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Drowning

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INTRODUCTION

Drowning is an endemic 'disaster' all over the world usually related to leisure situations affecting mostly the young that turn into a dramatic and unexpected event for the majority of the population. Parents, friends, relatives, babysitters or guardians may feel not only profound loss and grief, but also guilt for a failure to fulfil protection responsibilities, or intense anger at others who did not provide adequate supervision or medical care.

According to the World Health Organization, 0.7% of all deaths worldwide are due to unintentional drowning, resulting in approximately 42 drowning deaths every hour, every day [1]. This number greatly underestimates the real figures, even for high income countries [2]. Estimates suggest that researchers see only 6% of the problem, as dataset measurement is usually based on attendance at hospitals or by counting death certificates, rather than focusing where drowning occurs – at the pre-hospital setting [3]. Almost all drowning victims are able to help themselves or are rescued in time by bystanders or professional rescuers. In areas where a lifeguard service operates fully, less than 6% of all rescued persons need medical attention and 0.5% of those need cardiopulmonary resuscitation (CPR) [4]. In one report of rescues by bystanders, almost 30% of persons rescued from drowning required CPR [5], which may demonstrate a more severe drowning picture than where lifeguards are on duty. Unfortunately, lifeguard or layperson rescues and first aid attendance are rarely considered in national databases, and the result is a distorted drowning burden scenario worldwide. From 1972 to 2002 the Fire Department of Rio de Janeiro–Lifeguard Service made approximately 166,000 rescues on the beaches, and 8500 victims needed to be attended by the medical team in a drowning resuscitation centre. In this scenario of a full lifeguard service operation, approximately 290 rescues were reported for each death (0.34%), and one death for each 10 victims admitted for medical care in a drowning resuscitation centre [4,6]. The bias produced by not counting the real drowning figures not only affects the importance given to the problem, keeping it as a neglected public health problem [7], but also gives the false impression that every drowning demands CPR and consequently the requirement to know how to resuscitate – a reactive action – becomes the most important tool to save people from drowning.

Drowning involves principles and interventions that are rarely, if ever, found in any other medical situation. It occurs in a hostile environment that does not seem dangerous and this by itself poses a significant problem. The exposure-adjusted, person-time estimations for drowning are 200 times higher than road traffic fatalities [8]. Nevertheless, over 85% of drowning deaths can be prevented by a series of intervention actions [9,10]. When preventative measures fail, responders need to be able to perform the necessary steps to interrupt the drowning process. The first challenge is to recognize someone in the water at risk of drowning and appreciate the need for rescue and emergency medical services (EMS or ambulance) appropriately. Early self-rescue or rescue by others may stop the drowning process and prevent the majority of initial and subsequent water aspiration, respiratory distress and medical complications.

The drowning process happens quickly, but it is critical that rescuers take precautions so they do not become another victim by engaging in inappropriate or dangerous rescue responses [5,11]. Removing the victim from this hostile environment has the potential to do harm to the rescuer, especially for those who are not properly trained or for laypeople with no training at all. This operation may represent a high-risk situation to professional medical responders not trained in water safety. Therefore, it is essential not just for lifeguards but for health professionals to be aware of the complete sequence of actions in drowning, especially how to help a victim who is still in the water [12]. Untrained rescuers should be advised to only provide help from out of the water. Safe rescue techniques for untrained rescuers include reaching to the drowning person with an object such as a pole, towel or tree branch or by throwing a buoyant object. These quick, safe responses are often neglected and should be taught as part of water safety education, to health professionals as well. The recently published article 'Creating a drowning chain of survival' [12] refers to a series of water safety interventions that, when put into action, should reduce the mortality associated with drowning and attempted aquatic rescue. The term 'chain of survival' has provided a useful metaphor for the elements of the emergency cardiac care system for sudden cardiac arrest; however, the drowning process interventions and patient management involve principles and actions that are specific to emergency drowning situations. A unique drowning chain of survival can guide the important lifesaving steps for lay and professionals rescuers and may significantly improve chances of prevention, survival and recovery for people in potential danger in water [12].

SCIENTIFIC EVIDENCE ON DROWNING

Much has changed in beach lifeguarding from its early origins as a purely voluntary humanitarian service to a professional vocation. But drowning is essentially an out-of-hospital 'disease' involving a high number of physical (water temperature, surf conditions, hazards etc.) and human (lifeguard and victims – physical fitness, preconditions or morbidity, behaviours etc.) variables, the action and interaction of which are largely unknown [13,14]. With the low level of scientific evidence-base, best practice tends to be based on expert opinion formed from experience (level of evidence 4). This situation will only be improved with the completion of more high-quality definitive research.

The expectation of the public to be protected when they visit the beach and the increasingly litigious society in which we live have driven the requirement for high standards. In many cases, these lifeguarding standards need to be properly tested by the application of scientific research. Furthermore, it is imperative not only to include current scientific research but also to consider the practical implications and provide reasonable recommendations for the application of this research and further research that could enhance our understanding and contribute to saving more lives.

Drowning varies in severity and this variation should be recognized; different grades of drowning need specific approaches and stratification to reduce bias. At its worst, the prognosis for a drowning cardiopulmonary arrest, despite the continuing effort to improve resuscitation and post-resuscitation care, remains poor. Although modern CPR has existed for more than 50 years, the majority of old and new interventions, other than stopping the drowning process early and providing ventilation and chest compression, have not been shown to improve survival rates [4,13,15]. More than half of survivors sustain neurological injury to some degree and fewer than 12% show

full recovery and are eventually able to return to work [4,6,13,15,16]. If drowning is not stratified appropriately by severity, there is a large variation in survival, implying that these conflicting results are due to differences in the definitions of variables, which creates misleading conclusions and outcomes [4,14,17]. The challenge for researchers is to stratify their cases into subgroups to reduce bias without losing statistical power, especially with cases requiring CPR where there is usually much missing information. Such cases are known as the 'Labiruzzle quiz' [14], a CPR challenge with missing puzzle pieces, where researchers have to collect as many variables as possible and are challenged to select a track based on the best available scientific evidence.

For the proper advance in drowning science, it is essential for researchers to accept and use the 'drowning Utstein Style', a set of guidelines for uniform reporting of drowning and resuscitation [18]. These guidelines include the adoption of uniform definitions and nomenclature, a glossary of key terms, an updated chain of survival, recommendations based on medical evidence and best practice, and uniform classifications and registration systems. By using the Utstein guidelines for reporting drowning cases, researchers should be able to collaborate and share hypotheses. There remains a strong requirement to create a web-based multicentre data management system, a tool that would compare standard data on drowning.

Any research reporting an improvement in lifeguarding intervention or treatment must be treated with great caution, as the lifeguarding world is anxious to put into practice new techniques to save more people. Such claims must be validated properly in a realistic scenario before being introduced and increasing variability and confusion.

As with much published science, drowning study results are mostly positive (publication bias) and the process of research is almost all positive, which suggests that the novelty of having research conducted and the increased attention from such could lead to temporary increases in productivity and improvement in the quality of the service – the Hawthorne effect [19].

The aim of this chapter is to bring together the most up-to-date scientific research on drowning with a commentary on its application to the real world of the beach.

DEFINITION AND TERMINOLOGY

A new definition of drowning was established in 2002 and adopted by the World Health Organization [20]: 'Drowning is the process of experiencing respiratory impairment from submersion or immersion in liquid'.

The drowning process is a continuum, beginning with respiratory impairment as the victim's airway goes below the surface of the liquid (submersion) or when water splashes over the face (immersion). If the victim is rescued at any point, the process of drowning is interrupted, and it is a nonfatal drowning. If the victim dies at any point, it is a fatal drowning. Any submersion or immersion incident without evidence of respiratory impairment should be considered a water rescue and not a drowning. Terms such as 'near-drowning', 'dry or wet drowning', 'secondary drowning', 'active and passive drowning' and 'delayed onset of respiratory distress' should not be used [20]. A uniform way to report data following drowning to allow comparison among different centres is to adopt the Utstein template for reporting drowning deaths [18,21].

PATHOPHYSIOLOGY

When a drowning person can no longer keep his or her airway clear, water entering the mouth is voluntarily spat out or swallowed. The next conscious response is to try and hold the breath, but this lasts for no more than seconds [22]. When the victim is no longer able to protect their airway, some amount of water is aspirated into the airways, and coughing occurs as a reflex response. In less than 2% of cases [23,24], laryngospasm may be present, but the onset of hypoxia will terminate this rapidly. If the person is not rescued, aspiration of water continues and hypoxaemia quickly leads to loss of consciousness and apnea at the same time. A sequence of cardiac rhythm deterioration with a period of tachycardia followed by bradycardia, pulseless electrical activity (PEA) and, finally, asystole has been suggested [25,26]. The whole drowning process, from submersion or immersion to cardiac arrest, usually occurs in seconds to a few minutes, but in unusual situations, such as rapid hypothermia, this process can last for up to an hour [27].

In some cases, even an early and effective rescue will not prevent medical consequences of the

drowning process. In those cases, basic life support (BLS) and advanced life support may be needed. When it is safe and appropriate, rescue breathing may need to be initiated while the victim is still in the water [3,28].

If the person is rescued alive, the clinical picture is determined predominantly by the volume of water that has been aspirated and the reactivity of the person's airways to this water, but not to the type of water (salt or fresh). Water in the alveoli can cause surfactant destruction and washout. Salt and fresh water aspiration cause similar degrees of pathology [25] although there are differences in osmotic gradients. In either situation, the effect of the osmotic gradient on the very delicate alveolar-capillary membrane can disrupt the integrity of the membrane, increase its permeability and exacerbate fluid, plasma and electrolyte shifts [25]. The clinical picture of the damage, depending on the amount of water aspirated, the reactivity of the person's airways and damage caused to the alveolar–capillary membrane, is a regional or general pulmonary oedema that may decrease in different proportion the exchange of O_2 and CO_2 [4,25,29].

In animal research, the aspiration of 2.2 mL of water per kilogram of body weight leads to a severe disturbance of the exchange of oxygen, decreasing the arterial oxygen pressure (PaO_2) to approximately 60 mm Hg within three minutes [30]. In humans, it seems that as little as 1–3 mL/kg of water aspiration produces profound alterations in pulmonary gas exchange and decreases pulmonary compliance by 10%–40% [25]. The combined effects of fluid in the lungs, loss of surfactant and increased capillary–alveolar permeability (alveolitis) can result in decreased lung compliance, increased right-to-left shunting in the lungs, atelectasis and bronchospasm [25].

One of the unique features, and a last stage of drowning, is that apnea and hypoxia cause and precede the cardiac arrest by a few seconds or minutes. In most drowning cases, the heart tissue is relatively healthy and stops due to the hypoxia insult, after a period of apnea [4,11]. In those cases, immediate in-water resuscitation provides the greatest benefit, if provided safely and effectively [28].

If the victim needs CPR, neurological damage is similar to other arrest situations but exceptions exist. Hypothermia associated with drowning can provide a protective mechanism that allows victims to survive prolonged submersion episodes [3,27]. Hypothermia can reduce brain oxygen consumption, prolonging the interval until cellular anoxia and adenosine triphosphate (ATP) depletion occur. Hypothermia reduces the electrical and metabolic activity of the brain in a temperature-dependent fashion. The rate of cerebral oxygen consumption is reduced by approximately 5% per degree Celsius reduction in temperature within the range of 37°C–20°C [31].

DROWNING CHAIN OF SURVIVAL – PREVENTION TO HOSPITAL

The drowning chain of survival is a new concept that is presented in Figure 9.1.

Prevent drowning to be safe in and around the water

Prevention is the most effective step in the chain of drowning survival. It has been estimated that the great majority of drownings may be preventable [10,32]. Unintentional drowning incidents have the highest case fatality rates compared to other injuries. In the nations with the highest drowning rates, there are often no rescue systems or EMS/ambulance or

Figure 9.1 Drowning chain of survival. (From Szpilman D, et al., *Resuscitation*, 85(9), 1149–52, 2014.)

hospital intensive care units to manage victims of drowning. In high income nations, only 10%–20% of drowning victims who go into cardiac arrest survive despite receiving the care outlined in each link in the chain of survival, and fewer than 30% of survivors are neurologically intact [21,33–35]. Thus, prevention of drowning is paramount. Drowning requires multiple layers of protection. To be effective, drowning prevention must be used by individuals near, on or around the water and by those who supervise or care for others in water settings.

Recognize distress and ask someone to call for help

The first challenge to the provision of help is to recognize a person in distress in the water and know how to activate the lifeguard and emergency medical services (EMS/ambulance). Frank Pia [36], the first author to hypothesize the 'instinctive drowning response' in a film in 1970s, contradicted the prevailing notions that most victims struggle at the water surface, call or wave for help and actively attempt to attract rescuers. He showed that a person who is struggling and about to drown cannot usually call for help, which consequently proved to be of major importance in recognizing the primitive movement patterns that reflect a potential risk or an actual drowning.

In 1995, Langendorfer and Bruya [37] identified key developmental components of aquatic readiness and water competency, which included the following: body position, from vertical to horizontal; arm actions, from ineffective to effective; leg actions, from ineffective to effective; and combined actions, little/no progress to efficient forward progress. They called this an 'aquatic readiness assessment'. A drowning risk assessment (DRA) was created using the developmental principle of regressive change [38]. The identified recognizable elements of a person at high risk of drowning include the following: near-vertical body position, ineffective downward arm movements, ineffective pedalling or kicking leg actions and little or no forward progress in water. It was also noted that many lifeguarding programs fail to adequately train lifeguards in observational skills. Lanagan-Leitzel [39,40] demonstrated that trained lifeguards and lifeguard instructors were unable to identify drowning victims in video scenarios. A lack of ability to recognize a person at risk of drowning is a high professional risk for any lifeguard to carry. Interestingly, non-lifeguards trained in DRA were equally as likely as lifeguards to identify persons at risk of drowning. This fact may present an opportunity to educate laypeople on the importance of being able to recognize a person drowning and then send someone to call for help.

Sending someone to call for help upon recognizing a person in water distress is a key element in the drowning response chain that ensures early activation of the EMS (ambulance)/rescue services or, if unavailable, a skilled helper. Delays in activating EMS (ambulance)/rescue services increase the risk of fatal drowning.

Provide flotation to stop the process of drowning

In drowning, the first priority or tactical goal is to interrupt the drowning process by providing flotation (buoyancy) to the victim. This is especially important if the victim cannot be immediately removed from the water. Providing flotation as an interim measure to reduce the submersion risk is a strategy not widely employed in aquatic emergencies, despite buying valuable time for emergency services to arrive or for those on the scene to plan rescue efforts. Most rescuers tend to focus on the strategic goal of getting the victim out of the water even if there is a high threat to life or rescuer safety, multiple victims or delays in executing the rescue [41,42]. Devices such as ring buoys (lifebuoys) are purpose-designed to provide flotation; however, they are not always available at the scene of a drowning incident. Therefore, improvised buoyancy aids such as empty plastic bottles/containers, bodyboards, surfboards, driftwood, ice chests and so on should be used [43,44]. It is critical that laypeople take precautions not to become another victim by engaging in inappropriate or dangerous rescue responses [5,11]. Given the number of bystanders who get into difficulty or drown while attempting to rescue others, reaching out with, throwing or dropping a buoyancy aid without entering the water is the preferred method of providing flotation to a drowning victim [45].

A panicked and struggling victim can be dangerous to a would-be rescuer. A victim attempting to cling to life and breathe can drown their would-be rescuer. For this reason, it is always best to approach

a struggling victim with an intermediary object. Lifeguards use rescue or torpedo buoys for this purpose, which can also double as thorax and face flotation devices to keep the head out of the water and the airways free [11].

In-water resuscitation if indicated and possible

A conscious victim should be brought to land, and basic life support should be started as soon as possible [4,28].

If not interrupted, the drowning process leads first to unconsciousness and apnea, followed by cardiac arrest within minutes. During this short window of opportunity, immediate in-water resuscitation (ventilation only) provides the greatest benefit if provided safely and effectively.

For an unconscious victim, in-water resuscitation can increase the discharge from hospital without sequelae by more than threefold [28]. In-water resuscitation is only possible if the rescuer is highly trained and if the action consists of ventilation alone. Attempts at chest compression while the rescuer and victim are in deep water are futile, so checking for a pulse does not serve any purpose [28]. Victims with only respiratory arrest usually respond after a few rescue breaths. If there is no response, the victim should be assumed to be in cardiac arrest and should be moved as quickly as possible to dry land where effective CPR can be initiated (Figure 9.2) [28].

Another medical concern is the possibility of cervical spine injury (CSI). Few studies have examined how often in-water CSI occurs. One such study, concerning sand beaches, retrospectively evaluated 46,060 water rescues and demonstrated that the incidence of CSI in this setting is very low (0.009%) [46]. In another retrospective survey of more than 2400 drownings, only 11 (<0.5%) had a CSI and all of these had a history of obvious trauma from diving, falling from a height or a motor vehicle accident [47]. Other water locations may have different rates depending on a wide variety of elements. Furthermore, any time spent immobilizing the cervical spine in unconscious victims with no signs of trauma could lead to a cardiopulmonary deterioration and even death. Considering this low incidence of CSI and the high risk to wasted time in ventilation when needed, routine cervical spine immobilization of water rescues, without reference to whether a traumatic injury was sustained, is not recommended [46–48].

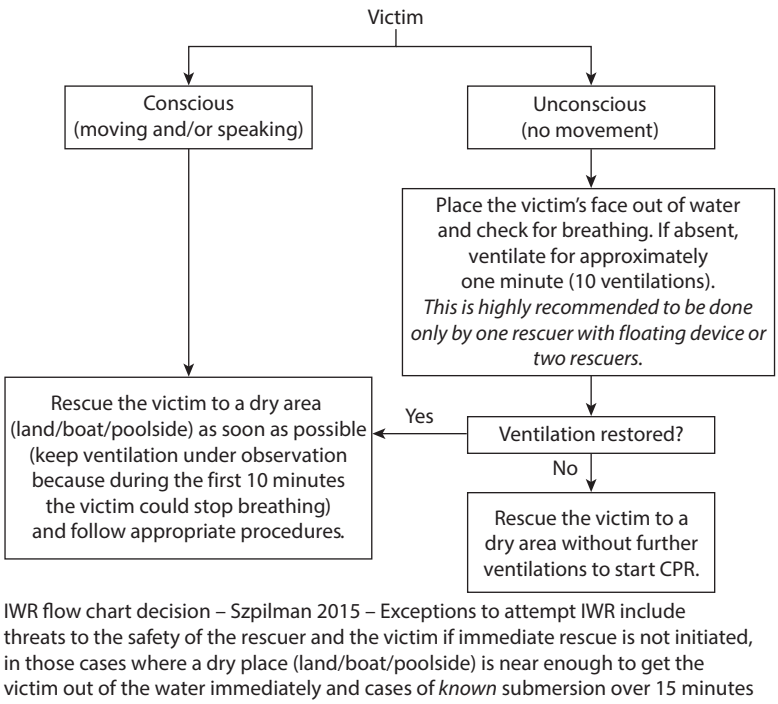


Figure 9.2 In-water basic life support flow chart decision – only for use by lifeguards and trained providers.

Rescuers who suspect a spinal cord injury should float the victim, supine, into a horizontal position allowing the airways to be out of water and check if there is spontaneous breathing. If not, they should start protocols for in-water resuscitation (mouth-to-mouth) without putting themselves or the victim in the water at greater risk. If there is spontaneous breathing, the rescuer should stabilize the victim's neck by hand in a neutral position; keep floating the victim using, if possible, a back support device before moving the victim; rescue the victim to a dry place, maintaining the neck in a neutral position as much as possible; align and support the head, neck, chest and body if the victim must be moved or turned [49]. Therefore, no attempt to immobilize the spine should be made without a strong indication and certainly not in cases where the victim appears lifeless [50].

Remove from water – Rescue only if safe to do so

Removing the victim from water is essential in order to reduce further aspiration and provide a definitive end to the drowning process [28]. Removal to dry land also allows for better assessment and care of the victim and safety for the rescuer.

Several strategies for removal can be used. For lay/untrained rescuers, attempt to remove the victim without fully entering the water by utilizing rescue techniques such as throwing assist, reaching assist and wading assist with equipment [12]; assist the victim to get out of the water by giving directions, i.e. pointing out to the closest and safest place to get out of the water or how to perform a self-rescue; if everything else fails, the lay rescuer may consider entering the water to attempt to rescue the victim. The entry of an untrained person into the water to rescue someone is very dangerous [5]. According to the New Zealand National Drowning Database [42], 81 would-be rescuers drowned between 1980 and 2012 while attempting to rescue someone. To enter the water is a personal decision theoretically related to the following: relationship with the victim; depth of the water/distance to swim; swimming and rescue skills of the lay responder; level of danger involved; consequences of not providing aid to the victim; age of victim; and other factors.

The attempt to perform a rescue typically involves three phases: approach, contact and stabilizing the victim. In order to mitigate the risk to the layperson during the contact and stabilization phases, they must bring a source of flotation [45].

Transporting drowning victims from the water and positioning them on land requires unique adaptations described in Table 9.1 [51].

Provide care as needed – Basic life support to hospital

Early basic and advanced life support improves drowning outcomes and should be initiated as soon as possible at the drowning scene [3].

Initial management of a drowning victim on land

As soon as the drowning person is removed from the water, lay and professional rescuers must recognize the drowning severity, especially if there is a life-threatening situation such as an isolated respiratory or full cardiopulmonary arrest, so that immediate care can be provided. If a rescuer is in doubt as to whether the person is alive or not, they should always start CPR as this gives the patient a much greater chance of survival [4].

One of the most difficult medical decisions a lifeguard or an emergency medical technician (EMT) must make is how to treat a drowning victim appropriately. Cardiopulmonary or isolated respiratory arrest comprises approximately 0.5% of all rescues. The questions that arise include the following: Should the rescuer administer oxygen, call an ambulance, transport the person to a hospital or observe for a time at the site? Even hospital emergency physicians may be in doubt as to the most appropriate immediate and continued support, as drowning victims vary in severity of injury. Based on these needs, a classification system was developed in Rio de Janeiro (Brazil) in 1972 and updated in 1997 [4] to assist lifeguards, ambulance personnel and physicians with treatment. It was based on an analysis of 41,279 rescues, of which 2304 (5.5%) needed medical attention. It was revalidated in 2001 by a 10-year study with 46,080 rescues [6]. This classification (Figure 9.3) [4] is stratified into six grades plus a rescue and a non-resuscitation condition encompassing all the support from the site of the accident to the hospital. It recommends the most appropriate intervention/treatment and shows the likelihood

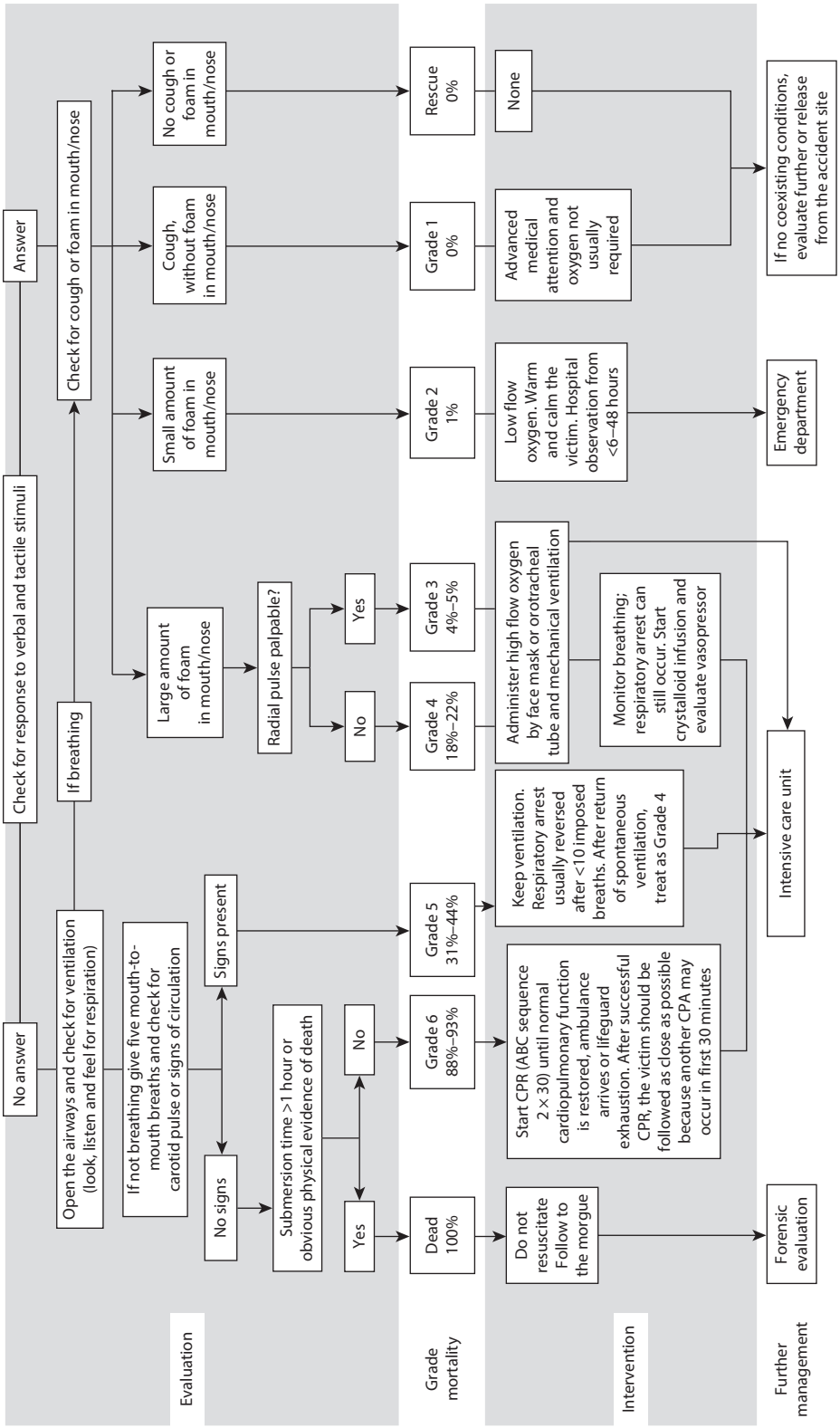
Table 9.1 Recommendations for positioning a drowning victim without suspected spinal injury according to setting and the condition of the victim

Setting	Condition of the drowning victim: Conscious victim	Condition of the drowning victim: Exhausted, confused or unconscious victim
In water (during rescue)	Position victim according to the rescue technique chosen.	Whenever possible, rescuers should keep the face of the victim out of the water, extend the neck to open the airway and keep it clear during the rescue process. 
Recovery onto land	Transport vertically with head up. Keep horizontal if immersion was prolonged or in cold water. 	Transport in as near a horizontal position as possible but with the head still maintained above body level. The airway should be kept open and the victim should be kept horizontal if prolonged immersion or cold water is involved.
On land	Maintain the victim in a supine position with head up.	If cardiopulmonary resuscitation is required, place victim supine, as horizontal as possible, and parallel with the waterline. 

(Continued)

Table 9.1 *(Continued)* Recommendations for positioning a drowning victim without suspected spinal injury according to setting and the condition of the victim

	Condition of the drowning victim	
Setting	**Conscious victim**	**Exhausted, confused or unconscious victim**
		Unconscious but breathing: place in recovery position. 
		The Basic Life Support Working Group of the International Liaison Committee on Resuscitation has agreed on six principles that should be followed when managing an unconscious, spontaneously breathing victim [52]: • The victim should be in as near a true lateral position as possible with the head dependent to allow free drainage of fluid. • The position should be stable. • Any pressure on the chest that impairs breathing should be avoided. • It should be possible to turn the victim onto the side and return to the back easily and safely, having particular regard for the possibility of cervical spine injury. • Good observation of and access to the airway should be possible. • The position itself should not give rise to any injury to the victim.



This classification system can help to stratify risk and guide the interventions. The mortality was calculated on the basis of time from the site of drowning until hospital discharge. Information is based on a retrospective review of 41,279 rescues recorded by lifeguards, of which 94% (38,975 cases) were just rescues (no water aspiration) and 6% of these cases involved the receipt of medical attention, but 1% (473) were not reported with sufficient information to classify the grade of presentation [21,34]. Of the 1,831 persons seen by a medical doctor at the Drowning Resuscitation Centre in Rio de Janeiro from 1972 to 1991, 65% were classified as Grade 1 presentations (1189 cases), 18% as Grade 2 (338), 3% as Grade 3 (58), 2% as Grade 4 (36), 1% as Grade 5 (25), and 10% as Grade 6 (185) [21].
ABC, airway–breathing–circulation; CPR, cardiopulmonary resuscitation; CPA, cardiopulmonary arrest.

Figure 9.3 Drowning severity classification for lifeguards.

of death based on the severity of injury. The severity is easily assessed by an on-scene rescuer, EMT or physician using only clinical variables [4].

Once on land, the victim should be placed supine with trunk and head at the same level (in general parallel to the shore line) and the standard checks for responsiveness and breathing should be carried out [28]. If the victim is unconscious but breathing, the recovery position (lateral decubitus) should be used [51]. If the victim is not breathing, rescue ventilation is essential [4,11,50,53].

Cardiac arrest from drowning is due primarily to lack of oxygen, when the usually healthy heart muscle stops beating following a period of apnea [4,11,50,53,54]. For this reason, it is important that CPR should follow the 'traditional' airway–breathing–circulation (ABC) [55] and not the circulation–airway–breathing (CAB) sequence – start with five initial rescue breaths followed by 30 chest compressions, and continue with two rescue breaths to 30 compressions until signs of life re-appear, rescuer exhaustion occurs or advanced life support becomes available. In drowning, the European Resuscitation Council [53] recommend an initial five ventilations instead of two (the American Heart Association's recommendation) [50] as upper airway management is always challenging due to vomiting and the fluid that interferes with airway management, making the initial ventilations and an effective alveolar expansion more difficult [50,56].

Cardiac compression–only CPR, is not advised in drowning [50,53,54].

The most frequent complication during a resuscitation attempt is regurgitation of the stomach contents, which occurs in more than 65% of victims who need rescue breathing alone and in 86% of those who require CPR [57]. The presence of vomitus in the airway can result in further aspiration injury and impairment of oxygenation [28]. Active efforts to expel water from the airway (abdominal thrusts or placing the victim head down) should be avoided as they only delay the initiation of ventilation, increase the risk of vomiting by more than fivefold and lead to a significant increase in mortality [28,51]. If vomiting occurs, turn the victim's mouth to the side, remove the vomitus with a finger sweep or cloth or use suction and continue resuscitation.

It is important to recognize that resuscitation of drowning victims often takes place under very different circumstances. There may be problems recovering the victim to dry land, and the delay until emergency medical system arrival may be longer than usual. On the other hand, victims are generally young, and the rate of success is potentially higher [5,26,35]. These variables influence lifeguards' decisions and the correct course of action.

The cost-effectiveness of providing an automated external defibrillator (AED) at sites of aquatic activity has been debated, as the predominantly cardiac arrest rhythm on drowning is asystole [58]. On the other hand, cardiac arrest at aquatic sites may occur due to causes other than drowning when the presence of an AED may be lifesaving [58].

Recommendations for when to start and stop resuscitation are different from non-drowning-related cardiac arrest (Table 9.2) [3,26].

The majority of people with mild distress may not actually aspirate water and, thus, EMS/ambulance

Table 9.2 Drowning: When to initiate CPR and when to discontinue

Question	Recommendations
On whom to begin CPR?	• Give ventilatory support for respiratory distress/arrest to avoid cardiac arrest. • Start CPR in all victims submerged <60 minutes who do not present obvious physical evidence of death (rigor mortis, body decomposition or dependent lividity).
When to discontinue CPR?	• Basic life support should continue unless signs of life reappear, rescuer becomes exhausted or advanced life support takes over. • Advanced life support should be ongoing until the patient has been rewarmed (if hypothermic) and asystole persists for more than 20 minutes.

Source: Data from Szpilman D, et al., *N Engl J Med*, 366, 2102–10, 2012.

Table 9.3 Description of cases requiring further medical help after rescue from the water (MPS 06)

(a) The following persons should be sent to hospital in most cases:
- Any patient who lost consciousness even for a brief period.
- Any patient who required expired air resuscitation (rescue breathing).
- Any patient who required cardiopulmonary resuscitation.
- Any patient in whom a serious condition is suspected such as heart attack, spinal injury, other injury, asthma, epilepsy, stinger, intoxication, delirium.

(b) The following persons may be considered for release from care at the scene if, after 10–15 minutes of careful observation, while being warmed with blankets or other coverings as required, the patient has ALL of the following. In such cases, it is unwise for the patient to drive a vehicle and the patient should be so advised. If any of these conditions do not apply or if the lifesaver has any doubt, then the patient should be advised to seek early medical attention.
- No cough
- Normal rate of breathing
- Normal circulation as measured by pulse in strength and rate and blood pressure (if available)
- Normal colour and skin perfusion
- No shivering
- Fully conscious, awake and alert

(c) There is always a risk of delayed lung complications. All immersion victims should therefore be warned that if they later develop cough, breathlessness, fever or any other worrying symptom, they should seek medical advice immediately. It is preferable that these persons not return to a home environment where they are alone for the next 24 hours.

may not be summoned. Therefore, it is important to educate lifeguards and responders about when to call the EMS (ambulance) or to seek medical assistance/hospital care in cases of drowning. Table 9.3 describes who needs further medical help after rescue from the water [59].

Advanced pre-hospital management

In addition to immediate BLS, advanced life support teams should be alerted as soon as possible to attend the incident.

A victim with pulmonary damage may initially be able to maintain adequate oxygenation through an abnormally high respiratory rate and can be managed by administering oxygen by face mask at a rate of 15 litres of oxygen/minute. Early intubation and mechanical ventilation is indicated when the victim shows signs of deterioration or fatigue (Grades 3 and 4) [4]. New airway devices, such as the supraglottis airway, need to be carefully evaluated before incorporation into daily use by lifeguards. The important clinical issue here is not whether it is comfortable or quick for the lifeguards to use, but whether it is fit for the purpose of properly ventilating a drowning victim [56]. Once intubated, most victims can be oxygenated and ventilated effectively. Despite continuous, copious, pulmonary oedema fluid appearing in the endotracheal tube, suctioning can disturb oxygenation and should be balanced against the need to ventilate and oxygenate [60,61]. Pre-hospital providers should insure adequate oxygenation to maintain arterial saturation between 92% and 96%, while insuring adequate chest rise during ventilation [62]. Positive end-expiratory pressure should be added as soon as it is available to decrease pulmonary arterial shunt and increase oxygenation [60]. If abdominal distention becomes a restriction to ventilation, an orogastric tube can be inserted, after a secure definitive airway is established.

Peripheral venous access is the preferred route for drug administration in the pre-hospital setting. Intraosseous access is an alternative route. Endotracheal administration of drugs is not recommended for drowning [53]. If hypotension is not corrected by oxygenation, a rapid crystalloid infusion should be administered, regardless of whether salt or fresh water has been inhaled [29].

The presenting rhythm in cases of cardiac arrest following drowning (Grade 6) is usually

asystole or PEA. Ventricular fibrillation is rarely reported, but may occur if there is a history of coronary artery disease, due to the use of epinephrine, or in the presence of severe hypothermia [26]. During CPR, if ventilation and chest compression do not result in cardiac activity, cumulative doses of epinephrine 1 mg IV (or 0.01 mg/Kg/dose) can be considered. Because of the mechanisms of cardiac arrest secondary to hypoxia and the effects of hypothermia, a higher subsequent dose, although controversial [63], may be considered if the initial doses fail.

Drowning is sometimes precipitated by an injury or medical condition (e.g. trauma, seizure, cardiac arrhythmia etc.) and this co-morbidity should be considered [4,64] especially by professional responders, as it might guide specific approaches to rescue and resuscitation. On Rio de Janeiro beaches, precipitant causes are discernible in 13% of all cases attended by the medical staff: alcohol (37%); convulsion (18%); trauma, including boating accidents (16.3%); cardiopulmonary disease (14.1%); skin diving and scuba diving (3.7%); diving resulting in head or spinal cord injuries; and others, e.g. homicide, suicide, syncope, cramps or immersion syndrome (11.6%) [65].

The majority of drowning victims will have aspirated only small amounts of water, if any, and will recover spontaneously. Only 6% of all who are rescued by lifeguards need medical attention in a hospital [4]. Rescue and Grade 1 victims presenting with good arterial oxygenation (pulse oximetry) without adjuvant therapy and no other associated morbidity can safely be released home.

Emergency department attendance is recommended for all Grades 2–6 patients. Most Grade 2 victims tolerate non-invasive oxygen administration, will normalize their clinical situation within 6–8 hours and can be sent home [4]. Those who deteriorate are admitted to an intermediate care unit for prolonged observation.

Hospital attendance

For Grades 3–6 patients, who usually need intubation and mechanical ventilation support, assistance at an intensive care unit may be required [4]. As the pulmonary lesion is caused by temporary and local injury, pulmonary distress following drowning tends to heal much faster than other diseases, and there is usually no late pulmonary sequelae [60]. Water in the lungs is absorbed (fresh water faster, salt water more slowly) into the blood across the pulmonary capillary membrane and excreted in urine within 24–48 hours. There are very few procedures that may help the lung to heal other than mechanical ventilation and to wait to wean the patient off ventilation until after 24–72 hours. It is common practice to be careful to wean a drowning case from mechanical ventilation before 24 hours, even when they appear to be breathing adequately; it is suggested that the local pulmonary injury has not yet been repaired and this may cause the return of pulmonary oedema with the need for re-intubation, leading to a prolonged hospital stay and further morbidity [66].

At the emergency department, after the airway has been secured, oxygenation has been optimized, the circulation stabilized and a gastric tube has been inserted, thermal insulation of the patient should be instituted. This step is followed by physical examination, measurement of arterial blood gases and chest radiography. Metabolic acidosis occurs in the majority of cases and will be compensated for better minute ventilation [29]. Routine use of sodium bicarbonate is not recommended.

In most drowning cases, the circulation becomes adequate after oxygenation, rapid crystalloid infusion and restoration of normal body temperature [25,60]. Early cardiac dysfunction can occur following severe drowning [25], which adds a cardiogenic component to the non-cardiogenic pulmonary oedema. No evidence supports the use of a specific fluid therapy for salt and fresh water drowning [25], i.e. the use of diuretics or water restriction [11].

Meanwhile, if not taken before, a history of events surrounding the drowning incident including rescue and resuscitation activities and any current or previous illness should be checked [21]. If the victim remains unresponsive without an obvious cause, a toxicology investigation and a computed tomography of head and neck should be considered [67].

Electrolytes, blood urea nitrogen, creatinine and hematocrit are not routinely recommended. Abnormalities are unusual [4,30] and correction of electrolyte imbalance is rarely needed [68].

Pneumonia is initially often misdiagnosed with the early radiographic appearance of water in the lungs. In a series of hospitalized cases, only 12% had pneumonia and needed antibiotics [69].

Prophylactic antibiotics tend to select out more resistant and aggressive organisms and are not routinely recommended [70].

In some cases, hypothermia is just a reflection of prolonged submersion time and a bad prognosis. In other victims, early hypothermia is an important reason why survival without neurological damage is possible [27,50,71]. Recent reports on drowning have documented good outcomes in post-resuscitation patients who were kept hypothermic or treated with therapeutic hypothermia, despite poor predicted outcomes [53,72]. The paradox in drowning resuscitation is that the hypothermic victim needs to be warmed initially in order to effectively resuscitate, but then may benefit from induced therapeutic hypothermia after successful resuscitation [3].

OUTCOME

With the progresses of intensive care therapy, prognostics are more and more based on neurologic outcome. Grades 1–5 drownings return home safely without sequelae in 95% of cases [4]; important medical complications of drowning other than neurological are rare and are almost all restricted to Grade 6. In hospital, permanent neurological damage is the most worrisome outcome of initial survival after CPR. Victims who remain comatose or deteriorate neurologically should undergo intensive assessment and care [73]. We need to answer questions such as: How can we know who we should make the effort to resuscitate? How long should we continue to resuscitate? How different should the treatment be? And what should we expect as life quality after successful resuscitation? Both at the rescue site and in the hospital, no one indicator for Grade 6 appears to be an absolutely reliable indicator of outcome [74]. Based on the largest submersion time registered in cold water (66 minutes) with complete recovery [11], resuscitation should be started without delay in each victim without a carotid palpable pulse who has been submerged for less than one hour, or who does not present obvious physical evidence of death (rigor mortis, putrefaction or dependent lividity). A long-time submersion with successful resuscitation is not only possible in cold or icy water: some anecdotal cases have been reported to survive in warm water without sequelae [4,75,76]. Multiple studies have established that outcome is almost solely determined by a single fate factor – duration of submersion [3,4,11,28,57,75,77].

Basic and advanced life support enables victims to achieve the best outcome possible. After successful CPR, it is crucial to stratify neurological severity; this will allow comparison of different therapeutic approaches. Various prognostic scoring systems have been developed to predict which patients will do well with standard therapy and which are likely to have a significant cerebral anoxic encephalopathy and will require aggressive measures to protect the brain. One of the most powerful scoring systems is the evaluation of the consciousness level related to the Glasgow coma scale at the period immediately after resuscitation (first hour) (Conn & Modell Neurological Classification) [78]. Data suggest that patients who remain profoundly comatose (i.e. decorticate, decerebrate or flaccid) 2–6 hours after the drowning incident are brain-dead or have moderate to severe neurological impairment. Patients who are improving but remain unresponsive have a 50% likelihood of a good outcome. Most patients who are definitely improving and are alert or are stuporous or obtunded but respond to stimuli 2–6 hours after the incident have normal or near-normal neurological outcomes.

These prognostic variables are important in counselling family members of drowning victims in the early stages after the incident. They are helpful for deciding which patients are likely to have a good outcome with standard supportive therapy and which are candidates for intensive cerebral resuscitation therapies.

Drowning represents a tragedy that all too often is preventable. Perhaps the majority of cases are the end result of common sense violations, alcohol consumption or neglect of responsible childcare. This picture needs a radical preventive intervention.

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