

## REVIEW ARTICLE

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## Prevention of and Emergency Response to Drowning

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WE DEVELOP FROM EMBRYOS THAT ARE SURROUNDED BY WATER. AFTER being born, we need water to live. Water views relax us, and water sports entertain us. Perhaps that is why many of us have difficulty perceiving water as dangerous. Yet every year, thousands of Americans die from being underwater for too long. According to the World Health Organization, “Drowning is the process of experiencing respiratory impairment from submersion/immersion in liquid.”<sup>1</sup> It can result in death, nonfatal injury, or no injury. More than any other factor, the duration of submersion predicts the outcome.<sup>2</sup> Because submersion occurs before the health care system comes into play, a discussion of drowning prevention precedes a discussion of treatment.

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## EPIDEMIOLOGY

In 2020, a total of 5419 people died from drowning in the United States.<sup>3</sup> Although most fatal drownings are accidental, 9% of the drownings in 2020 were ruled to be suicides, and in 6%, the intended circumstances could not be determined. Fatal drowning was the leading cause of death for children between the ages of 1 and 4 years.<sup>3</sup> When the *Journal* last reviewed this topic, in 2012, it was the second leading cause of death from injury for toddlers.<sup>4</sup> Mortality rates among patients treated at U.S. hospitals for drowning have ranged from 10 to 17%.<sup>5</sup>

From 2010 through 2019, fatal drowning rates had been declining in the United States among people under 30 years of age. However, the rates increased almost 17% in 2020 over the rates in 2019, according to a special report from the Centers for Disease Control and Prevention (CDC).<sup>6</sup> Investigators at the CDC speculate that social changes related to coronavirus disease 2019 (Covid-19) may have resulted in increased exposures to natural bodies of water and decreased access to environments in which safety measures were in place.

Most people who survive drowning recover fully, but some are left with catastrophic neurologic impairment.<sup>7</sup> In 2020, it was estimated that 7435 people were treated in hospital emergency departments in the United States for nonfatal drowning.<sup>3</sup>

More than 90% of fatal drownings occur in low- and middle-income countries.<sup>1</sup> In 2017, it was estimated that more than half of the unintentional drowning deaths in the world occurred in four countries: China, India, Pakistan, and Bangladesh.<sup>8</sup> Although fatal drownings have been on the decline globally,<sup>8</sup> they are underreported<sup>9</sup> because drownings due to suicide, homicide, and transportation or weather disasters have traditionally been counted under those categories of death rather than under drowning. Furthermore, vital statistics in low-income countries are often drawn from hospital data, and rural drownings may not be reflected in

official mortality reports. This underreporting limits an estimation of aggregate mortality due to drowning.

Across countries, sex and age have been identified as major factors associated with the risk of drowning.<sup>1</sup> In 2020, U.S. rates of fatal drowning among males were at least double those among females throughout the life span, and the rates among adolescent boys and young adult men (from ages 15 through 24 years) were approximately 5 times the rates among adolescent girls and young adult women.<sup>3</sup> Rates of fatal drowning are higher among very young children than in any other age group. In the United States in 2020, the rate of fatal drowning among children who were 1 to 4 years of age was 2.70 deaths per 100,000, as compared with 0.44 per 100,000 among children who were 10 to 14 years of age.<sup>6</sup> Rates tend to increase again in adulthood, peaking among very old adults.<sup>3</sup>

A trend analysis of fatal drownings among people under the age of 30 years revealed racial and ethnic disparities, with the highest mortality among American Indians and Alaska Natives and among Black persons.<sup>10</sup> Other groups that have higher-than-average rates of drowning include people with epilepsy, those with autism spectrum disorder, and those with cardiac arrhythmias such as long-QT syndrome.<sup>11</sup> Snorkeling, in particular, may be a high-risk activity for older adults who have underlying heart disease.<sup>12</sup>

#### CIRCUMSTANCES OF DROWNING

Drownings occur in various situations, depending on the person's vulnerability and environment. Among infants, who cannot leave their homes independently, most fatal drownings in the United States occur in bathtubs. Children younger than 14 years of age are most likely to drown in swimming pools, whereas teens and adults tend to drown in natural bodies of water.<sup>13</sup> Older women,<sup>14</sup> as well as people with epilepsy,<sup>15</sup> are most likely to drown in bathtubs.

According to a review of data from selected countries, approximately 10 to 30% of fatal drownings associated with recreational aquatic activity may be attributable to contemporaneous alcohol use.<sup>16</sup> In the United States, drownings are often assumed to be due to recreational activities. However, the commercial fishing industry in the United States has an occupational fa-

tality rate that is 29 times as high as the national average among all workers,<sup>17</sup> and most of the deaths in that industry are due to drowning.<sup>18</sup> Drowning also causes most deaths associated with hurricanes or tropical cyclones and tsunamis.<sup>19</sup> Internationally, migrants are at risk for drowning when they cross bodies of water between countries.<sup>20</sup>

#### PREVENTION

Drowning is an understudied public health problem, especially in low- and middle-income countries.<sup>21</sup> However, there are evidence-based measures that can be applied to prevention. Because toddlers are at highest risk for drowning, supervision by a caregiver is often emphasized as the cardinal principle in prevention. Empirical studies have shown an association between supervision and the risk of injury.<sup>22</sup> Simply advising caregivers to watch their children is inadequate, however, since the advice does not specify the level of supervision that different circumstances require. Supervision also implies a level of vigilance that may not be realistic for caregivers over extended periods of time. For example, children have drowned when their caregivers were using the bathroom.<sup>23</sup> Supervision should not be conceptualized as present or absent but rather as having three dimensions, according to Saluja et al.: "attention, proximity and continuity."<sup>24</sup> When very young children are near water, "touch" or "arm's length" supervision is required.<sup>11</sup>

Innovative work carried out in Bangladesh suggests that formal day care, organized at the community level, may reduce toddler drownings.<sup>25</sup> Day care is, in effect, professionalized child supervision. It recognizes that for adults to give their undivided attention to protecting young children, they cannot be simultaneously tasked with cooking, cleaning, and fetching water for their families. In low-income countries, improvements to basic infrastructure, such as the provision of piped water and the building of bridges, would reduce the need to access potentially dangerous bodies of water during the course of daily life and, as a result, would reduce drowning rates.

Given the inherent unreliability of supervision, placement of physical barriers is recommended, where possible, to separate vulnerable persons from water hazards. In Australia, for

example, four-sided (i.e., perimeter) fencing around residential swimming pools has been shown to reduce toddler drownings by 83%.<sup>26</sup> Well-crafted legislation can lead to increased installation of fencing.<sup>27</sup> Often, however, such measures are diluted by giving homeowners a mix of tested and untested choices for barriers. Evidence also supports teaching children water competency, including basic swimming skills for children who are 1 year of age or older.<sup>11,28</sup> Lessons should incorporate a message for caregivers to maintain vigilance, because young children cannot be “drowning-proofed.”

As children age and venture farther from home, they are more likely to be exposed to bodies of water with their peers and to swim without authorization or supervision, which can lead to an increased risk of drowning. Under such social conditions, teens and young adults, particularly males, may engage in risk taking that includes alcohol use. In addition to modeling sober engagement in water activities, caregivers can steer older children to swimming areas with lifeguards and make sure that the children understand that even people who know how to swim should always wear U.S. Coast Guard–approved personal flotation devices when they are on the water. Legislation may be an effective tool for increasing the use of life jackets among males, who are less likely than females to follow recommendations that promote their use.<sup>29</sup> Some promising educational approaches have been described, including teaching parents how to protect their children from drowning<sup>30</sup> and persuading adults to wear personal flotation devices.<sup>21</sup> Generally, however, the field of water safety has been overly reliant on education, despite evidence suggesting that environmental modifications and regulation could reduce drowning-related morbidity and mortality<sup>31,32</sup> (Table 1).

#### EMERGENCY RESPONSE TO DROWNING

Given the limitations of current approaches to primary prevention, it is necessary to strengthen our systematic response to a drowning victim. Many treatment advances for drowning start with layperson involvement while the emergency response system is accessed. This safeguard is enhanced by providing widespread training in conventional cardiopulmonary resuscitation (CPR)

**Table 1. A Social-Ecologic Framework Applied to Drowning Prevention.\***

<b>Intrapersonal level</b>
Age
Sex
Socioeconomic status
Race or ethnic group
Resident status (e.g., migrant or tourist)
Residency (e.g., rural, suburban, or urban)
Underlying medical conditions
Water-competency skills
Risk perceptions
Knowledge of evidence-based preventive measures
<b>Interpersonal level</b>
Quality of supervision provided by caregivers of young children near water
Social norms regarding alcohol use
Social norms regarding PFD use
<b>Community level</b>
Offer low-cost or free water-competency training to all young children
Promote swim lessons tailored to high-risk populations
Set up PFD loaner programs near water hazards
Arrange for lifeguards at designated swimming areas (including hotel, motel, and apartment pools)
Provide widespread training in bystander CPR and water-rescue skills among community members
Provide support for caregivers of toddlers
Educate parents about the threat that water poses to their children
Develop early-warning systems and evacuation plans for weather emergencies
Install physical barriers on high bridges
Cover wells and cisterns, preferably with pumps that allow water extraction without lid removal
<b>Policy level</b>
Require residential pools to be fenced on all sides, with self-closing, self-latching gates
Require recreational boaters to wear PFDs
Enforce water safety regulations consistently
Discourage residential construction in flood zones
Regulate public modes of water transport
Oversee the safety of workers in the commercial fishing industry
Ensure that development efforts prioritize the provision of piped water
Include safe water crossings in infrastructure investment
Fund research into clinical management of drowning victims
Address climate change more effectively

\* The information is adapted from McLeroy et al.<sup>33</sup> The framework highlights the complex interplay among the four levels; intervention can occur at any level and tends to be more successful when more than one level is involved. The intrapersonal (i.e., individual) and interpersonal levels list possible targets of intervention, and the community and policy levels list suggested interventions. CPR denotes cardiopulmonary resuscitation, and PFD personal flotation device.

(i.e., compression with ventilation), which has been associated with improved outcomes.<sup>34</sup> Bystanders should also be trained in how to rescue a drowning person without putting their own lives at risk.<sup>35</sup>

In an analysis of 49 studies, the duration of submersion was a predictor of drowning outcomes in most of the studies, and age was a predictor in many of them, with younger age

associated with a better prognosis.<sup>2</sup> The authors of this analysis commented that most of the data they were able to access were drawn from emergency medical services (EMS) and hospital records, which probably excluded people who were swiftly rescued or who died at the scene. None of the studies had been conducted in low-income countries, even though such countries account for most drownings. Once drowning victims have been removed from the water, they should be assessed for signs of cardiac activity. In cases of cardiac arrest, hypoxia should be considered the primary cause, and CPR, including ventilation, should be initiated as soon as possible.<sup>34</sup> Increased survival rates, as well as better neurologic outcomes, have been associated with ventilatory assistance.

A consensus statement has been developed to address resuscitation of drowned persons during the period of widespread Covid-19.<sup>36</sup> The statement calls attention to reducing the need for resuscitation (e.g., by intensifying measures to prevent drowning), using personal protective equipment, and basing the choice of resuscitation techniques on the risk of Covid-19.

The initial professional response to drowning is typically delegated to EMS and emergency departments. Hypothermia can cause cardiac arrest in patients with prolonged immersion (especially in circumstances that do not involve asphyxia [e.g., when the head is above water]) and requires appropriate treatment.

When the patient arrives at the emergency department, pulse oximetry, capnography, and chest radiography should be performed as soon as possible, along with the measurement of arterial blood gas levels and blood glucose, creatinine, and electrolyte levels. The results will determine how care should be provided. Aggressive intervention — possibly including endotracheal intubation — may be necessary if hypoxemia, hypercarbia, or acidosis is detected.<sup>37</sup> A value for the partial pressure of carbon dioxide in arterial blood that is greater than 50 mm Hg may indicate that the patient requires intubation and lung-protective ventilation. Other tests include electrocardiography and repeat radiography if the patient's respiratory symptoms, such as tachypnea, persist. Several studies have suggested that children who have normal mentation that does not deteriorate under observation, who do

not require supplemental oxygen, and whose vital signs remain normal may be considered for discharge from the emergency department after 6 hours.<sup>34</sup>

However, a scoping review on drowning found no randomized, controlled trials addressing any of nine topics related to drowning that required updating, including resuscitation, airway management, oxygen administration, use of an automated external defibrillator, bystander CPR, ventilation strategies, extracorporeal membrane oxygenation, and protocols for hospital discharge. Trials of these interventions are challenging to undertake, but the authors concluded that there is an “urgent need” for more rigorous investigation of how drownings should be managed.<sup>34</sup> In a 2021 review, Szpilman and Morgan concluded that there was “a deficit of high-quality scientific evidence at all stages of the patient's journey following a drowning event, particularly in the hospital setting.”<sup>38</sup>

The Utstein style is a system of uniform reporting of data on drowning-related resuscitation. Utstein-style guidelines were revised in 2015, with the goal of “improving the clarity of scientific communication and the comparability of scientific investigations.”<sup>39</sup> Templates were devised to record detailed data in the categories of victim information, scene information (including the quality of resuscitation), hospital course, and patient disposition. If applied consistently, this standardized information would be available for investigations designed to advance the understanding of drowning. Similarly, in publications over the past 10 years, there has been a consistent appeal for randomized trials, particularly in low- and middle-income countries. Such investigations would more comprehensively populate the Utstein-style data system and lead to evidence-based guidelines for treating and preventing drownings.<sup>2,34,39</sup>

#### FUTURE PROSPECTS

Several recent developments may affect drowning rates. The United Nations General Assembly has adopted a resolution on global drowning prevention that involves a comprehensive and practical framework that “will require partnership, research, and action across a range of sectors” (e.g., transportation ministries and other branch-

es of government) to improve water safety<sup>9</sup>; the document also calls for improvements in data collection on drowning. The World Health Organization is developing a “Non-fatal Drowning Categorization Framework” that should advance our understanding of the global burden of drowning on public health. In keeping with recommendations from the two organizations, the United States has recently developed its first National Water Safety Action Plan (<https://www.watersafetyusa.org/newsap.html>). This 10-year plan will focus on advancing the following six evidence-based drowning prevention strategies: data and public health surveillance (to help identify risk groups and the circumstances of drownings); supervision and lifeguards; life jackets and personal flotation devices; rescue and CPR; barriers, entrapment, and electrical safety; and water safety, water competency, and swim lessons. Every 5 years, progress toward best practices and toward ad-

ressing research gaps is planned to be assessed at the national, state, and community levels.

Drones have shown promise for locating drowning victims and delivering flotation devices to them quickly.<sup>40</sup> Geospatial methods have been used to elucidate risk factors for drowning.<sup>41</sup> These signs of progress are timely, because there is evidence that climate change will lead to an increase in deaths from drowning.<sup>20</sup> A renewed emphasis on evidence-based programs and policies is needed to address drowning-related morbidity and mortality. Greater global engagement is also necessary, given the disproportionately large drowning burden on low- and middle-income countries.

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Disclosure forms provided by the authors are available with the full text of this article at [NEJM.org](http://NEJM.org).

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## Double Take Video: Atrial Fibrillation and Catheter Ablation



In this instructional video, Drs. Jane Leopold, Elliot Antman, and William Sauer provide an overview of the classification and diagnosis of atrial fibrillation, management strategies, and mitigation of stroke risk with anticoagulation therapy.