
Submersion Injuries and Drowning in the Rural Emergency Department

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Vignette

On Memorial Day, you are working as solo coverage in a small community emergency department (ED) and three patients arrive by ambulance from the scene of a personal watercraft accident at a nearby lake. A 13-year old male was the passenger riding with a 19-year old male when they struck a submerged tree trunk and crashed. Bystanders reported that the older rider was motionless after the crash and the younger rider struggled to keep them both above the water until rescuers arrived twelve minutes later. One 32-year old female rescuer also came for evaluation because she “swallowed some water” during extrication. Upon arrival in the ED, the 19-year old has a pulse of 52, BP 88/50 with mumble sounds as his best speech, a nasal fracture, and weak respiratory effort. The 13-year old is awake but confused, tachypneic, and has diminished breath sounds on the right. The 32-year old female is ambulatory with a normal physical exam, but appears mentally distant with a flattened affect. As you prepare your airway cart, you begin to consider key management decision points, including:

1. *How likely is concomitant injury or intoxication in drowning victims?*
2. *What is needed to stabilize drowning victims in the ED?*
3. *What features of a drowning patient drive the decision for transfer?*
4. *What evidence exists about the prognosis for drowning victims and futility of resuscitation?*

Epidemiology of drowning in rural settings

The World Congress on Drowning and the World Health Organization have adopted the definition of “drowning” as “a process resulting in primary respiratory impairment from submersion in a liquid medium.”¹ This definition was adopted in hopes of improving epidemiologic study and reporting.² In engaging the literature it is important to realize that “drowning” refers to a process, not an outcome. The use of the term “near-drowning” is still common in the literature but discouraged by experts because it prevents survivors of drowning events from being counted among the victims.¹

The CDC reports that from 2004-2010, an average of 4924 Americans died annually from drowning.³ In the US drowning is the sixth most common reported cause of accidental traumatic death across all ages, with the young disproportionately affected. In 2010, drowning was the leading cause of unintentional traumatic death reported in the US for those 1-4 years old; for those ages 5-14 years, it was second only to motor vehicle collisions.³ Verbal autopsy reports from Bangladesh likewise show that children ages 1-4 are more likely to die from drowning than any other age group from any other

external cause.⁴ On average, there are 32 pediatric farm drowning deaths per year in the US, accounting for one third of farm deaths in American children.⁵ Rural pediatric drowning victims have risk factors in common with urban victims: absence of adult supervision, developmental stage, and a lack of effective barriers between children and the water.⁶

Rural location may increase mortality risk according to one study of pediatric patients with loss of consciousness in a freshwater drowning event, which found only 21% survived from rivers and creeks, compared with 65% survival among those who drowned at home.⁷ While reporting factors and rural emergency medicine services are hypothesized to account for some of the disparities between nations, the literature contains no comparisons clear enough to determine whether regional differences are demonstrating differences in the data or in how drowning victims are managed. For example, a Canadian study of unintentional adult deaths found a significantly elevated risk for accidental death by drowning in the most rural areas of the country, with similar findings reported in Ireland and China.⁸⁻¹⁰ A neutral effect was shown in a study of drowning mortality in Australia, which found no increased risk for drowning death in rural populations.¹¹ A still more negative study from Norway concluded the opposite, that trauma systems have benefitted urban areas but not helped limit mortality from drowning in rural areas, as rural drowning victims still tend to die at the scene.¹² Other adult risk factors such as alcohol use have been identified and may be more important than rural location in predicting the prognosis and mortality of severe drowning injury.¹³

Based on the elevated risk in many rural communities and established risk factors, public health education and preventive measures should be considered appropriate primary prevention in rural communities. A cost-effectiveness analysis in Bangladesh found that educational programs cost \$362 per disability-adjusted life year saved.¹⁴ While this data in favor of prevention is encouraging, such success may be difficult to replicate in other regions with higher costs of education and lower incidence of pediatric mortality and morbidity from drowning. More research is needed to determine the cost effectiveness of drowning

prevention measures in industrialized settings. The National Drowning Prevention Alliance (<http://www.ndpa.org>) is a US nonprofit organization that provides free and low-cost educational programs to prevent drowning.

Clinical and economic relevance in rural ED care

In 2010, the CDC reports that of the 12,900 patients who presented to the ED due to drowning, 20% were admitted to the same hospital at a total cost of \$40 million for ED and inpatient care.¹⁵ Realizing that a minority of patients are admitted to the presenting hospital, a structured evaluation of drowning victims will allow the rural practitioner to identify the few patients who require local admission among the majority whose best disposition is either discharge home or transfer to higher care.

Pathophysiology and spectrum of drowning injury

Drowning injury, regardless of the medium, involves a series of insults that ultimately result in respiratory failure. Upon being submerged, the victim usually struggles to maintain the mouth and nose above water. Once unable to maintain access to air, volitional breath-holding is usually performed until hypercarbia and hypoxia trigger an involuntary gasp. Gaspings may occur earlier in cold-water submersion. Laryngospasm may preclude large-volume aspiration for some victims while others with a patent larynx will allow large-volume aspiration. The distinction of low-volume aspiration drowning events as “dry drowning” is not a significant clinical distinction from high-volume liquid aspiration, as patients’ pathophysiology and management needs remain similar throughout their course.² Hypotonic aspirates may enter the bloodstream via the alveolar capillaries and contribute to blood volume, while hypertonic aspirates may draw water into the alveolar space. In either scenario, the alveolar interface is obstructed, resulting in diffusion limitation and hypoxic respiratory failure.

The spectrum of presentation after a drowning event ranges from asymptomatic to critically ill, and patients of intermediate severity may deteriorate quickly due to pulmonary inflammation and acute respiratory distress

syndrome (ARDS). Pollutants and organic matter in the aspirated liquid may accelerate the onset of ARDS.

Cardiovascular collapse in drowning victims should be considered secondary to the common pathway of respiratory failure, hypoxia, and acidemia. Though laboratory models have been able to provoke significant electrolyte and volume changes in animals, human drowning victims in fresh or salt water do not commonly develop significant changes in hematocrit or serum electrolyte levels.¹⁶ Routine testing for electrolytes remains indicated for these patients as a component of either initiating critical care measures or a short but comprehensive period of cardiac monitoring. However, given the low probability of significant disturbances a patient need not be transferred to a higher level of care if only for the purpose of laboratory evaluation.

Evaluating the drowning patient in the rural ED

When given the opportunity to speak with prehospital providers in the field, the rural ED physician should have a structured method for deciding which patients are appropriate for presentation to a small ED and which

patients might benefit best from rapid transport to a larger institution with ICU capabilities. Table 1 is a guide for advising transport decisions for prehospital providers on scene prior to initial hospital transport.

For those patients received at the rural ED, standard attention should be given to airway, breathing, circulation, and mental status. History about the drowning event and early management, gathered from witnesses and EMS, is especially important for assessing risk in the unresponsive patient. On secondary survey, specific attention should be given to seek concomitant hypothermia, intoxication, and injury, depending on the setting. It should be noted that this triage scheme allows for educated release of asymptomatic patients, yet as with many conditions their management would be different if presenting to the hospital setting. The existing evidence suggests that a physician providing medical command for EMS personnel in the field can accept informed refusal of transport for the asymptomatic patient, given their low risk of significant deterioration. In such situations, medical command physicians should maintain vigilance for those patients who may lack capacity due to intoxication or concomitant injury.

Table 1: Prehospital Management and Classification of Drowning Patients

	The Asymptomatic Patient		The Symptomatic Patient			The Patient in Respiratory or Cardiopulmonary Arrest	
Grade	0	1	2	3	4	5	6
Mortality (%)	0	0	0.6	5.2	19	44	93
Pulmonary Exam	No cough or dyspnea	Normal auscultation with cough	Rales, small amount of foam	Acute pulmonary edema	Acute pulmonary edema	Respiratory arrest	Cardiopulmonary arrest
Cardiovascular	Radial pulses	Radial pulses	Radial pulses	Radial pulses	Hypotension	Hypotension	
On-Scene Management	Release at scene, education	Rest, Rewarm, Reassure, Release	O2 via nasal cannula; observe for 6-24 hr	O2 via NRB; ACLS	O2 via NRB; ACLS	Load and Go	
Transport	No	No	Transport or observation	Yes	Rapid	Rapid	
En Route Management			Vital Signs	Vital Signs	Possible ETT and manage pressure	ACLS	
Hospital			ED or overnight observation	Admission for observation	ICU	ICU	ICU

Courtesy of Tracy Cushing, MD. Adapted from Cushing TA, Hawkins SC, Sempstrott J, Schoene RB. *Submersion Injuries and Drowning*. Sixth Edit. (Auerbach P, ed.). Elsevier Inc.; 2012:1494-1513.e5.¹⁷ Originally adapted from Szpilman D: Near-drowning and drowning classification: A proposal to stratify mortality based on the analysis of 1,831 cases, *Chest* 112:660, 1997.¹⁸

Concomitant Intoxication: A large-scale study in Sweden¹⁹ examined blood ethanol and drug levels among drowning fatalities. Among unintentional drowning victims who died, 44% tested positive for ethanol. Males were more likely positive than females, risk peaked at ages 30-69, and the proportion of alcohol-positive drowning was highest among those who drowned in streams and rivers. Positive tests for ethanol were found in 68% of snowmobile riders who drowned after breaking through ice, 54% of those who fell from boats, and 30% of those drowned in other motor vehicles; conversely, of 44 patients in SCUBA diving accidents there were no positive tests. Almost 25% of those who drowned had one or more pharmaceuticals in their blood. Benzodiazepines and antidepressants were most common, especially in the older age groups. Compared to unintentional drowning, suicide events were associated with a higher prevalence of psychoactive drug use. An American study showed similar findings among boaters, with risk of death increasing in proportion with blood alcohol content.²⁰ For those adolescents and adults who survive to hospital presentation, it is reasonable to presume alcohol and drug use preceded any drowning event, regardless whether the drowning was accidental or intentional. While some populations such as divers have shown low rates of concomitant intoxication, it is still reasonable to presume substance use during early management and testing.

Cormorbid Injuries: Most drowning victims are uninjured. A review of 2,244 patients in Washington State found only 0.5% of cases had cervical spine injuries, with all such injuries having occurred in open water, all had clinical signs of serious injury, and all had a history of either diving into water, motorized vehicle crash, or fall from height. No cervical spine fractures were identified in low-impact submersions.²¹

A similar retrospective review of 143 pediatric drowning victims found that the only injuries identified were cervical spine injuries. These injuries occurred in boys and girls equally, occurred in older children and teenagers, and all but one were caused by a diving mechanism.²² Given the available evidence, it is considered prudent to immobilize

the cervical spine of drowning patients when there is a clear history of traumatic injury or diving, signs of serious trauma, or an entirely unwitnessed event.

Management Decisions

Initial ED management for the acute drowning victim is focused on assessment and correction of the patient’s underlying hypoxic respiratory failure. Initial symptoms may include cough, throat pain, chest pain, or dyspnea. Symptoms can evolve rapidly in the 4-6 hours following a drowning event, so all patients should be monitored for at least four hours regardless of condition on initial presentation to the ED.

For those patients whose oxygen saturation is not maintained on a high-flow mask, or whose respiratory status is rapidly deteriorating, CPAP or endotracheal intubation with mechanical ventilation should be instituted. Serial arterial blood gas measurements can be used to monitor sufficiency of alveolar ventilation, gas exchange, and peripheral perfusion. For those patients who demonstrate mental status alterations out of proportion to respiratory failure or blood gas findings, consider further workup for intoxication or intracranial trauma, to include transfer as necessary. Nearly all patients who arrive without having undergone cardiac arrest are expected to survive with good neurologic outcomes.^{1,23}

Table 2: Prognostic factors for drowning victims in the Emergency Department
Good Alert on admission, hypothermic, brief submersion time, on-scene basic or advanced life support, good response to initial resuscitation measures
Bad Fixed dilated pupils in ED, submerged >5 min, no resuscitation attempts for more than 10 minutes, preexisting chronic disease, arterial pH <7.10, coma on admission to ED

Courtesy of Tracy Cushing, MD. Adapted from Cushing TA, Hawkins SC, Sempsrott J, Schoene RB. *Submersion Injuries and Drowning*. Sixth Edit. (Auerbach P, ed.). Elsevier Inc.; 2012:1494-1513.e5.¹⁷

For patients who arrive comatose, the management priorities remain the same in order to optimize

oxygenation and perfusion of the brain. Drowning victims who sustain cardiac arrest then regain adequate spontaneous circulation but remain comatose should not be actively re-warmed to temperature values above 32° to 34° C (90° to 93° F). If core temperature exceeds 34° C (93.2° F), hypothermia at 32° to 34° C (90° to 93° F) should be achieved as soon as possible and sustained for 12 to 24 hours.²⁴

Patients who present with fever, altered mental status, or worsening respiratory distress more than 24 hours after a drowning or immersion event may have been inoculated with endemic bacteria, parasites, or fungi.²⁵ A careful examination should focus on central nervous system, nasopharyngeal and pulmonary sources of infection and

treatment tailored to local environmental risks.

Evidence Review Section: The following questions were chosen in the hopes of addressing questions that are expected to naturally arise in the treatment of most drowning patients, whose answers might reduce iatrogenic complications, guide decision-making in resource-limited settings, and improve patient-centered outcomes such as disability and death. For a broader discussion of drowning in a wider variety of clinical settings, the handbook published by The World Congress on Drowning is the benchmark for expert consensus and review of literature.¹ The recommendations in this section are offered according to the American College of Chest Physicians' 2006 guidelines for grading quality of evidence.²⁶

Table 3: Evaluation and Disposition of Drowning Victims in the Rural Emergency Department
<p>Check Airway/Ventilation</p> <ul style="list-style-type: none"> • Adequate Ventilation <ul style="list-style-type: none"> ○ Supplemental oxygen: nonbreathing mask at 12-15 L/min • Inadequate ventilation <ul style="list-style-type: none"> ○ Borderline patients: consider CPAP ○ Comatose patients or those with PaO₂<90 mmHg on 15 L/min nonbreathing mask or PaCO₂>45: endotracheal intubation with PEEP as necessary
<p>Diagnostics</p> <ul style="list-style-type: none"> • Arterial blood gas (ABG) studies for mechanically ventilated patients, SpO₂ monitor for spontaneously breathing patients • Chest radiograph • Cardiac monitor • Cervical spine radiograph/trauma evaluation if indicated by mechanism • Assessment for hypothermia, hypoglycemia, electrolyte abnormalities • Assessment for intoxication if mental status altered out of proportion to injuries and ABG
<p>Further Interventions</p> <ul style="list-style-type: none"> • Intravenous access, hydration • Nasogastric tube if significant aspiration/ingestion of water
<p>Disposition</p> <ul style="list-style-type: none"> • Criteria for 4-6 hour observation then discharge: <ul style="list-style-type: none"> ○ Asymptomatic (no cough or respiratory complaints) ○ No vital sign or exam abnormalities to include normal SpO₂ in room air, normal lung auscultation, normal Glasgow Coma Scale ○ No diagnostic abnormalities (normal chest radiograph) ○ No preexisting condition that prevents accurate assessment of above • Local admission <ul style="list-style-type: none"> ○ Patients with normal findings being admitted for observation only, such as those with normal findings but tenuous preexisting illness. • Transfer to higher echelon of care or ICU admission <ul style="list-style-type: none"> ○ ICU admission preferred for all patients with vital sign abnormalities, respiratory symptoms, chest radiograph findings, cervical spine trauma. ○ Cardiopulmonary status should be managed as fully as possible prior to transfer ○ Oxygenation to PaO₂ >60mmHg and perfusion with MAP > 65 are desirable endpoints before and during transfer

Adapted, with permission, from Cushing TA, Hawkins SC, Sempsrott J, Schoene RB. *Submersion Injuries and Drowning*. Sixth Edit. (Auerbach P, ed.). Elsevier Inc.; 2012:1494-1513.e5.¹⁷

Question #1: For victims of drowning or submersion injuries, does the use of prophylactic antibiotics improve disease severity or mortality when compared with standard treatment?

Search parameters: Database MEDLINE, terms (((drowning) OR (immersion) OR (near-drowning) OR (submersion)) AND ((antibiotics) OR (prophylactic antibiotics) OR (antimicrobial) OR (antifungal))) with limits (English language), (human species). This search rendered 175 results, five of which were relevant.

The five available studies are retrospective case review series. None found a significant difference between patients treated with prophylactic antibiotics and those who did not receive prophylactic antibiotics with respect to pneumonia, ARDS, septicemia, CNS infection, or death.^{16,27-30}

Recommendation: Prophylactic antibiotics should not be routinely given to victims of drowning or submersion. Unless the medium aspirated was grossly contaminated, microbiology diagnostics and antimicrobial treatments should be withheld but implemented promptly at the onset of clinical signs of infection. Recommendation rating: 2C

Question #2: In victims of drowning, does therapeutic hypothermia improve neurologic outcomes or survival when compared with standard treatment?

Unfortunately, no randomized controlled trials exist on the role of targeted temperature therapy in drowning victims, with most of the body of evidence coming from retrospective case series. The standard of care remains driven primarily by expert opinion, as there is no clear evidence to show that therapeutic hypothermia causes harm or benefit to drowning victims.³¹ The existing reports have suggested neutral effects³² as well as benefit,³³⁻³⁶ while the only existing study suggesting harm is on a birth asphyxia population.³⁷

A panel of experts during the World Congress on Drowning in 2002 concluded that “drowning victims with restoration of adequate spontaneous circulation who remain comatose should not be actively re-warmed to temperature values above 32° to 34° C (90° to 93° F). If core temperature exceeds 34° C (93.2° F), hypothermia at 32° to 34° C (90° to 93° F) should be achieved as soon as possible and sustained for 12 to 24 hours.”²⁴ The World Congress on Drowning in 2002 ultimately deferred to local guidelines for cardiac arrest.¹

Local practice for management of cardiac arrest is usually informed by guidelines published by the American Heart Association (AHA) and the International Liaison Committee on Resuscitation (ILCOR). The 2010 AHA and international consensus guidelines³⁸ for management of cardiac arrest recommend that comatose patients with spontaneous circulation after out-of-hospital arrest from ventricular fibrillation should be cooled to 32 to 34°C for 12 to 24 hours. Benefit is unclear but considered possible in those with return of spontaneous circulation (ROSC) from asystole. The ILCOR guidelines from 2003 were used in formulating the 2010 guidelines and state that, “Unconscious adult patients with spontaneous circulation after out-of-hospital cardiac arrest should be cooled to 32°C to 34°C for 12 to 24 hours when the initial rhythm was ventricular fibrillation.”³⁹ The target temperature of choice for post-arrest cooling therapy was brought into question by a benchmark 2013 study⁴⁰ that enrolled comatose patients with ROSC after out-of-hospital arrest of any initial rhythm, randomized them into two treatment arms with targeted temperatures of 33°C or 36°C, and found no significant difference in neurologic disability or death. In response to that 2013 study, ILCOR issued an update to their 2003 guidelines stating that while further research is necessary to establish the ideal temperature to target in postarrest care, their recommendations remain unchanged from 2010.⁴¹ In this 2013 update, ILCOR neither endorsed nor condemned the use practice of targeting 36°C.

The use of therapeutic hypothermia after out-of-hospital cardiac arrest is thus an active area of controversy beyond the scope of this discussion. There is no strong evidence

available at this time to suggest that drowning patients with cardiac arrest should be treated differently from those in arrest without having drowned. Concomitant conditions such as hypothermia or spinal injury may, however, guide significant changes in resuscitation management.

Recommendation: Adherence to the 2002 World Congress on Drowning recommendations that recommend targeted temperature management, as it is currently aligned with recommendations rendered by the AHA and ILCOR: “drowning victims with restoration of adequate spontaneous circulation who remain comatose should not be actively re-warmed to temperature values above 32° to

34° C (90° to 93° F). If core temperature exceeds 34° C (93.2° F), hypothermia at 32° to 34° C (90° to 93° F) should be achieved as soon as possible and sustained for 12 to 24 hours.”²⁴ **Grade: 2C**

Question #3: In victims of drowning, what elements of physical examination or diagnostic studies predict poor neurologic outcome or death?

Several scoring systems have been devised to improve triage and prognostics for drowning victims (Table 4).⁴²⁻⁴⁵ All published scoring systems were built using retrospective chart review data.

Table 4: Comparison of Scoring Systems to Determine Prognosis of Drowning Patients in the Emergency Department ³¹⁻³⁴

Study	Methods	n, type	Outcome	Scoring	Subgroups	n	Outcome Present	Odds Ratio (95% CI)	p
Gonzalez-Luis, 2001	retrospective chart review	60, children	death or serious neurologic impairment	Pediatric Risk of Mortality Score (PRISM)	< or = 8	16	0	control	n/a
					17 to 23	9	6	61 (2.8-1359.2)	0.0092
					24 and over	8	8	561 (10.2-30825.9)	0.002
Christensen, 1997	retrospective multivariate analysis	274, children	death or serious neurologic impairment	Derived Rule	Predicted good	195	15	control	n/a
					Predicted poor	79	74	177.6 (62.3-506.4)	<.0001
Modell, 1980	retrospective chart review	131, 57 adults, 74 children	death or serious neurologic impairment	Neurologic Exam at 1-2h	Awake	61	0	control	n/a
					Blunted	31	3	15.1 (0.75-302.3)	0.075
					Comatose	29	13	100.6 (5.7-1783.0)	0.0017
Conn, 1980	retrospective chart review	96, children	death or severe neurologic impairment	Neurologic Exam at 1-2h	Awake	51	0	control	n/a
					Blunted	6	0	7.9 (0.1-434.3)	0.31
					Comatose 1 (decorticate)	9	3	55.5 (2.56-1198.9)	0.01
					Comatose 2 (decerebrate)	16	7	81.3 (4.27-1546.2)	0.003
					Comatose 3 (flaccid)	14	12	515 (23.2-11416.7)	0.0001

While these systems suggest that a comatose presentation is a statistically significant risk for death or disability, it is important to note that there are patients in each series who made full unpredicted recoveries. No system yet devised is fully predictive of a poor outcome. Given the catastrophic impact of a poor outcome on the patient and the patient's family, it is reasonable to presume for the first 48 hours that every comatose patient has the rare, and still unpredictable, potential for full recovery.

Recommendation: For drowning victims who present comatose, families should be counseled on the relatively poor prognosis as these patients have elevated likelihood of death or neurologic disability. Given the unpredictable yet finite possibility full recovery, full-spectrum intensive care should be offered for at least the first 48 hours. **Grade: 1C.**

Vignette Resolution:

You first secure the cervical spine and airway of the obtunded 19-year old patient and begin to manage him for presumed neurologic shock secondary to cervical spine injury. Second, you focus on the confused 13-year old and note his SpO₂ is 88% on 10 liters of supplemental oxygen. You preoxygenate him using non-invasive positive pressure ventilation then intubate him for hypoxemic respiratory failure with impending ARDS, start a lung-protective ventilator protocol based on ARDSnet⁴⁶, and you give no antibiotics. As the boys are having their post-intubation x-rays done, you initiate ICU transfers for both of them to give full-spectrum care for at least 48 hours. The woman with a normal exam was observed by the nurses with attention to oxygen saturation and respiratory status until you are free to see her. With a normal chest x-ray, electrolytes, and exam, she is simply monitored on cardiac telemetry and pulse oximetry for four hours, then released home with a referral to a counselor for traumatic stress.

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