Special Resuscitation Situations Part 2: Submersion

Submersion: Overview

- Submersion events, imprecisely referred to as *drowning* or *near-drowning* (see "Submersion Definitions" below), are most common in the pediatric and young adult age groups.[1-3] These events can be traumatic for the relatives and loved ones of victims and for emergency providers.
  - — Parents, baby-sitters, or guardians may experience grief and guilt for failing to protect the victim. They may also feel intense anger toward others who did not provide adequate supervision.
  - — Neighbors, friends, bystanders, and emergency personnel may feel guilty for participating in a rescue attempt that resulted in death or neurologic impairment.
- Many issues surrounding prevention of submersion events are complex and controversial:
  - — Appropriate targets for injury prevention efforts.[4]
  - — Siblings bathing together without adult supervision.[5] In one study from Utah every bathtub drowning occurred when siblings were bathing together without adult supervision.[5] Submersions occurred when one sibling reportedly stood or sat on another or held a sibling under the water.[5]
  - — Pediatric "drowning proofing" is an unproven concept[6] that is specifically discouraged by the American Academy of Pediatrics.[7]
  - — Legal ordinances for swimming supervision[8] and pool fencing vary widely.[9-12]
  - — Legal ordinances regulating water sports, personal watercraft,[13,14] boating,[15] life vests,[16] and flotation devices[17] vary widely.[18]
  - — Some submersion episodes that involve homicide,[19] manslaughter,[20] and suicide[21-23] are euphemistically termed "nonaccidental" or "intentional" drownings.
- Many fatal submersion events or those that result in neurologic impairment are preventable tragedies. Many are the result of poor judgment, alcohol consumption,[24-27] or inadequate supervision of children.[5,26]
- Despite the ACLS emphasis on immediate treatment, the definitive therapy for submersion events is *prevention*. As in cardiac arrests associated with hypothermia (see Part 1 of this chapter) or trauma (see Part 5 of this chapter), the most effective way to reduce the number of deaths due to submersion is to prevent the initiating event or provide immediate treatment to prevent a cardiac arrest. Once a victim of submersion, hypothermia, or trauma deteriorates to a state of cardiac arrest, the chances for a successful outcome are minimal.
- Rescue of submersion victims occurs on or near the water, exposing rescue teams to danger. Never forget the principle of rescuer safety: rescuers should make sure the area is safe and should avoid becoming second victims.

Pathophysiology

Submersion leads to hypoxia that can ultimately cause cardiac arrest.

- Submersion hypoxia can produce other complications, including hypoxic encephalopathy and acute respiratory distress syndrome (ARDS). These complications of submersion events are beyond the scope of this chapter.
- The duration of hypoxia is the critical determinant of submersion outcome. The duration of hypoxia can be reduced first by early rescue from the water, then by immediate provision of basic and advanced life support. Rapid **A**irway and **B**reathing support play the major role in resuscitation from submersion. This emphasis contrasts with emphasis on rapid initiation of **C**hest compressions and **D**efibrillation, appropriate for most adult victims of sudden cardiac arrests.

Rescuers should be prepared to treat trauma (see Part 5 of this chapter) or hypothermia (see Part 1) that may be associated with submersion.

- Submersion victims may require cervical spine precautions. C-spine immobilization is recommended for victims of submersion associated with trauma, such as a dive or fall into water.[28] If you are unsure if trauma occurred, assume that C-spine immobilization is needed.

- Submersion victims may develop primary or secondary hypothermia:
  - *Primary hypothermia* can develop when a submersion occurs in icy water (<5°C, <41°F). In icy water core body hypothermia may develop before the submersion causes significant hypoxia. It is possible that such cold-water submersion may provide some protection from hypoxia and organ ischemia. The published studies reporting good outcome from prolonged submersion describe young, small victims submerged in icy water.
  - *Secondary hypothermia* occurs as a consequence of heat loss through evaporation after rescue from the water and during attempted resuscitation. Hypothermia in these victims offers no protective effects.

Submersion Definitions

Unsatisfactory Nomenclature

A number of experts have noted that there are almost as many terms for drowning and submersion events as there are authors.[1-3]

- People often incorrectly apply the term *drowning* to victims who die within 24 hours of a submersion episode. But the term should apply only to submersion victims who fail to regain or maintain a pulse and respirations after initial resuscitative efforts.
- The term *near-drowning* is applied to submersion victims who survive more than 24 hours, but only if active interventions were needed for one or more submersion complications. Such complications can include pneumonia, ARDS, sepsis, or neurologic sequelae.
- Rescuers and emergency personnel find these definitions irrelevant because 24 hours must pass before the distinction can be made between drowning and near-drowning.

Table 1 presents many of the terms used in discussions about submersion, the conventional definitions, and some shortcomings of the terms. It is obvious that these terms and definitions lack many of the essential criteria for a successful nomenclature:

- The definitions are not based on consensus; the terms have different meanings for different users. In published articles the terms are defined by individual assertion rather than by international, multispecialty consensus.
- The terms do not adequately discriminate among mutually exclusive sets of patients.
- The terms fail to reflect different levels of severity and lack any relationship to outcomes.
- The terms fail to reflect clinical reality because many victims cannot be classified until hours, even days, pass.
- The terms fail to guide clinical care because they are unrelated to prognosis or outcome.
- The classification of victims is not based on simple or readily applied assessments.

The Need for Uniform Definitions and Reporting

As suggested above, researchers, EMS managers, and clinicians need a uniform approach for international reporting of submersion outcomes. Researchers in the area of out-of-hospital resuscitation faced a similar problem in the 1970s and 1980s.[32,33] In the early 1990s international efforts led to the development of the "Utstein Style for Uniform Reporting of Outcomes From Cardiac Arrest" for out-of-hospital events,[34] in-hospital events,[35] and pediatric cardiopulmonary emergencies.[36]

Critical Concepts: Prevention of Submersion Episodes

- Keep only a few inches of water in the bathtub when bathing young children. Never leave young children unsupervised in bathtubs.
- Never leave children alone in or near the pool even for a moment.
- Be sure adults and adolescents are trained in CPR so that they can rescue a child if necessary.
- Surround your pool on all 4 sides with a sturdy 5-foot fence. The house should not form one of the barriers to the pool if there is a doorway from the home to the pool area. Be sure that the gates self-close and self-latch at a height that children cannot reach.
- Keep rescue equipment—a shepherd's hook (a long pole with a hook on the end) and a life preserver—and a portable telephone near the pool.
- Avoid inflatable swimming aids such as "floaties." They are *not* a substitute for approved life vests and can give children a false sense of security.
- Generally children are not developmentally ready for swim lessons until after their fourth birthday.[7] Swim programs for children under 4 should *not* be seen as a way to decrease the risk of drowning.
- Whenever infants or toddlers are in or around water, an adult should be within arm's length, providing "touch supervision."

Proposed Approach to Defining and Grading Submersion Events

To stimulate international discussion of the shortcomings of submersion nomenclature and initiate preliminary solutions,

TABLE 1. Submersion-Related Nomenclature: Conventional Definitions and Shortcomings

Term	Conventional Definition	Shortcomings
Submersion event ***(Also may be referred to as "drowning event")***	■ A person's head (or airway openings) becomes covered or stays covered with liquid (usually water) ■ Duration is sufficient to pose a risk of hypoxia ■ Aspiration into the hypopharynx, trachea, or bronchioles occurs to a degree that induces repeated coughing	■ Covers such a wide range of events that some grading of pathophysiologic severity must be used[29]: — Grade 0: Submersion does not induce coughing — Grade 1: Small aspiration results in coughing but normal lung auscultation — Grade 2: Small aspiration produces coughing and rales in one lung — Grade 3: Acute pulmonary edema (rales in both lungs), normal cardiac function (no hypotension) — Grade 4: Acute pulmonary edema (rales in both lungs), impaired cardiac function and hypotension — Grade 5: No spontaneous respirations, pulse present — Grade 6: No spontaneous respirations, no pulse
Drowning	■ Death from suffocation after a submersion event in liquid (usually water) ■ Death <24 hours after a submersion event	■ A postmortem term that should be applied only to people who have died from a submersion event. ■ A more precise definition would be failure to regain a pulse after initial resuscitative efforts.
Near-drowning	■ Survival for >24 hours after a submersion event ■ Event must be severe enough to require some medical intervention for submersion-related complications	■ An ambiguous term because it implies that all near-drowning victims survive. But it includes deaths from complications >24 hours after submersion.
Submersion syndrome	■ A term proposed to cover both drowning and near-drowning after a submersion episode (head goes below water)	■ More precision cannot be gained by lumping together 2 imprecisely defined terms. ■ People seldom are aware of or make the important distinctions between *immersion* and *submersion*.
Immersion syndrome	■ Sudden death after immersion (not submersion) in very cold water ■ Probably due to an arrhythmia induced by vagal stimulation	■ Often confused with *cold water immersion* (<25°C or <77°F),[30] which poses risks of hypothermia and submersion secondary to hypothermia (ie, swim failure).
Secondary drowning	■ Death occurring minutes to days after a near-drowning episode from a complication of the submersion	■ A problem term because it classifies death by initial event, not by complications (eg, ARDS). ■ Overlaps in some patients with near-drowning.
Postimmersion syndrome	■ Deterioration (not death) of an apparently well victim after a submersion event	■ Can be confused with immersion syndrome. ■ *Immersion* has a different meaning than *submersion*.

(Continued on next page)

Table 1. Submersion-Related Nomenclature: Conventional Definitions and Shortcomings (Continued)

Term	Conventional Definition	Shortcomings
"Wet" drowning or near-drowning	■ A drowning or near-drowning that occurs *with* significant aspiration ■ Occurs when a large amount of water enters the lungs	■ Unclear whether water entered because of respiratory efforts or passively after death. ■ A distinction between "wet" and "dry" has little or no clinical significance.
"Dry" drowning or near-drowning	■ A drowning or near-drowning that occurs *without* significant aspiration ■ Occurs when laryngospasm blocks entrance of water into the lungs	■ Found in <10% of drowning victims who go to autopsy. ■ Disputed by some experts. If no water is in lungs at autopsy, victim may have died before the submersion.[31] ■ If coughing is universally accepted as a critical finding, this term would disappear.

participants in the Guidelines 2000 Conference developed an approach to grading submersion episodes (Figure 1). This algorithm can be used by epidemiologists to support a prospective database of submersion cases.

The algorithm is largely derived from the work of Szpilman and his Brazilian collaborators.[29] It has been validated retrospectively, demonstrating a relationship to outcomes (Table 2). In the summer of 2002 the AHA cosponsored an international symposium on defining and grading submersion events. Participants expressed agreement with the general principles of this algorithm and reviewed early drafts of the Figure. The final version (Figure) reflects a number of modifications derived from this symposium. Continued use and evaluation of this algorithm, as well as final recommendations from the 2002 and subsequent symposia, could lead to future revisions and increased effectiveness.

The Proposed Submersion Episode Grading Algorithm: Underlying Concepts

- Definitions of submersion events should reflect the pathophysiology of submersion.
  - — The pathophysiology of submersion represents a continuum from the moment of involuntary *submersion* (head slips under the water), followed by some degree of aspiration, ineffective and then absent breathing, and then progressive hypoxia leading to irreversible apnea and then asystole *(drowning death)*.
- An effective grading system needs to reflect clinical signs demonstrated in victims rescued during the stages in the submersion continuum.
  - — **Submersion:** The initial stage is an actual *submersion*. The head slips under water (or other liquid), there is no access to air, and some hypoxia develops, with some aspiration of fluid into the hypopharynx,

Table 2. Severity Grades for Submersion Events Based on Clinical Findings With Associated Mortality Rates

Severity Grade	Clinical Findings	Mortality (%)[29]
1	Some coughing, normal auscultation	0
2	Coughing; with abnormal auscultation: rales in some lung fields on one side	0.6
3	Coughing; abnormal auscultation with acute pulmonary edema (bilateral rales); good cardiac function (no hypotension)	5.2
4	Coughing; abnormal auscultation with acute pulmonary edema (bilateral rales) with poor cardiac function (hypotension)	19.4
5	No spontaneous respirations, pulse is present	44
6	Cardiopulmonary arrest: no spontaneous breathing, no pulse	93

trachea, and lungs. "Submersion" is not really a problem until either hypoxia or aspiration occurs. Otherwise a person is simply swimming under water or voluntarily holding his/her breath.

— **Aspiration:** Experienced observers consider entrance of water into the respiratory passages with resultant stimulation of gag and cough reflexes as an essential stage in submersion events. *Coughing* is a critical dichotomous assessment point (Box 6). Coughing is an obvious physical sign with prognostic significance. If the victim is not coughing and has normal lung auscultation, the victim is classified as a *water rescue*. Although aspiration is assumed to occur during the stereotypical "struggle to keep the head above water," observers report many different scenarios. Modell eloquently presents the range of submersion events that observers describe.[37]

— **Apnea or breathlessness:** Absence of spontaneous breathing is an unambiguous physical sign that also relates to outcomes. Many submersion definitions fail to mention presence or absence of spontaneous breathing when rescuers get the victim to shore or to a location where they can initiate resuscitative efforts.

— **Spontaneous circulation:** If the period of hypoxia is prolonged, the heart stops beating. Hypoxia produces a well-established sequence of cardiac deterioration with tachycardia, then bradycardia, then a pulseless phase of ineffective cardiac contractions (PEA or VF/pulseless VT phase), followed by complete loss of cardiac rhythm and electrical activity (asystole). For this reason the absence of a pulse and other signs of circulation are easily assessed by rescuers, and their absence suggests that significant hypoxia has developed.

Outcome of Submersion

The Challenges

Emergency care providers face a number of difficult questions when attempting resuscitation of submersion victims:

- Should rescuers attempt resuscitation for a 60-year-old victim pulled from a tropical vacation swimming pool cyanotic, cold, breathless, and pulseless after 10 minutes of submersion?
- What is the prognosis for a 5-year-old child who is cyanotic, cold, breathless, and pulseless when he is pulled from a frozen pond 30 minutes after falling through the ice and slipping underwater?
- Should Emergency Department personnel continue CPR and ACLS interventions for submersion victims who remain breathless and pulseless after 40 minutes of resuscitative efforts in the field? What if a family member or emergency responder risked his/her life in recovering the victim from the water?
- What is the value of restoring a heartbeat and spontaneous respirations to a child whose chance of meaningful neurologic recovery is virtually zero?

Such clinical and ethical challenges have stimulated considerable interest in outcome prediction for submersion victims. Accurate outcome prediction would assist rescuers in recognizing

- Fatal submersion events for which resuscitative efforts should not be started
- Submersion events for which resuscitative efforts should be stopped in the field without "lights and siren" transport

Accurate outcome prediction would also help prevent the tragedy of successful restoration of a beating heart and breathing lungs for victims with devastating and irreversible hypoxic neurologic insult.

Research in Outcome Prediction

Predictors of outcome have been generated on the basis of retrospective surveys and epidemiologic analyses rather than prospective studies. Retrospective analyses of a large observational database of submersions in children and adolescents (up to 20 years of age) from King County and Seattle, Washington, have contributed valuable insight into submersion outcome.[27,38-40] This work confirmed duration of submersion as the most powerful predictor of outcome.[40] With increasing duration of submersion, the following associations with death or severe neurologic impairment were observed:

- 0 to <5 minutes: 10%
- 5 to <10 minutes: 56%
- 10 to <25 minutes: 88%
- 25 minutes: 100%

Note how 5 more minutes of submersion in the 5 to <10 minutes group increases mortality almost 6 times compared with the 0 to <5 minutes group.

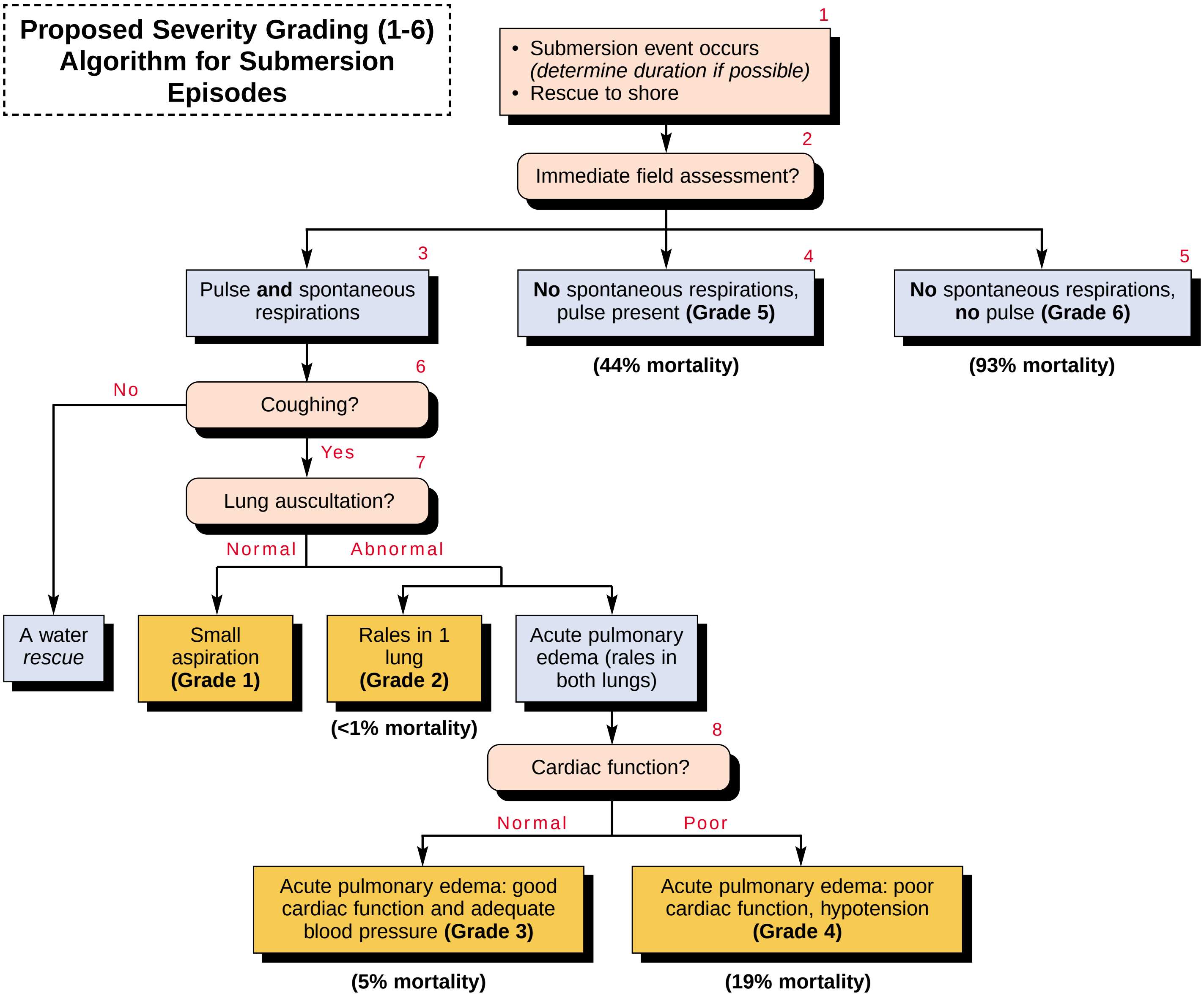
In a further analysis of 77 pediatric submersion victims for whom EMS personnel attempted resuscitation, 100% mortality was associated with the following factors[39]:

- Submersion duration >25 minutes
- Resuscitation duration >25 minutes
- Pulseless cardiac arrest on arrival in the ED

Slightly lower mortality rates were also associated with the following factors[39]:

- VT/VF was observed on the initial field ECG: 93% mortality
- Pupils were dilated and unresponsive to light on arrival in the ED: 89% mortality
- Severe acidosis was documented in the ED: 89% mortality
- Respiratory arrest occurred after arrival in the ED: 87% mortality

FIGURE. Proposed Algorithm for Grading of Submersion Episodes to Facilitate Uniform International Reporting



- Victims never regained consciousness, remaining comatose at the scene and on arrival at the hospital: 100% mortality

Submersion victims who have spontaneous circulation and breathing in the field, before arrival at the ED, usually recover with good neurologic outcomes. In the King County database, no deaths occurred among victims who were responsive at the scene or in the ED.[27]

Several classification systems have attempted to use clinical findings as predictors of outcome for submersion victims.[29,37] The most coherent and logical approach derives from a long-term analysis of 1831 submersion episodes from the beaches of Brazil.[29]

Unlike other researchers in this area, Szpilman and colleagues[29] did not start with an implicitly derived classification scheme and force each case into the scheme. Instead they derived the classification grades empirically after recognizing that the worse the cardiopulmonary compromise, the worse the mortality rate (see Table 2). The Szpilman classification system is based on identification of cardiopulmonary compromise that is easily assessed by an on-scene physician using only 4 variables: coughing (yes or no), auscultation of the lungs, blood pressure, and heart rate.[29]

Critical Concepts: Application of Proposed Grading Algorithm for Submersion Episodes

Box 1

- A submersion event occurs. If possible determine the duration of submersion.
- If the rescuer can do so safely, the rescuer should open the victim's airway and check breathing and provide rescue breaths in the water if needed.
- Proceed with rescue to shore. Pay close attention to safety of both rescuer and victim. Take C-spine precautions (maintain cervical spine immobilization) as indicated.

Box 2

- After the victim is rescued to shore (or another firm surface), immediately assess the ABCs of BLS: airway, breathing, and circulation.
- Immediately initiate all indicated BLS, ACLS, and pediatric resuscitation interventions based on the presence or absence of a patent airway, spontaneous respirations, and spontaneous pulse. These interventions include the following:
  - — Send a second rescuer to phone 911. The lone rescuer should remain with the victim and provide 1 minute of rescue support (whatever steps of CPR are needed) before leaving the victim to phone 911.
  - — Provide basic life support, including all elements of the primary ABCs. When indicated provide ventilations and chest compressions. Continue until a defibrillator is available.
  - — Once an AED is available, check for the presence of VF/VT ("shockable rhythm") and deliver defibrillatory shocks if indicated.
  - — Provide advanced adult and pediatric life support, including insertion of airway devices, establishment of IV access, and administration of IV medications.

Box 3

- Submersion victims with spontaneous respirations and a sustained pulse are classified on the basis of 3 criteria:
  - — Coughing (Box 6)
  - — Lung auscultation (Box 7)
  - — Cardiac function, eg, blood pressure (Box 8)

Box 4

- Submersion victims who have no spontaneous respirations but have a detectable pulse are classified as *Grade 5*. On the warm-water beaches of Brazil with rapid BLS- and ACLS-level response teams, 56% of submersion victims with a severity of Grade 5 survive to hospital discharge.[29]
- If spontaneous respirations cannot be restored during resuscitative efforts and spontaneous cardiac activity ceases (asystole), treat as a *Grade 6* (Box 5).

Box 5

- Submersion victims who have no spontaneous respirations and no pulse on initial field assessment are classified as *Grade 6*. In Brazil only 7% of these nonbreathing, pulseless submersion victims survive to hospital discharge.[29]
- Victims are classified as *drowning deaths* if they fail to respond to initial resuscitative efforts and fail to regain or sustain spontaneous respirations and pulse.

Box 6

- Auscultate the lungs. Assess whether victim is coughing.
- Coughing in submersion victims implies water aspiration.
- Submersion victims who are not coughing, have clear lungs on auscultation, and have maintained spontaneous circulation and respirations since rescue to shore are classified as *water rescues.*
- Submersion victims who are coughing repeatedly are further classified by the findings on lung auscultation.

Box 7

- The auscultation findings are used to further classify submersion victims with coughing:
  - — Grade 1: Normal lung auscultation. Because these victims have been coughing, they are considered to have aspirated only a small amount of water.
  - — Grade 2: Lung auscultation reveals some rales, but in only one lung.
  - — Grades 3 and 4: Lung auscultation reveals *acute pulmonary edema* (rales in both lungs). See Box 8 to separate Grade 3 from Grade 4.

Box 8

- In victims with acute pulmonary edema (rales in both lungs), cardiac function and blood pressure distinguish between Grades 3 and 4:
  - — Grade 3: Good cardiac function and adequate blood pressure (5% mortality reported in Brazil[29])
  - — Grade 4: Impaired cardiac function and hypotension (19% mortality reported in Brazil[29])

Outcome Prediction for Submersion Victims: Conclusions

Fate Factors but No System Factors for Submersion Victims

Adult Out-of-Hospital Cardiac Arrest

The landmark work of Eisenberg et al[41] on out-of-hospital cardiac arrest identified what he termed *fate factors* and *system factors*.

- *Fate factors* are age, gender, initial arrest rhythm, location of arrest, and whether the arrest was witnessed. Although probability of survival is related to these factors, they cannot be changed or modified by rescuers.
- *System factors* include time to CPR, time to defibrillation, and time to and quality of early advanced care. These factors are amenable to effective organization and implementation of prehospital care. Community-based efforts to improve system factors and establish a strong Chain of Survival have revolutionized the approach to emergency medical services worldwide.[42]

Submersion Events

The epidemiologic studies of submersion events paint a pessimistic picture for improving submersion outcomes. Multiple studies have established that outcome is determined largely by a single fate factor—duration of submersion.[29,39,40,43,44] The longer it takes to identify and rescue a submersion victim, the worse the outcome.

The duration of hypoxia during submersion cannot be changed despite the best BLS and ALS efforts. Immediate bystander CPR, however, can limit the duration of hypoxia to the time of submersion only. Delayed CPR results in a longer period of hypoxia.

Immediate provision of BLS and early ALS contribute to the best outcome possible, given the duration of submersion. Nonetheless the relative contributions of these interventions are modest at best. Table 3 illustrates this problem. (Note that these are not published figures but rather data extrapolated from published sources.[29,39,40,43,44])

Table 3 shows that early BLS and ACLS significantly improve the chances of survival. But this data also shows the greater power that duration of submersion exerts over outcome. For example, victims rescued from the water within 5 minutes of submersion have a 70% chance of survival with late BLS and ACLS care and a 90% chance with immediate care. A person rescued from the water several minutes later, after 5 to <10 minutes of submersion, has markedly lower chances of survival regardless of whether BLS and ACLS care is immediate (44%), early (35%), or late (30%).

Although survival from submersion episodes has increased in recent years, this increase does not appear to be attributable to improvements in medical treatment.[27]

"Do-Not-Start" and "When-to-Stop" Guidelines for Submersion Events

With the duration of submersion such a powerful determinant of outcome, one obvious guideline for emergency personnel would be not to initiate resuscitative efforts for a submersion victim with no respirations, no pulse, and a duration of submersion >25 minutes. But there are 2 critical problems with this guideline:

- It is often impossible to determine the precise duration of submersion.
- There are well-publicized anecdotes of successful resuscitations after prolonged submersions. The survivors in these cases are almost exclusively young children submerged in icy cold water, and many of these "survivors" have severe neurologic impairment. It is impossible to derive valid information from lay press reports of submersions or rescues. It is difficult for EMS systems to adopt specific do-not-start guidelines in the face of public perception that "miracle survivors" are commonplace.[45]

It seems reasonable to develop do-not-start and when-to-stop guidelines, based on objective information on the duration of submersion, for submersion victims who

Table 3. Probability of Neurologically Intact Survival to Hospital Discharge Based on Duration of Submersion and Time to Basic and Advanced Life Support* (Extrapolated on Published Data[29,39,40,43,44])

Duration of Submersion (minutes)	Probability of Survival With Late BLS and Late ACLS	Probability of Survival With Early BLS and Late ACLS	Probability of Survival With Immediate BLS and ACLS
0 to <5	70%	80%	90%
5 to <10	30%	35%	44%
10 to <25	3%	5%	12%
≥25	0%	0%	0%

*Late is defined as BLS and ACLS personnel arriving >10 minutes after water rescue; early, BLS personnel arrive <10 minutes after water rescue; and immediate, BLS and ACLS personnel are present when victim is recovered from the water.

are in cardiopulmonary arrest upon rescue from the water (submersion severity grade 6). Very few of these victims are going to survive. For example, even in an excellent system like the one on Brazilian beaches, where physicians respond to submersion events, the survival rate for victims in cardiopulmonary arrest is only 7%, regardless of the duration of submersion.[29]

- As a rule of thumb, about half of victims submerged for 5 to <10 minutes are pulseless upon water rescue.[29,39,40]
- Virtually all victims who ultimately survive from severity grade 6 (not breathing, no pulse) will demonstrate a pulse in the field after a period of full BLS and ACLS interventions.
- King County data confirm this observation, noting that survival is unlikely if cardiac arrest persists despite resuscitation attempts for 25 minutes.[39,40] In studies from this EMS system, no one, not even pediatric victims, survived to hospital discharge if spontaneous circulation did not return within 25 minutes of the start of resuscitative efforts.
  - Informal clinical guidelines in many EMS systems have evolved along the lines of "In normothermic victims, if pulse and respirations have not returned after 25 to 35 minutes of BLS and ALS support, they never will."

If the victim fails to respond to initial BLS, rescuers should evaluate the core temperature as soon as possible to rule out hypothermia. The rescuer should consider prolonging resuscitation attempts for a grade 6 submersion victim if the victim's core temperature is <30°C (86°F). A core temperature at this level is an indication for active internal rewarming.

- If the core temperature is >34°C (93.2°F), the hypothermia is insignificant and should not alter the duration of the resuscitation attempt.
- Between a core temperature of 30°C (86°F) and 34°C (93.2°F), clinical practice varies. Conservative protocols prolong the resuscitative effort until active external rewarming of truncal areas brings the core temperature up to >34°C (93.2°F). Little evidence supports this approach.

Resuscitation Guidelines for Cardiac Arrest Associated With Submersion

BLS Guidelines for Submersion Victims

Rescuer Safety

A cardinal rule of emergency medicine holds that the rescuer's primary obligation is to his/her personal safety. The rescuer must avoid creating "a second victim." The rescuer must always minimize danger to himself/herself. Rescuers should never attempt risky actions that are beyond the scope of their training and experience.

Associated Trauma

Submersion events may be associated with trauma, and the issue of cervical spine immobilization is a difficult one. If the likelihood of head, neck, or spinal cord injury is significant, the rescuer should immobilize the head and neck and open the airway with a jaw thrust. But these maneuvers take time and may delay the effective provision of rescue breathing.

- Rescuers should suspect spinal injuries in all submersions associated with diving; body, wind, or board surfing; falls from motorboats or sailboats; hang gliding; parasailing; or submersions associated with falls from or crashes of personal watercraft. Rescuers should immobilize the cervical spine for these victims.
- *Routine* cervical spine immobilization of *all* submersion victims is not recommended.[28] In a retrospective survey of more than 2244 submersion victims, only 11 (<0.5%) had a C-spine injury, and all 11 had obvious trauma from diving, falling from height, or a motor vehicle crash.[28]

First-responding rescuers who suspect a spinal cord injury should

- Use their hands to stabilize the victim's neck in a neutral position (without flexion or extension).
- Open the airway using a jaw thrust without head tilt or chin lift. This method of airway opening is very difficult to perform in water, so the rescuer must weigh the likelihood of cervical spine injury against the need for immediate rescue breathing in the water.
- Provide rescue breathing while maintaining the head in a neutral position. This method of rescue breathing is very difficult during in-water rescue.
- Float the victim, supine, onto a horizontal back-support device before removing the victim from the water.
- Align and support the head, neck, chest, and body if the victim must be turned.
- If you must move the victim, use a log-roll.

Associated Hypothermia

Consider the potential for hypothermia in all *submersion* events, especially when the initial *immersion* occurs in cold water. It is important to recognize that immersion in cold water is more likely to result in submersion with hypoxia than in development of protective central hypothermia.[46-48] This occurs because swimming in cold water typically produces a sequence of exhaustion, "swim-failure" (inability to maintain horizontal swimming angle with body becoming more vertical relative to water surface), increasingly severe submersions, and finally hypoxia.

This potentially terminal hypoxia occurs at relatively modest levels of central hypothermia. These levels of hypothermia are insufficient to prevent organ ischemia.[48] For example, in the Tipton et al study,[48] competitive swimmers became exhausted after 60 to 90 minutes of swimming in 10°C (50°F) water. At that time of "swim failure" their rectal temperatures had only dropped to 35°C (94.5°F), a temperature that was still too high to exert any protective effect.[48]

To treat associated hypothermia, remove wet garments, dry the victim as soon as possible, and provide active rewarming when indicated (see Part 1: "Hypothermia").

- Cover the victim with blankets or other materials to provide passive rewarming and to prevent further heat loss.
- Obtain rectal or tympanic (core body) temperature as soon as practical, and initiate hypothermia protocols as indicated in the Hypothermia Algorithm (Figure 1 in Part 1 of this chapter).
- If significant hypothermia is thought to be present, resuscitative efforts should continue until core temperature is measured to ensure that hypothermia is not contributing to ineffective resuscitative efforts.

Airway and Breathing

Airway and **B**reathing are the first and most important treatment steps for the submersion victim, and they should begin as soon as they can safely be provided. Rescue breathing should begin in the water if possible.[49]

- Flotation devices and some appliances can facilitate support of airway and breathing in the water if rescuers are trained in their use. Untrained rescuers should not attempt to use such adjuncts. Rescuers should not delay rescue breathing for lack of such equipment if they can otherwise provide it safely.

No Need to Drain Water From the Lungs

Do not attempt to drain water from the lungs. Lay rescuers may think that draining the lungs of water after submersion makes intuitive sense.[2] But the total volume of water aspirated by submersion victims is modest, is distributed widely throughout the lungs, and is absorbed rapidly into the central circulation.[50] There is no need to drain the lungs after submersion, and no evidence that attempts will remove fluid from the lungs. Attempts to drain lungs after fluid aspiration in research settings showed that most fluid obtained comes from the stomach and not from the lungs.[51]

Reviews of this topic by the Institute of Medicine,[51] by the American Heart Association,[52] and in recognized textbooks in resuscitation[3] and emergency medicine[1,2] all conclude that there is no evidence to justify routine attempts to drain water from the lungs after submersion.

Attempts to remove water from the breathing passages by any means other than suction can be harmful.[53-63] Abdominal thrusts, for example, have been reported to cause regurgitation of gastric contents and subsequent aspiration,[54,55,57] spinal cord injuries,[51] pharyngeal obstruction,[63] and rupture of the stomach.[53,56,58-61]

Most important, provision of the Heimlich maneuver delays the initiation of ventilation that is critical to reverse hypoxia. Although proposals for routine use of the Heimlich maneuver for submersion victims occasionally surface in the lay press,[64] this maneuver should be reserved for victims of choking and foreign-body airway obstruction.[65,66] *It should not be used routinely for submersion victims.*

Recent evidence suggests that chest compressions are superior to the Heimlich maneuver for generating intrathoracic pressures sufficient to expel foreign material.[67] The international *ECC Guidelines 2000* recommend that healthcare providers provide the Heimlich maneuver only if submersion victims have evidence of foreign-body airway obstruction.[68]

Vomiting During Resuscitation

Vomiting often occurs during chest compressions or rescue breathing, complicating efforts to maintain a patent airway. In a 10-year study in Australia vomiting occurred in more than 65% of victims who needed rescue breathing and in 86% of those who required both rescue breathing and chest compressions.[43] Even in victims who required no interventions after water rescue, vomiting occurred in 50% once they reached shore.

If vomiting occurs, turn the victim's mouth to the side and remove the vomitus with a finger sweep, a cloth, or suction. If head, neck, or spinal cord injury may be present, remove the vomitus by log-rolling the victim with the head, neck, and torso aligned and turned as a unit.

Chest Compressions

As soon as the victim is removed from the water and 2 rescue breaths are delivered, check for signs of circulation:

- The lay rescuer will check for general signs of circulation (breathing, coughing, or movement in response to rescue breaths).
- The healthcare provider will check for general signs of circulation plus the presence of a central pulse. The pulse may be difficult to detect in a submersion victim, particularly if the victim is cold.

If signs of circulation are absent, start chest compressions at once. In general, rescuers should attempt chest compresions only on shore or on board a stable vessel or floating surface. External chest compressions can be performed in the water if rigid flotation devices are used or if the victim is extremely small and can be supported on the rescuer's forearm. Proper use of in-water resuscitation flotation devices requires device-specific training.

Defibrillation for BLS Providers

If there are no signs of circulation, rescuers should attach an AED to evaluate the rhythm and deliver a shock if prompted by the AED. Although most submersion victims demonstrate asystole, some victims may demonstrate VF/pulseless VT. You cannot safely attempt defibrillation in standing water. Victims will need to be moved out of standing water. Dry the patient's chest before attaching electrodes for monitoring or for defibrillation.

Deliver up to 3 shocks. Then if hypothermia is present, evaluate the victim's core body temperature. If the victim's core body temperature is <30°C (<86°F) and VF persists, do not give further shocks until the victim's core body temperature rises above 30°C (86°F). Resume BLS and ACLS care until that time (see Part 1: "Hypothermia" in this chapter).

ACLS Guidelines for Submersion Victims

Airway and Breathing

The submersion victim in cardiac arrest requires ACLS, including tracheal intubation. Early tracheal intubation is valuable for

- Improved oxygenation and ventilation
- Direct removal of foreign material from the tracheobronchial tree
- Application of continuous positive airway pressure (CPAP) or positive end-expiratory pressure (PEEP)

Circulation and Defibrillation

Victims in cardiac arrest may present with asystole (most common), pulseless electrical activity, or pulseless VT/VF. Rescuers should follow PALS and ACLS guidelines for treatment of these rhythms. Treat submersion victims with severe hypothermia (core body temperature <30°C or <86°F) according to the recommendations for hypothermia:

- Limit defibrillation attempts to 3 if hypothermia is severe, and withhold further shocks and intravenous medications until the core body temperature rises above 30°C or 86°F.
- If moderate hypothermia is present (core body temperature 30°C to 34°C or 86°F to 93.2°F), space intravenous medications at longer than standard intervals (see Part 1: "Hypothermia" in this chapter). Attempt defibrillation with each drug administered in a drug-shock, drug-shock pattern.
- In children and adolescents VT/VF on the initial ECG is an extremely poor prognostic sign.[39]

Summary

- Prevention remains the most powerful therapeutic intervention for submersion events.
- Limiting the duration of submersion remains the second most powerful therapeutic intervention.
- Resuscitation-focused organizations must develop an international consensus approach to uniform reporting of submersion events and their outcomes. The lack of an agreed-upon nomenclature is a major obstacle to effective research in the epidemiology and treatment of submersion events.
- Submersion events must be graded by severity. This grading is based on the clinical signs, ranging from simple aspiration with coughing to apnea with a beating heart to cardiopulmonary arrest (no breathing, no pulse).
- Do-not-start and when-to-stop guidelines are urgently needed to reduce danger to rescue personnel, poor use of resources, and the number of survivors with profound neurologic impairment.
  - — Evidence now exists that supports the following "do-not-start resuscitation" guideline: *Do not start resuscitative efforts for victims of submersion who were submerged for >25 minutes if there are no respirations and no heartbeat upon rescue from the water and if the victim is normothermic (core body temperature >34°C). No* international consensus group has yet made such a recommendation.
  - — Evidence now exists that supports the following "when-to-stop resuscitation" guideline: *Stop resuscitative efforts if there has been no response (no respirations, no heartbeat) after >25 minutes of full BLS and ACLS interventions.* No international consensus group has yet made such a recommendation.
  - — Isolated reports of neurologically intact survivors after >25 minutes of submersion or >25 minutes of attempted resuscitation pose the major obstacle to definitive do-not-start and when-to-stop guidelines. An inspirational anecdote will always trump good science in this regard.
- When treating submersion victims, rescuers should consider the possibility of associated trauma and associated hypothermia.
  - — A history or strong suspicion of trauma associated with a submersion event is the major indication for C-spine immobilization.
  - — Routine C-spine immobilization for all submersion victims is not recommended at this time because it may compromise the delivery of rescue breathing.
  - — The neuroprotective value of hypothermia for submersion victims in cardiac arrest is probably exaggerated. This effect is possible only when the hypothermia is severe (core body temperature <30°C or <86°F) and the body cooling preceded the submersion hypoxia.
- ACLS personnel should strongly support effective prevention activities, which may at times require legislative and regulatory initiatives. Important prevention activities include
  - — Safe pool design with self-closing, self-locking gates and fencing that encloses the pool on all sides
  - — Trained lifeguards at public pools and beaches
  - — Public swim areas fully equipped with rigid backboards, cervical collars, and BLS supplies, including AEDs
  - — Swimming and lifesaving classes
  - — Lay rescuer CPR-AED training

— Widespread availability and appropriate use of personal flotation devices

— Unremitting, responsible, and mature adult supervision for all infants and children when near any source of the 1 to 2 inches of water necessary for a submersion death

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