2024 American Heart Association and American Academy of Pediatrics Focused Update on Special Circumstances: Resuscitation Following Drowning: An Update to the American Heart Association Guidelines for Cardiopulmonary Resuscitation and Emergency Cardiovascular Care

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abstract

Drowning is the third leading cause of death from unintentional injury worldwide, accounting for 7% of all injury-related deaths. In the United States, drowning is the leading cause of death in children 1 to 4 years of age and second leading cause of death due to unintentional injury in those aged 5 to 14 years. Drowning generally progresses from initial respiratory arrest due to submersion-related hypoxia to cardiac arrest; thus, it can be challenging to distinguish respiratory arrest from cardiac arrest because pulses are difficult to accurately palpate within the recommended 10-second window. Therefore, resuscitation from cardiac arrest due to this specific circumstance must focus on restoring breathing as much as it does circulation. Resuscitation from drowning may begin with in-water rescue breathing when safely provided by rescuers trained in the technique and should continue with chest compressions, in keeping with basic life support guidelines, once the drowned individual and the rescuer are in a safe environment (eg, dry land, boat).

This focused update incorporates systematic reviews from 2021 to 2023 performed by the International Liaison Committee on Resuscitation related to the resuscitation of drowning. These clinical guidelines are the product of a committee of experts representing the American Academy of Pediatrics and the American Heart Association. The writing group reviewed the recent International Liaison Committee on Resuscitation systematic reviews, including updated literature searches, prior guidelines related to resuscitation from cardiac arrest following drowning, and other drowning-related publications from the American Academy of Pediatrics and the American Heart Association. The writing group used these reviews to update its recommendations aimed at resuscitation from cardiac arrest following drowning in children.

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TOP 10 TAKE-HOME MESSAGES FOR RESUSCITATION OF CHILDREN FOLLOWING DROWNING

1. The Drowning Chain of Survival focuses on the primary prevention of drowning, which is vitally important for children; early recognition of drowning; and considerations for safe rescue and resuscitation.
2. Our current recommendations for drowning resuscitation support standard pediatric basic life support (BLS) and pediatric advanced life support (ALS) as the cornerstones of resuscitation.
3. In drowning resuscitation, airway management and ventilation are of particular importance because of the continuum from respiratory arrest to cardiac arrest following drowning.
4. Immediate initiation of rescue breathing by trained rescuers may utilize the first means available (mouth-to-mouth, pocket mask, or bag-mask ventilation).
5. Cardiac arrest following drowning is generally the result of severe hypoxemia; therefore, oxygen administration is recommended when available.
6. Trained rescuers should provide rescue breaths as part of cardiopulmonary resuscitation (CPR) in cardiac arrest following drowning and may initiate with breathing (airway, breathing, chest compressions) or with compressions (chest compressions, airway, breathing).
7. Providing in-water rescue breathing, if the rescuer is appropriately trained and it's safe to do so, may prevent the progression to cardiac arrest following drowning.
8. The use of an automated external defibrillator (AED) after initiation of high-quality CPR may be lifesaving in cardiac arrests following drowning that present with shockable rhythms, which are a minority—especially in children.
9. Public-access defibrillation (PAD) programs may yield important benefits when instituted in aquatic environments and large public areas where cardiac arrest may be more likely even when not the result of drowning.
10. Knowledge gaps in drowning prevention and resuscitation require future research, especially in resource-limited regions.

Abbreviations: AAP, American Academy of Pediatrics; AED, automated external defibrillator; AHA, American Heart Association; ALS, advanced life support; BLS, basic life support; COR, Class of Recommendation; CPR, cardiopulmonary resuscitation; ECC, emergency cardiovascular care; EMS, emergency medical services; ILCOR, International Liaison Committee on Resuscitation; LOE, Level of Evidence; OHCA, out-of-hospital cardiac arrest; PAD, public-access defibrillation

INTRODUCTION

Scope of the Guidelines

These guidelines are designed primarily for health care professionals, trained rescuers, and untrained lay rescuers resuscitating children who have drowned. We have defined "trained rescuer" as an individual with appropriate training to perform the task discussed in a given recommendation. This is independent of the individual's occupation or ethical duty to respond. Lifeguards, swimming instructors, emergency medical technicians, paramedics, police, firefighters, other volunteers, and off-duty health care professionals, if appropriately trained for the task mentioned in the recommendation, would be considered trained rescuers and would be expected to respond in the manner recommended. Trained rescuers must have the appropriate expertise and training necessary for that specific resuscitation task and have access to the equipment necessary to perform the specific skill. An "untrained lay rescuer" is an individual who lacks the expertise to safely perform a specific resuscitation task. A health care professional could be considered trained or untrained depending on the skill required for the task recommended. For example, an off-duty health care professional who has training in BLS and ALS would be expected to deliver chest compressions with rescue breathing. On the other hand, a health care professional who is not skilled at water rescue would be considered untrained for in-water rescue breathing. In-water rescue is a skill typically not learned by health care professionals but common to most aquatic first responder training (eg, lifeguards).

The background provided and our recommendations are directed toward the pediatric population (inclusive of infants, children, and adolescents up to 18 years of age) whenever possible, on the basis of the available evidence. The literature we cite is from studies including the pediatric population aged <18 years, and we've purposely excluded studies only enrolling those 18 years and older. Pediatric BLS guidelines related to drowning apply to children without signs of puberty, and pediatric ALS guidelines are inclusive of those aged <18 years as defined in the Pediatric Basic and Advanced Life Support chapter of the "2020 American Heart Association Guidelines for Cardiopulmonary Resuscitation and Emergency Cardiovascular Care."[1] A separate set of guidelines comprehensive of recommendations in both adults and children is being published simultaneously in *Circulation*. This is the first publication on drowning resuscitation guidelines for children, independent of adults, that is endorsed by both the American Academy of Pediatrics (AAP) and the American Heart Association (AHA). The rationale for writing 2 separate focused updates was twofold: (1) to evaluate pediatric data in drowning resuscitation independent of adults, and (2) to provide the subsequent recommendations to an audience of health care professionals who provide care for drowned children, citing primarily pediatric literature.

This guideline is focused on resuscitation of children following drowning. Because the drowning process follows a continuum from respiratory arrest to cardiac arrest, these guidelines include recommendations for initial resuscitation throughout that continuum in children. The World Health Organization defines drowning as "the process of experiencing respiratory impairment from submersion/immersion in liquid." Outcomes are classified as fatal drowning (death) or nonfatal drowning (morbidity or no morbidity).[2,3] Any other terms previously used to describe drowning are not recommended, including near drowning, secondary drowning, and dry drowning.

Prevention is a key component to any discussion on drowning because the majority of drownings do not progress to respiratory or cardiac arrest. In a 2018 study from Brazil, data reported by lifeguards for 2044 drowning rescues found that only 14 (0.7%) required respiratory resuscitation or CPR.[4] Considering all interventions undertaken by a fully operational lifeguarding system, the incidence of resuscitation is only 1 in every 112 000 lifeguard actions (0.0009%).[4] An in-depth review of drowning prevention is outside the scope of this focused update on resuscitation, but this topic has been recently reviewed in an AAP technical report,[5] by the World Health Organization,[2,6] by the Wilderness Medical Society,[7] and in narrative reviews.[8,9] A brief summary of evidence-based prevention strategies is outlined later in this article, within the context of the Drowning Chain of Survival.

The recommendations in this focused update provide guidance on the application of BLS and ALS for the resuscitation of children in the special circumstance of drowning. This update is not intended to modify BLS and ALS in resuscitation circumstances other than drowning. These guidelines are not intended for other special circumstances, such as the COVID-19 pandemic.[10–12]

Organization of the Writing Group

This writing group included a diverse group of volunteers from the AAP, the AHA, and the International Liaison Committee on Resuscitation (ILCOR), with representative clinical expertise in drowning, pediatrics, adult and pediatric critical care, anesthesiology, emergency medicine, prehospital emergency medical services (EMS), education, and research. A call for candidates was distributed to AAP subject matter experts and AHA emergency cardiovascular care (ECC) subject matter experts, and members with recognized expertise in adult and pediatric resuscitation were nominated by the writing group co-chairs. Writing group members were selected by the AAP Executive Committee and the AHA ECC Science Subcommittee and then approved by the AHA Manuscript Oversight Committee.

The AAP and the AHA have rigorous conflict of interest policies and procedures to minimize the risk of bias or improper influence during the development of guidelines. Before their appointment, writing group members disclosed all relevant commercial relationships and other potential (including intellectual) conflicts.[13] Appendix 1 of this article lists disclosure information and the writing group members' relevant relationships with industry.

Methodology and Evidence Review

Updated AAP/AHA guidelines for CPR and ECC are developed in concert with ILCOR's continuous evaluation of new resuscitation science.[13] This 2024 focused update addresses the AAP/AHA guidelines for CPR and ECC following drowning and is based on 7 systematic reviews completed by the ILCOR BLS Task Force,[14,15] used to generate updated treatment recommendations and good practice statements. The BLS Task Force reviewed the following 7 drowning topics in 2022 and 2023: in-water resuscitation versus delayed resuscitation; oxygen administration following drowning; AED first versus CPR first in cardiac arrest following drowning; chest compressions, airway, breathing versus airway, breathing, chest compressions; implementation of PAD programs; ventilation with equipment versus without equipment before hospital arrival following drowning; and compression-only CPR. The draft BLS systematic reviews were posted online for public comment, and the final wording has been published in the Consensus on CPR and ECC Science with Treatment Recommendations summaries from 2022[14] and 2023.[15] Full details on the ILCOR systematic review process can be found in the "2023 International Consensus on Cardiopulmonary Resuscitation and Emergency Cardiovascular Care Science With Treatment Recommendations: Summary from the Basic Life Support; Advanced Life Support; Pediatric Life Support; Neonatal Life Support; Education, Implementation, and Teams; and First Aid Task Forces" publication."[15] The expert writing group for this 2023 Special Circumstances focused update analyzed and discussed the systematic reviews and carefully considered the treatment recommendations drafted by the ILCOR BLS Task Force to update AAP/AHA drowning guidelines. Guideline recommendations of each module were drafted by 2 writing group members and then reviewed and refined by all writing group members during regular meetings. The final recommendation wording was reviewed and approved by all writing group members.

Class of Recommendation and Level of Evidence

As with all AHA guidelines, each recommendation in this focused update is assigned a Class of Recommendation (COR) on the basis of the strength and consistency of the evidence (Table 1). The Level of Evidence (LOE) is based on the quality, quantity, relevance, and consistency of the available evidence. For each recommendation, the writing group discussed and approved specific recommendation wording and the COR and LOE assignments. The specific criteria used to determine COR and LOE have been

TABLE 1 Applying Class of Recommendation and Level of Evidence to Clinical Strategies, Interventions, Treatments, or Diagnostic Testing in Patient Care (Updated May 2019)*

CLASS (STRENGTH) OF RECOMMENDATION	LEVEL (QUALITY) OF EVIDENCE‡
CLASS 1 (STRONG) — **Benefit >>> Risk** **Suggested phrases for writing recommendations:** • Is recommended • Is indicated/useful/effective/beneficial • Should be performed/administered/other • Comparative-Effectiveness Phrases†: – Treatment/strategy A is recommended/indicated in preference to treatment B – Treatment A should be chosen over treatment B	**LEVEL A** • High-quality evidence‡ from more than 1 RCT • Meta-analyses of high-quality RCTs • One or more RCTs corroborated by high-quality registry studies
CLASS 2a (MODERATE) — **Benefit >> Risk** **Suggested phrases for writing recommendations:** • Is reasonable • Can be useful/effective/beneficial • Comparative-Effectiveness Phrases†: – Treatment/strategy A is probably recommended/indicated in preference to treatment B – It is reasonable to choose treatment A over treatment B	**LEVEL B-R** — **(Randomized)** • Moderate-quality evidence‡ from 1 or more RCTs • Meta-analyses of moderate-quality RCTs
CLASS 2b (WEAK) — **Benefit ≥ Risk** **Suggested phrases for writing recommendations:** • May/might be reasonable • May/might be considered • Usefulness/effectiveness is unknown/unclear/uncertain or not well-established	**LEVEL B-NR** — **(Nonrandomized)** • Moderate-quality evidence‡ from 1 or more well-designed, well-executed nonrandomized studies, observational studies, or registry studies • Meta-analyses of such studies
CLASS 3: No Benefit (MODERATE) (Generally, LOE A or B use only) — **Benefit = Risk** **Suggested phrases for writing recommendations:** • Is not recommended • Is not indicated/useful/effective/beneficial • Should not be performed/administered/other	**LEVEL C-LD** — **(Limited Data)** • Randomized or nonrandomized observational or registry studies with limitations of design or execution • Meta-analyses of such studies • Physiological or mechanistic studies in human subjects
CLASS 3: Harm (STRONG) — **Risk > Benefit** **Suggested phrases for writing recommendations:** • Potentially harmful • Causes harm • Associated with excess morbidity/mortality • Should not be performed/administered/other	**LEVEL C-EO** — **(Expert Opinion)** • Consensus of expert opinion based on clinical experience

COR and LOE are determined independently (any COR may be paired with any LOE).

A recommendation with LOE C does not imply that the recommendation is weak. Many important clinical questions addressed in guidelines do not lend themselves to clinical trials. Although RCTs are unavailable, there may be a very clear clinical consensus that a particular test or therapy is useful or effective.

* The outcome or result of the intervention should be specified (an improved clinical outcome or increased diagnostic accuracy or incremental prognostic information).

† For comparative-effectiveness recommendations (COR 1 and 2a; LOE A and B only), studies that support the use of comparator verbs should involve direct comparisons of the treatments or strategies being evaluated.

‡ The method of assessing quality is evolving, including the application of standardized, widely-used, and preferably validated evidence grading tools; and for systematic reviews, the incorporation of an Evidence Review Committee.

COR indicates Class of Recommendation; EO, expert opinion; LD, limited data; LOE, Level of Evidence; NR, nonrandomized; R, randomized; and RCT, randomized controlled trial.

described in detail previously.[13] The use of COR/LOE and knowledge chunks follows existing AHA format.[16]

Guideline Structure

This focused update is organized into knowledge chunks, grouped into discrete modules of information on specific topics or management issues.[13,16] Each modular knowledge chunk includes a table of recommendations that uses the standard AHA nomenclature of COR and LOE. Recommendations are presented using the hierarchical order of COR: most potential benefit (Class 1), followed by lesser certainty of benefit (Class 2a and then 2b), and, finally, potential for harm or no benefit (Class 3). The ordering of recommendations by COR does not necessarily reflect the sequence in which care should be provided. A brief synopsis is provided to put the recommendations into context with important background information and overarching management or treatment concepts. Recommendation-specific text clarifies the rationale and key study data supporting the recommendations. When appropriate, additional tables are included. Hyperlinked references facilitate quick access and review.

Document Review and Approval

The AAP conducted peer review of this focused update by providing a draft to various stakeholder groups (committees, councils, and sections). Suggested edits were combined and reviewed by members of the AAP Senior Leadership Team and Board of Directors. This focused update was also submitted for blinded peer review to 5 subject matter experts nominated by the AHA and 1 organizational review conducted by the AAP. Before appointment, all peer reviewers were required to disclose relationships with industry and any other conflicts of interest, and all disclosures were

reviewed by AHA staff. Peer reviewer feedback was provided for guidelines in draft format and again in final format. All guidelines were reviewed and approved for publication by the AAP Board of Directors, the AHA Science Advisory and Coordinating Committee, and the AHA Executive Committee. Comprehensive disclosure information for peer reviewers is listed in Appendix 2.

These recommendations supersede the last full set of AHA recommendations for drowning, made in 2020,[17] and prior drowning guidelines.[18–20] All other recommendations and algorithms published in the 2020 AHA Guidelines for CPR and ECC remain the official recommendations of the AHA ECC Science Subcommittee and writing groups.[17,21] The writing group consisting of AAP and AHA representatives voted on and approved all guideline recommendations.

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MAJOR CONCEPTS

Drowning Chain of Survival

The Drowning Chain of Survival (Figure) refers to a series of interventions that, when put into action by trained rescuers or untrained lay rescuers, reduce mortality associated with drowning. The Drowning Chain of Survival was first developed in 2002 and was updated in 2014, after recognition that the Drowning Chain of Survival,

FIGURE.
Drowning Chain of Survival.
Reproduced from Szpilman D, Webber J, Quan L, et al. Creating a drowning chain of survival. *Resuscitation.* 2014 Sep;85(9):1149–52.

which is heavily focused on prevention and rescue, has several unique differences from traditional cardiac arrest Chains of Survival. A Delphi process was conducted among drowning prevention and resuscitation experts at the World Conference on Drowning Prevention in 2013 to facilitate the creation and refinement of the Drowning Chain of Survival, while aligning with contemporary medical and lifeguarding science.[1]

Primary prevention is the best way to reduce injury and death from cardiac arrest following drowning, similar to other causes of cardiac arrest. However, once the drowning process begins, the Drowning Chain of Survival highlights several key differences. The first challenge for rescuers is to recognize someone at risk of drowning and identify the need for rescue. Open bodies of water make recognition of those in distress difficult because waves may obscure visualization at the surface. Furthermore, the drowning process happens quickly,[2,3] and those in distress will rapidly submerge, lose consciousness, and be hidden from those not actively seeking them. As a result, during this process of drowning, persons may not be able to verbalize or signal when they need help.[4]

Drowning often involves an underestimation of the dangers of the aquatic environment or an overestimation of water competency (ie, overconfidence in swimming ability based on the conditions encountered).[5] Other important factors include access to swim lessons (which may be a marker for socioeconomic status), lack of familiarity with water conditions and hazards, and the presence of neurodevelopmental disorders such as epilepsy and autism and other chronic conditions that significantly increase risk.[6] This risk is conferred not only to the person drowning but also to those attempting rescue who may themselves succumb to drowning. In pediatric drowning the rescuer is often a family member willing to take significant risks to rescue their loved one. In this setting, it may be challenging to implement a stepwise approach to rescue (eg, provide a flotation device if possible before a direct-contact rescue), understanding incremental increases in the threat posed to the rescuer. But such an approach is crucial to avoid fatalities to the rescuer as well.[7] Responders' knowledge of the complete sequence of steps in the Drowning Chain of Survival will maximize balancing the need for rapid rescue and intervention, while prioritizing rescue safety.[8]

1. **Prevent drowning:** The most effective way to reduce the number of drowning deaths is primary prevention. It has been estimated that more than 90% of all drownings are preventable.[9–11] Primary preventative approaches may vary in different settings. Five evidence-based interventions can prevent pediatric drowning: (a) installing 4-sided, isolation fencing around swimming pools, (b) wearing approved life jackets, (c) providing swimming lessons especially for children and non-swimmers, (d) swimming where there are lifeguards, and (e) ensuring close and active supervision of weak or nonswimmers in and around water.[11–14]
2. **Recognize distress and ask someone to call for help:** Recognizing a person in distress and sending for help is a key element that ensures early activation of professional rescue and EMS.[4] Recognition of drowning may be challenging because drowning persons may not be able to verbalize distress or signal for help using their arms, given the instinctive drowning response that prioritizes attempts to breathe.
3. **Provide flotation to the drowned person to prevent submersion:** It is critical that rescuers take precautions to not become a second victim by attempting inappropriate or dangerous rescue responses.[2,3] The safest method to initiate help during a drowning involves remaining out of the water, calling for rescue services (ie, a lifeguard, EMS), throwing flotation material, and waiting for a professional to arrive.
4. **Remove from water, only if safe to do so:** Removing a drowned person from the water is essential to terminating the drowning process. It also allows further assessment and medical management.[15] When selecting a removal technique and timing of extrication, rescuers must take into consideration their experience and the environment. Extrication from the water is preferably in a near-horizontal position, but with the head maintained above body level and airway open, when the patient is in shock or likely

cardiac arrest. If the patient is conscious and the rescuers concern is to avoid vomiting and facilitate spontaneous respirations, a more vertical position may be preferable. Because it may be challenging for rescuers to determine whether some patients are in shock, extrication from the water in the most feasible position is suggested so as not to delay initiation of resuscitation.

5. **Provide care as needed by using BLS and ALS:** Cardiac arrest following drowning comprises <0.5% of all rescues.[9] Early BLS contributes to a good outcome and should be initiated as soon as possible.[19] Once EMS arrives, initiation of ALS is appropriate if cardiac arrest has occurred. All persons requiring any level of resuscitation following drowning (including only rescue breaths) should be transported to the emergency department.[16]

Prior AHA/AAP Publications About Drowning

The AHA has recently published guidelines on the resuscitation of children and adults from drowning. The AAP has recently published a policy statement and a technical report, which discuss the epidemiology of drowning in children, extensively discuss prevention strategies and advocacy opportunities, reiterate the Drowning Chain of Survival, and briefly touch on the resuscitation of persons following drowning.[13,16,17,20,21] These prior guidelines are the context in which this focused update is written and provide our starting point in terms of recommendations. This is meant to allow readers who are interested to go back to the most recent version of the drowning guidelines, which this focused update supersedes.

Other guidelines exist from organizations such as the European Resuscitation Council[21] and the Wilderness Medical Society,[18] which are beyond the scope of this update.

Multiple "layers of protection" are necessary for drowning prevention, especially in children, because it is unlikely that any single strategy will prevent drowning deaths and injuries.[17,18] These are summarized in the AAP policy statement and technical report on the prevention of drowning. Drowning prevention is best achieved by identifying the causes of drowning and then instituting a culturally acceptable prevention program that targets those individuals at greatest risk by using appropriate resources.[8,19]

With respect to resuscitation from cardiac arrest following drowning, the AHA has made a series of recommendations organized within different sections of prior guidelines. The 2010 AHA drowning recommendations were found in 3 chapters: Adult BLS, Pediatric BLS, and Cardiac Arrest in Special Situations.[22–24] The 2010 Pediatric BLS guidelines also recommended in-water rescue breathing.[22] Both the 2010 Pediatric BLS and Adult BLS guidelines recommend that lone rescuers administer 5 cycles of CPR before EMS activation.[22,23] The 2010 AHA Cardiac Arrest in Special Situations guidelines[24] recommended altering the sequence of resuscitation for health care professionals from the then-standard chest compressions, airway, breathing to airway, breathing, chest compressions in drowning and for use of an AED after drying the chest.

The 2020 adult BLS and ALS guidelines[25] support standard BLS and ALS as the cornerstones of treatment, with airway management and ventilation being of particular importance because of the respiratory etiology underlying most cardiac arrests following drowning. These guidelines reiterated some of the 2010 Cardiac Arrest in Special Situations[24] recommendations, such as rescuers should provide prompt CPR that includes rescue breathing and that all drowned persons requiring resuscitation should be transported to the hospital for evaluation, monitoring, and treatment. They also recommended against routine stabilization of the cervical spine without a suggestive history or physical findings. Additionally, it was recommended that rescuers provide in-water ventilation when safe and feasible.[25] The 2020 pediatric BLS and ALS guidelines[26] recommended that health care professionals consider multiple factors when predicting outcome of infants and children who are resuscitated from cardiac arrest following drowning, with submersion duration being one of the most important prognostic factors.[27] While not a formal guideline, the 2021 AAP technical report on the prevention of drowning for practicing pediatricians describes Hands-Only CPR as inappropriate in drowning and questions the benefits of deferring CPR to obtain an AED.

This focused update was based on systematic reviews performed by ILCOR since 2020. We therefore did not update recommendations related to cervical spine immobilization and transport of drowned persons to the hospital, which have appeared in prior guidelines.

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IN-WATER RESCUE BREATHING

Synopsis

Whenever an unresponsive child is found in the water, the rescuer is confronted with a difficult choice of whether to initiate rescue breathing immediately or once the drowned child has been removed from the water. The drowning process involves initial hypoxia that may progress to respiratory arrest followed by cardiac arrest if not promptly addressed in children.[1–8] In most cases of respiratory arrest following drowning, a prolonged in-water time before rescue breathing initiation can progress to cardiac arrest and death.[1–4] When respiratory arrest is corrected by rescue breathing that interrupts the drowning process, the death rate is lower (44%) than in those cases in which CPR (including chest compressions) is needed (93%).[1–6]

Recommendation for In-Water Rescue Breathing		
COR	**LOE**	**Recommendation**
2b	C-LD	1. It may be reasonable for appropriately trained rescuers to provide in-water rescue breathing to an unresponsive child who has drowned if it does not compromise their own safety.

Recommendation-Specific Supportive Text

1. One retrospective observational study of in-water resuscitation of nonbreathing drowned individuals rescued by lifeguards found higher odds of return of spontaneous circulation, survival to hospital discharge, and hospital survival with favorable neurological outcome compared to similar individuals who did not receive in-water resuscitation.[4] In-water rescue breathing may be considered only in situations in which an appropriately trained rescuer determines that the rescuer safety, equipment available, and distance to shore warrant its use. At any point during the rescue attempt, if the rescuer feels that the application of in-water rescue breathing is too difficult or is affecting personal safety, then the rescuer should opt to forgo its application.

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OXYGEN ADMINISTRATION FOLLOWING DROWNING

Synopsis

Hypoxia is the major sequelae of drowning and, when severe and prolonged, can lead to cardiac arrest. Even with effective CPR, cardiac output, cerebral oxygenation, and blood flow range from 12% to 42% of prearrest values.[1–3] Optimizing oxygenation may be beneficial because of decreased diffusion capacity of the lungs from aspiration. However, a full discussion on the pathophysiology of drowning is beyond the scope of this focused update.[4] Adult and pediatric BLS guidelines support the use of maximal available oxygen concentration during CPR.[5,6] Oxygen administration has regulatory and legal restrictions in several countries and requires the provision, use, and maintenance of equipment as well as an understanding of the mechanisms and risks of oxygen administration and storage. Use of oxygen may be limited in low- and middle-income countries.

Recommendation for Oxygen Administration Following Drowning		
COR	LOE	Recommendation
1	C-EO	1. Trained rescuers should provide supplemental oxygen if available to children with cardiac arrest following drowning.

Recommendation-Specific Supportive Text

1. No study directly addresses use, timing, or concentration of oxygen delivery to drowned children. The use of supplementary oxygen during and after CPR is accepted practice for trained rescuers providing resuscitation from drowning.[7,8] Oxygen supplementation should be provided only if it does not delay high-quality CPR. Hypoxemia is associated with worse outcomes,[9–15] and rapid reversal of hypoxemia through prompt bystander CPR is associated with improved outcomes from drowning.'[21] We do not make a recommendation about the use of pulse oximetry monitoring during drowning because of uncertainty regarding the effectiveness or the accuracy of pulse oximetry in the setting of CPR.[18,20,21]

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AED FIRST VERSUS CPR FIRST IN CARDIAC ARREST FOLLOWING DROWNING

Synopsis

Cardiac arrest following drowning is most commonly from a hypoxic drowning process; however, it may be less commonly from a primary cardiac event.[1] Initial shockable rhythms constitute a minority (2%–12%) of cardiac arrests following drowning,[2–6] though this data includes adult and pediatric subjects. The low incidence of shockable rhythm supports the emphasis placed on high-quality CPR with rescue breaths elsewhere in this document. When shockable rhythms are present following drowning, this is associated with higher odds of survival,[2,7,8] including improved survival after drowning in children.[8] The crude mortality rate from drowning is highest in younger children aged 1 to 4 years compared to other 5-year age bands across the pediatric population. Drowning in this younger population is more often unwitnessed,[3,9] which may partially explain the low incidence of shockable rhythms. Shockable rhythms following drowning may also be less common because of longer durations of submersion or longer response times.[3,5] Individuals may also present with shockable cardiac arrest due to nondrowning etiologies while in an aquatic setting. AEDs are feasible and safe to use in cardiac arrest following drowning.[10,11] A trend toward more frequent application of AEDs in cardiac arrest following drowning has been demonstrated.[12]

Recommendations for AED First *Versus* CPR First in Cardiac Arrest Following Drowning

COR	LOE	Recommendations
1	B-NR	1. In cardiac arrest following drowning, CPR with rescue breaths should be started before AED application.
2a	B-NR	2. AED use is reasonable in cardiac arrest following drowning.
3-Harm	C-LD	3. The initiation of CPR should not be delayed to obtain or apply an AED in cardiac arrest following drowning.

Recommendation-Specific Supportive Text

1. Observational studies of out-of-hospital cardiac arrest (OHCA), and specifically cardiac arrest following drowning, show improved outcomes when CPR including rescue breathing is initiated promptly.[13–15,21] One observational study of cardiac arrest following drowning found a decreased incidence of favorable neurological outcome associated with AED use,[5] which may represent delays in high-quality CPR while seeking an AED.
2. It is difficult to quantify the benefit of AED use in cardiac arrest following drowning given that shockable

rhythms occur less commonly in the drowning process. When shockable rhythms are present, AED application is safe and has conferred a survival benefit in some studies.[2,7,8]

3. While outcome data are mixed on AED use in cardiac arrest following drowning, when initial shockable rhythms are present in OHCA, AED use is associated with survival.[5,12] AED use is safe and feasible in cardiac arrest following drowning,[10,11] but AED application may present delays. AED application before EMS arrival was associated with a decreased likelihood of favorable neurological outcome, which may be due to a delay in initiating high-quality CPR with rescue breaths and compressions.[5]

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CPR IN CARDIAC ARREST FOLLOWING DROWNING

Synopsis

Children who are removed from the water without showing signs of normal breathing or consciousness are presumed to be in cardiac arrest.[1,2] Current pediatric BLS guidelines advise untrained lay rescuers to initiate chest compressions and rescue breathing without an initial pulse check because pulse checks are inaccurate and delay resuscitation.[1,3] Health care professionals may check for a pulse for up to 10 seconds before initiating CPR. Lay-rescuer CPR is associated with improved survival in cardiac arrest following drowning[4–6] and, therefore, should be initiated immediately and without delay after initial assessment of the child. Chest compressions, airway, breathing became the standard order for CPR in

Recommendations for CPR in Cardiac Arrest Following Drowning		
COR	**LOE**	**Recommendations**
1	B-NR	1. In cardiac arrest following drowning and after removal from the water, CPR with rescue breaths and chest compressions should be provided to children.
2a	B-NR	2. In cardiac arrest following drowning, if the rescuer is unwilling, untrained, or unable to provide rescue breaths, it is reasonable to provide chest compressions only, until help arrives.
2b	C-EO	3. In cardiac arrest following drowning, it may be reasonable for trained rescuers to initiate CPR with rescue breaths followed by chest compressions.

2010 for children and adults because it decreases the time to initiation of chest compressions by 5 seconds.[7,8]

Cardiac arrest following drowning is most often due to a hypoxic mechanism; therefore, rescue breathing is important to increase the likelihood of return of spontaneous circulation.[9] This differs from sudden cardiac arrest, which often results from a cardiac etiology and where the individual generally collapses with fully oxygenated blood. Compression-only CPR by a lay rescuer has been associated with reduced survival in children[10–12] in observational studies of cardiac arrest due to noncardiac etiologies, such as drowning, as well as in all pediatric OHCA.[13]

Recommendation-Specific Supportive Text

1. Multiple large observational studies of children with OHCA, and specifically cardiac arrest following drowning, show improved outcomes when CPR includes rescue breaths.[4,5,9,14,15]
2. Because of the evidence of improved outcomes in children when CPR includes rescue breaths,[4,5,9,14,15] only if the rescuer is unable (eg, untrained rescuer, rescued child has facial trauma) or unwilling to provide rescue breaths should compression-only CPR be performed in resuscitation of cardiac arrest following drowning. Rescue breaths should be included once a trained rescuer has arrived to assist.
3. There is no direct evidence evaluating the sequence of resuscitation in cardiac arrest following drowning. One small observational study found decreased odds of death as well as improved neurological outcome among individuals who suffered a cardiac arrest following drowning and received immediate in-water rescue breaths compared with delayed on-land CPR.[9] However, a manikin study found that time to completion of the first CPR cycle (30 compressions and 2 breaths) was 15 seconds shorter in a compressions-first strategy.[19] Initiating CPR with airway, breathing, chest compressions by trained rescuers is appropriate as long as there is no delay (eg, waiting for personal protective equipment or ventilation equipment).

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IMPLEMENTATION OF PAD PROGRAMS FOR DROWNING

Synopsis

OHCA can occur in high-use public areas such as airports, parks, beaches, and pools. Early defibrillation is associated with increased odds of survival; therefore, ensuring public access to defibrillators is important. PAD programs have been associated with improved outcomes for OHCA.[1,2] While initial shockable rhythms from drowning are uncommon (occurring in ≈2%–12% of cardiac arrest following drowning),[3–6] for those who do have an initial shockable rhythm, early defibrillation can be lifesaving. PAD programs have been demonstrated to be cost-effective.[7] Targeted AED placement compared with nationwide deployment has been demonstrated to have incremental cost-effectiveness[8];

Recommendation for PAD Programs for Drowning		
COR	**LOE**	**Recommendation**
2a	C-EO	1. Implementation of PAD programs is reasonable in areas where there is a high risk of cardiac arrest, including aquatic environments (eg areas with high population density, frequent utilization, other forms of exercise, long distances or response times to nearest AED).

however, cost-effectiveness data for AED placement in aquatic environments are lacking. This recommendation applies only to the programmatic placement of AEDs in aquatic environments (eg through public policies)—not to their specific use in resuscitation following drowning.

Recommendation-Specific Supportive Text

1. There is no direct evidence evaluating PAD programs for cardiac arrest following drowning. Twenty-six observational studies and 1 randomized controlled trial evaluating PAD programs in adult OHCA[1,9,10] and 2 observational studies evaluating PAD programs in pediatric OHCA[2] demonstrated improved outcomes. Two studies of PAD programs for cardiac arrest following drowning demonstrated feasibility in lifeboat and water park environments.[5,11]

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Recommendations for Prehospital Ventilation With or Without Equipment		
COR	**LOE**	**Recommendations**
2a	C-EO	1. It is reasonable for trained rescuers to provide rescue breaths by the first means available (mouth-to-mouth, pocket mask, or bag-mask ventilation) for children in cardiac arrest following drowning to avoid any delay in ventilation.
2a	C-EO	1. Provision of rescue breathing using equipment (bag-mask or advanced airways) should be optimized by providing rescuers a competency-based training program with regular retraining and maintenance of equipment.

PREHOSPITAL VENTILATION FOR THE TRAINED RESCUER WITH VERSUS WITHOUT EQUIPMENT FOLLOWING DROWNING

Synopsis

Ventilation is a priority during resuscitation in cardiac arrest following drowning.[1,2] This can be achieved by using mouth-to-mouth breathing, pocket masks, or other equipment (bag-mask, supraglottic airway, or tracheal intubation) on the basis of the rescuer's resuscitation skills and availability of ventilatory equipment. In OHCA, in general, current pediatric ALS guidelines support the use of bag-mask ventilation or an advanced airway (supraglottic airway or tracheal intubation) depending on the situation and the skill set of the rescuer.[3]

Recommendation-Specific Supportive Text

1. Rescue breathing is associated with improved outcomes in cardiac arrest following drowning[4–9]; therefore, we recommend its provision as soon as possible. No human drowning studies have directly compared the different methods to deliver rescue breaths.[1,2] Manikin studies enrolling lifeguards showed mouth-to-mouth ventilation resulted in less chest compression interruptions and more effective ventilation and tidal volume delivery than use of a pocket mask or bag-mask[10] or a face shield.[11]
2. Rescue breathing using equipment has not been compared to no equipment during resuscitation following drowning.[1,2] Ryan and colleagues[12] found no difference in survival with good neurological outcome between adults ventilated with tracheal intubation versus supraglottic airway versus bag-mask ventilation in cardiac arrest following drowning. Supraglottic airway use was associated with lower odds of survival to hospital admission compared with tracheal intubation and survival to discharge compared with bag-mask ventilation.[14] In children, tracheal intubation was associated with worse outcomes in prehospital[13,14] and in-hospital settings though intubation is also an indicator of disease burden.[13–15,21] CPR education research demonstrates that effective rescue breathing is a difficult skill to master and that training is most effective when it incorporates a hands-on aspect and is repeated to build retention.[16]

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TABLE 2 Research Topics to Address Knowledge Gaps in Drowning Resuscitation

Are untrained lay rescuers competent to distinguish respiratory arrest from cardiac arrest following drowning?
Are lifeguards competent to use bag-mask or supraglottic ventilation in children following drowning?
What is the competency level of different types of rescuers to perform in-water rescue breathing following drowning?
Are lifeguards competent to perform resuscitation in cardiac arrest following drowning on rescue crafts (surfboards, stand-up paddle boards, personal watercrafts, boats)?
What is the outcome of resuscitation in cardiac arrest following drowning in areas with and without trained lay rescuers (eg lifeguards)?
How does resuscitation with and without oxygen affect outcomes in cardiac arrest following drowning?
How does resuscitation using A-B-C versus C-A-B affect outcomes in cardiac arrest following drowning?
How does the use of an AED in the early stage versus in a later stage of the resuscitation affect outcomes in cardiac arrest following drowning?
Does the use of oxygen during transport of a drowned child to the hospital improve outcomes?
What is the outcome of different airway techniques (tracheal intubation, supraglottic airway, bag-mask, noninvasive ventilation) during transport of a drowned child to the hospital?
How does extracorporeal CPR in cardiac arrest following drowning affect outcomes?
Does targeted temperature management during or after resuscitation improve neurologic outcomes in cardiac arrest following drowning?
Does admission to a drowning center versus other health facilities (regionalization of the treatment of drowned children) affect outcomes in cardiac arrest following drowning?
Is drying the chest before using an AED on a drowned child necessary for safe defibrillation? Does drying the chest impact defibrillation success?

A-B-C indicates Airway, Breathing, Chest compressions; AED, automated external defibrillator; C-A-B, Chest compressions, Airway, Breathing; CPR, cardiopulmonary resuscitation.

KNOWLEDGE GAPS AND PRIORITIES OF RESEARCH

ACKNOWLEDGMENTS

The writing group identified several important drowning-related knowledge gaps that deserve priority for future research in the areas of drowning prevention and drowning resuscitation. Gaps in drowning prevention knowledge result from an incomplete epidemiologic profile of fatal and nonfatal drowning in different bodies of water. Additionally, there is a need for rigorous, well-designed studies based on theoretical frameworks that can assess the effectiveness of interventions to reduce drowning and may include a multistrategy approach.[1–4] Prevention of drowning is most relevant in low- and middle-income countries where up to 90% of all childhood drownings occur.[5]

Knowledge gaps in drowning resuscitation result from a dearth of prospective studies that use standardized drowning event reporting and outcomes.[6,7] This is highlighted by the lack of randomized controlled trials found in the ILCOR systematic reviews on drowning. Given the few studies with sufficient rigor to inform drowning resuscitation best practices, future research design considerations include using (1) definitions of fatal and nonfatal drowning,[8] (2) the Utstein template for drowning event reporting,[6,7] (3) multiple data sources for drowning,[9] (4) multiple regression analysis,[9,10] and (5) multisite collaborative research.[11,12] Acknowledging that the largest burden of drowning occurs in low- and middle-income countries, a critical knowledge gap includes the cultural and practical implications of drowning interventions (for both prevention and resuscitation). Critical knowledge gaps in drowning resuscitation research are summarized in Table 2.

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