survived to hospital discharge, and 1 of these patients had severe neurologic deficits.[50] Given the initial poor prognosis of this cohort (asystole, hypothermia), the outcomes are not surprising, but this study does show the feasibility of such a system, which may benefit patients presenting in cardiac arrest following drowning. The second study primarily focused on ECMO resuscitation of cardiac arrest patients presenting with severe hypothermia, and 12 of the 26 patients included were drowning patients. All 26 patients in the study group had ROSC after ECMO, compared to 10 of 32 of patients in the group that did not undergo ECMO. From the ECMO group, 10 of the 26 patients were discharged from the hospital with good neurologic outcome. Statistically significant predictors of poor outcome were asphyxial cause of cardiac arrest and asystole on arrival, with only 2 of the 14 patients in the asphyxia group discharged with good neurologic outcome.[51] Both of these studies show that, despite advances in ECMO and improvement in time to treatment, the severity of the initial drowning injury still predicts outcome. This is in line with other non-ECMO studies that have found a correlation between nonshockable rhythm and poor outcome. (See the "Prognostic Indicators" section on page 13.)

Medications

In the past, diuretics, empiric antibiotics, and corticosteroids were often given as part of the initial treatment of drowning patients. Over the past 3 decades, the literature has failed to provide evidence to support any of these treatment regimens. Drowning patients, especially those with severe injury, may present with nonspecific fevers and chest x-ray infiltrates early in the clinical course; however, these are findings that do not necessarily equate to an infectious process.[52]

In a retrospective study evaluating tracheal aspirates and broncho-alveolar lavages in 21 patients who subsequently developed confirmed pneumonias, the causative organisms were often resistant to standard empiric treatment.[53] The best approach is to focus on adequate initial resuscitation and stabilization and to monitor the patient for signs of pulmonary infection throughout the clinical course. If clinical evidence of pulmonary infection develops, treatment regimens should be guided by tracheal aspirate, bronchial lavage, or blood cultures.

A systematic review evaluating the use of corticosteroids in drowning patients found that most studies were small, poorly designed, and lacked controls.[54] No harm was found by administration of corticosteroids, but, given the lack of clear benefit and the potential for immunosuppression, their empiric use is not recommended for drowning patients. They may be considered during the clinical course as indicated by additional disease states.

Ceasing Resuscitative Efforts

An often difficult decision to make, and one that is not supported by robust evidence, is whether or not to prolong resuscitation efforts in a victim of drowning. This decision is further complicated by the understanding that survival after prolonged hypoxia may result in severe neurologic sequelae and by reports (albeit rare) of survival with good neurologic outcome after prolonged submersion and resuscitation.[46] Most of the data on this topic come from pediatric literature, and this population, in general, experiences better outcomes than the adult population.

A 2011 literature review and analysis of 43 drowning cases was conducted in an effort to establish a tool to assist search-and-rescue teams in making the decision of whether or not to continue their efforts. From this analysis, the authors concluded that survival is unlikely after 30 minutes of submersion in water > 6°C and after 90 minutes of submersion in water < 6°C. Of note, the majority of the cases analyzed were pediatric patients, and, as the focus of the study was primarily on search-and-rescue efforts, limited information regarding prehospital and hospital treatment was provided.[55] During the resuscitation of a hypothermic patient, efforts should be made to rewarm the patient to a core temperature > 32°C before ceasing the resuscitation, although in some patients this may not be possible.[26,27]

Disposition

Emergency Department Disposition

After the patient is stabilized in the ED, physical examination findings and response to treatment guide the decision to observe, admit, or discharge the patient. The fear of "secondary drowning," a condition which has not been proven in the literature to exist, has often led to an unnecessarily high rate of admissions for mildly symptomatic patients. Three studies have specifically evaluated disposition following drowning incidents. The first, a prospective study of pediatric and adult patients (mean age of 21 years) rescued from the ocean, includes 21 patients who were transported to the hospital and 31 patients who were released on the scene. Of the hospital patients, 12 were admitted to the intensive care unit (4 were intubated) for severe respiratory distress, 7 were discharged from the ED (mean time of 2.6 hours, range of 1-6 hours), and 1 was transferred to another facility and discharged the next day. Follow-up phone interviews with the patients released on the scene and discharged from the ED (33 patients total) found no delayed symptoms or returns to the hospital.[56]

Two retrospective pediatric studies evaluated a total of 120 drowning patients. In the first, of those patients who initially were asymptomatic but developed symptoms during their stay, symptoms appeared within 4.5 hours in all but 1 patient (in this patient, symptoms developed at 7 hours, and the patient had a good outcome).[57] In the second study evaluating patients who presented with a Glasgow Coma Scale score > 13, 100% of the patients recovered without any neurologic deficit, and any worsening of baseline symptoms occurred within 4 hours of presentation.[32] Based on this literature, recommendations on patient disposition can be made, with the understanding that data for the adult population are still lacking and that a more conservative approach may be warranted for patients with comorbidities sensitive to hypoxia. **(See Table 6.)**

Prognostic Indicators

Considerable focus has been placed on determining which historical, physical examination, or laboratory findings can be used to determine patient prognosis. Unfortunately, despite decades of research on this topic, most studies have yielded weak data or conflicting results and have generally shown that most clinical factors do not have adequate prognostic value. In patients who experience cardiac arrest secondary to drowning, a witnessed event, bystander CPR, shorter EMS arrival time, and a shockable rhythm have all been shown to correlate with survival to hospital admission, but not necessarily good neurologic outcome.[58-60]

The primary factor that has continuously been associated with survival with good neurologic outcome is short submersion time.[61] This finding, once again, highlights the importance of prehospital care and early reversal of hypoxia. Many of the studies focusing on prognosis come from pediatric literature, and the studies that include both adults and children have shown that adults, in general, have worse outcomes. Other factors that have shown promise in a few studies but display high variability in statistical significance are initial Glasgow Coma Scale scores and pupillary response. These are used as markers of cerebral and brainstem activity and are thought to represent the extent of hypoxic brain injury; however, both are impacted by hypothermia.[62]

Table 6. Disposition Of Patients Involved In Drowning Incidents

- Patients with no symptoms can be observed for 4-8 hours and discharged if no new symptoms develop and room air SaO_2 remains normal.
- Patients with mild symptoms and normal mentation should be observed for 4-8 hours in the ED, and can be discharged if symptoms improve and room air SaO_2 is normal.
- Patients with hypoxia refractory to oxygen via NRB/NC, continued shortness of breath, or altered mental status after 4-8 hours should be admitted for further observation and management.
- Patients requiring admission following observation, but not in critical condition 4-8 hours after presentation, can be managed in a ward bed.

Abbreviations: ED, emergency department; NC, nasal cannula; NRB, nonrebreather mask; SaO_2, oxygen saturation.

Prevention

Most of the literature and recommendations on the prevention of drowning focuses on the pediatric population, with close supervision, pool fencing, and swimming lessons all showing survival benefit.[63] Although no peer-reviewed literature exists describing the relationship between swimming ability and the risk of drowning in the adult population, it is the opinion of this author that familiarization with and confidence in the aquatic environment would decrease the risk of drowning in adults. Risk factors specific to adults are alcohol use, participation in high-risk activities, and the lack of life jacket use while boating. Minimizing these factors in the aquatic environment has the greatest potential for drowning prevention in the adult population. In addition, swimming in the presence of a lifeguard will likely provide the best chance of efficient rescue and access to treatment in the event of a drowning incident. Emergency clinicians should be encouraged to counsel patients on these preventative measures.

Controversies And Cutting Edge

Swimming-Induced (Immersion) Pulmonary Edema

Over the past 30 years, the acute onset of shortness of breath and pulmonary edema have been described following strenuous water activity such as long-distance swims and military training. The terms swimming-induced pulmonary edema and immersion pulmonary edema have both been used to describe this syndrome. Immersion pulmonary edema is also used in diving and hyperbaric medicine to describe a similar syndrome associated with diving with compressed gas. Most of the data on these symptoms following surface swimming without compressed air are in the form of case series and a single case-control study.[64] In these cases, symptoms are relatively minor in nature and no long-term effects or deaths were reported. In addition, while there is evidence of temporary changes in pulmonary function tests, no changes in cardiac function have been reported. There is 1 abstract of a 2013 article discussing "life-threatening" swimming-induced pulmonary edema following snorkeling, but the full article is not available, and the abstract includes no details of patient presentation or outcome.[65]

If a patient presents with these symptoms following strenuous water activity, a period of observation is warranted, with disposition based on ventilatory status and symptom evolution. While there are no guidelines to assist in the disposition of these patients, those with mild symptoms and no clinical decompensation after 4 to 8 hours can likely be discharged from the ED with strict return precautions. As with drowning, there is no indication for diuresis.

The Heimlich Maneuver

For decades, Dr. Henry Heimlich advocated for the use of abdominal thrusts as the initial treatment modality for drowning patients.[66] This practice was founded on the supposition that the lungs were full of water and must be drained before proper resuscitation could take place. To date, no quality data have been presented to support this practice. Contrary to Dr. Heimlich's concerns, the actual amount of water aspirated into the lungs is likely much smaller than once thought. Most importantly, the application of abdominal thrusts will delay much needed ventilations and likely lead to emesis, further complicating the patient's airway.

The use of the Heimlich maneuver in drowning patients has been criticized repeatedly in the literature

Risk Management Pitfalls In Drowning Patients

(Continued on page 15)

1. **"We have seen a spike in drowning deaths in our community, in addition to low rates of bystander CPR. Our department is going to initiate a campaign to provide compression-only CPR training to the community because it is quick and easy and will improve bystander willingness to help."**
   Drowning is primarily a hypoxic injury, and providing ventilations must be prioritized in the treatment of these patients. Cardiac dysfunction following drowning is likely secondary to systemic hypoxia, and ventilations remain an important component of CPR.

2. **"I am ready to discharge this woman who was rescued from the ocean while drowning. Her respiratory status has been fairly normal, but she keeps complaining of diffuse muscle aches. I think she is probably just worn out from the experience."**
   A significant amount of struggle during a drowning event can cause rhabdomyolysis. In patients with prolonged struggle, or with complaints of muscle aches or change in urine color, monitor serum creatinine kinase, potassium, and creatine levels to assess for rhabdomyolysis.

3. **"The family just arrived for this intubated drowning patient. I told them that he should have a fairly good neurologic outcome because I didn't see any signs of hypoxic injury on the initial head CT."**
   A normal initial head CT has little prognostic value in a drowning patient. However, if the initial CT is abnormal, patients tend to have a worse neurologic outcome.

4. **"When the patient arrived, he was breathing, but he had a large amount of foam coming from his airway. His oxygen saturation was low, so I planned to intubate him, but first I placed him in a recovery position for 2 minutes and tried to clear the airway with suction."**
   Patients who have suffered a moderate to severe drowning injury may have significant foamy material in their airways. While this may complicate further airway maneuvers, positive-pressure ventilations must be attempted despite this foam, and progress toward stabilizing the airway must be prioritized. Time spent attempting to completely clear the airway without providing ventilations will result in worsened systemic hypoxia.

5. **"After initial resuscitation, the chest x-ray had a small right-sided opacity, and the patient had a mild fever, so I decided to cover him empirically for aspiration pneumonia."**
   No studies have shown benefit to providing empiric antibiotics early in the treatment of drowning, unless submersion in a highly contaminated fluid is known. Often, drowning patients will initially have clinical signs of pulmonary infection (x-ray opacities, leukocytosis, and fevers) without an actual infection. These patients are best treated by further monitoring. If evidence of infection appears later in the treatment course, due to the highly atypical nature of pathogens causing pneumonia secondary to drowning, the best course of action is to tailor antimicrobials to tracheal or bronchial aspirate cultures.

and led to a 1995 Institute of Medicine report, in which the authors state that there is no scientific evidence to support its use in the initial treatment of drowning, unless ventilations are unsuccessful and thought to be obstructed by a solid object.[67]

Cervical Spine Immobilization

Once removed from the water, drowning patients are often placed in cervical spine immobilization, for fear of spinal injury that could lead to paralysis. This can be a dangerous practice, and it is not supported by available evidence. By allowing immobilization to be a treatment priority, the initial resuscitation is often suboptimal. In addition, the majority of drowning patients with moderate to severe injury are going to experience emesis from water ingestion and gasping during the drowning process. By placing these patients on a spinal immobilization board and securing the head, rescuers may be placing the patient's airway at risk for obstruction and aspiration. In 2 studies evaluating patients with cervical spine injuries associated with water activities, all had a history of high-risk activities and all had obvious signs of trauma or altered mental status.[20,21] For patients who are alert and oriented, risk stratification can be conducted using NEXUS or CCR criteria, and, in most patients, immobilization is unnecessary. In patients with obvious signs of trauma, or when a detailed history is unknown and the surroundings suggest possible trauma, cervical spine immobilization is indicated, as long as it does not interfere with resuscitation. For patients in respiratory or cardiac

Risk Management Pitfalls In Drowning Patients

(Continued from page 14)

6. **"EMS brought in this man after he fell into an icy lake while fishing. When they got here, I checked for a pulse for 10 seconds and, not feeling one, advised my staff to start CPR."**
   Severely hypothermic patients can often have profound bradycardia or peripheral vasoconstriction, making pulses difficult to palpate. If a hypothermic patient who still has organized cardiac activity receives CPR, this may cause a lethal arrhythmia in the cold myocardium. On arrival, pulse and respiration checks for hypothermic patients should last 30 seconds to 1 minute before initiating CPR. In addition, bedside ultrasound may be utilized to detect cardiac motion, perfusion through peripheral arteries, and respiratory effort.

7. **"After 4 hours in the ED, the patient looked well, had normal vital signs, and no complaints. I just didn't feel comfortable sending him home because I didn't want him to suffer secondary drowning."**
   The available evidence allows for safe discharge after 4 to 8 hours of observation in the ED if the patient has normal mentation and normal vital signs, and no shortness of breath. Admission for further observation is unnecessary at this point. Secondary drowning, an outdated term describing delayed morbidity, does not occur in patients who remain asymptomatic after the initial ED observation period.

8. **"After intubation and stabilization, the initial chest x-ray showed diffuse pulmonary edema. I decided to administer furosemide to facilitate diuresis."**
   Inducing diuresis is a dated treatment modality with no proven benefit. Evidence of pulmonary edema and atelectasis may be seen on x-ray due to direct pulmonary injury from aspiration, but this does not necessarily indicate systemic hypervolemia or cardiac failure.

9. **"The patient arrived in cardiac arrest, and his initial core temperature was 30°C. We continued resuscitation for 20 minutes, but did not attempt to rewarm him given the possible neuroprotective effects of hypothermia. "**
   Rewarming is a treatment priority for patients who are found to be hypothermic and in cardiac arrest. If resuscitation is successful, therapeutic hypothermia can be considered, but the evidence for benefit associated with drowning remains scant.

10. **"My patient looked well, but since she experienced a drowning event in salt water, I decided to measure her serum electrolytes and admit her for observation in case of delayed electrolyte abnormalities."**
    There is no clinical distinction between salt-water and fresh-water drownings, and the basic treatment is the same. Additionally, there is no benefit to measuring serum electrolyte levels or admitting otherwise asymptomatic patients.

arrest, inline stabilization should occur in synchronization with resuscitative efforts if adequate personnel are present.

Summary

Drowning is a global problem that affects all populations. Early reversal of systemic hypoxia has the greatest impact on outcome and must remain the focus of resuscitation and treatment. In the prehospital environment, focus on providing effective ventilations, treating hypothermia, and rapidly transporting any symptomatic patient to advanced care. On arrival to the ED, keep the focus on protecting the airway and assuring adequate ventilations based on patient condition, and continue treating hypothermia. Once stabilized in the ED, determine disposition based on the examination and response to treatment, consider patients displaying mild injury for observation and discharge, and admit patients displaying moderate to severe or worsening symptoms.

For additional information on the management of drowning patients, in particular pediatric patients, see the June 2014 *Pediatric Emergency Medicine Practice* issue titled "Pediatric Submersion Injuries: Emergency Care And Resuscitation," available at: www.ebmedicine.net/pediatricsubmersioninjuries.

Case Conclusions

The 35-year-old man who presented to the ED with mild symptoms continued to improve and was taken off nasal cannula an hour into his visit. You spoke with him about the possibility of delayed clinical effects and convinced him to stay in the ED for observation. After 5 hours of observation, he remained asymptomatic and his SaO_2 *remained normal on room air. He was discharged with instructions to return if he developed shortness of breath, severe cough, or if his family noticed a change in his behavior.*

The 70-year-old woman continued to have large amounts of emesis. Due to her lethargy and possible airway compromise, you decided to not use NIPPV. Given her weak pulse and initial respiratory arrest, you had a high suspicion for severe injury and decided to continue to endotracheal intubation for airway protection and to optimize ventilation. She was placed on mechanical ventilation and admitted to the ICU.

Once you determined that the 5-year-old boy was pulseless and you sent the bystander to activate EMS, you decided to begin CPR with ventilations, remembering that reversal of systemic hypoxia is the primary goal of treatment. By the time EMS arrived, the patient had regained a pulse and was moaning. EMS continued assisted ventilations via BVM and transported the patient to the ED.

Time- And Cost-Effective Strategies

- Consider discharge after 4 to 8 hours of ED observation for patients with mild or no symptoms, normal vital signs, and normal mentation.
- Do not obtain laboratory studies in drowning patients with mild or no symptoms, unless indicated by a specific complaint.
- Do not obtain cervical spine imaging in drowning patients who are alert and oriented, nonintoxicated, deny midline cervical spine tenderness, and do not have significant mechanisms of injury. In patients who are unevaluable, obtain imaging on those with known trauma, obvious signs of trauma, or in whom no history is known.
- Do not administer prophylactic antibiotics in the initial treatment of drowning patients. If concern for pneumonia arises later in the treatment course, antibiotic choice should be guided by tracheal or bronchial cultures.

References

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

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

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1. Which of the following is the most common dysrhythmia found in pulseless drowning patients
   a. Atrial fibrillation
   b. Ventricular fibrillation
   c. Ventricular tachycardia
   d. PEA and asystole

2. Which of the following patients should undergo spinal immobilization and imaging?
   a. Glasgow Coma Scale score of 15, no spinal tenderness, rescued from rip current
   b. Glasgow Coma Scale score of 15, no spinal tenderness, no other injuries, fell out of canoe
   c. Glasgow Coma Scale score of 12, unevaluable spine, last seen diving into water
   d. Glasgow Coma Scale score of 12, unevaluable spine, witnessed submersion without trauma

3. **Which of the following is the primary goal of acute treatment of a drowning patient in the ED?**
   a. Reversal of hypothermia
   b. Reversal of hyperkalemia
   c. Reversal of hypoxia
   d. Reversal of hypotension

4. **What is the best course of action for a drowning patient who has been on nonrebreather mask with high-flow oxygen at 15 L/min for 30 minutes and who is experiencing emesis and worsening mentation?**
   a. Take off the nonrebreather mask and administer aggressive suctioning
   b. Continue the nonrebreather mask at highest setting
   c. Initiate full-face NIPPV
   d. Set up for intubation

5. **What is the primary treatment for a hypotensive drowning patient without evidence of trauma?**
   a. Optimize oxygenation and administer crystalloids
   b. Vasopressor administration
   c. Colloid administration
   d. Packed red blood cell transfusion

6. **What is the best course of treatment in a patient who has a Glasgow Coma Scale score of 15 with unlabored breathing, but requires nonrebreather mask to keep SaO_2 > 90%?**
   a. Intubate for airway protection
   b. Continue to observe with nonrebreather with probable admission
   c. Discharge from ED
   d. Change to nasal cannula

7. **After intubation, which of the following is the preferred initial mechanical ventilation strategy?**
   a. Airway pressure release ventilation
   b. Prone positioning
   c. Continuous passive airway pressure with low PEEP
   d. ARDS-based settings

8. **Which of the following is the most significant indicator of a poor prognosis in a drowning victim?**
   a. Prolonged submersion
   b. Glasgow Coma Scale score < 12
   c. Sluggish pupillary reflex
   d. Age < 12 years

9. **What is the best treatment plan for a drowning patient who presents to the ED with a mild cough, normal mentation, and normal vital signs without supplemental oxygen?**
   a. Arterial blood gas, serum electrolytes, and chest x-ray to determine disposition
   b. Observation in the ED for 4 to 8 hours and discharge if no clinical changes
   c. Admit to hospital for observation
   d. Intubate for airway protection and admit to the intensive care unit

10. **Administration of which of the following has shown the best evidence for improving mortality in drowning patients?**
   a. Oxygen
   b. Furosemide
   c. Methylprednisolone
   d. Antibiotics

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