BMJ Best Practice

Drowning

The right clinical information, right where it's needed

Last updated: Nov 09, 2017

Table of Contents

Summary

- Drowning is defined as the process of experiencing respiratory impairment from submersion or immersion in liquid.
- Drowning is a leading cause of injury and death among young people.
- It has been estimated that 80% to 90% of all drownings are preventable.
- Hypoxaemia is the primary cause of morbidity and mortality, and its reversal must remain the focus of treatment.

Definition

Drowning is the process of experiencing respiratory impairment from submersion or immersion in liquid.[1] This 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 time, the process of drowning is interrupted, resulting in a non-fatal drowning. Any submersion or immersion incident without evidence of respiratory impairment (aspiration) should be considered a water rescue rather than a drowning. Terms such as 'near-drowning', 'dry or wet drowning', 'active and passive drowning', 'secondary', and 'delayed onset of respiratory distress' should not be used.[1] [2]

Epidemiology

The most recent World Health Organization report estimates that around 372,000 people die from drowning around the world every year.[3] However, international data may drastically underestimate drowning figures, even for high-income countries.[4] This is due, in part, to categorisation issues, in which intentional drowning deaths and drowning deaths subsequent to natural disasters are not coded in drowning mortality data. In addition, there are large variations between countries in the quality and means of data collection. The latter primarily concerns low- and middle-income countries, which are thought to account for over 90% of global drowning deaths.[3]

In the US, more than 4400 deaths due to drowning were recorded in 2015.[5] Of the 1235 unintentional injury deaths in 1- to 4-year-old children, more were attributable to drowning (390) than to motor vehicle accidents (332).[5] There are approximately 6500 drowning deaths reported annually in European Union member countries.[6]

In 2009, 182 ICD-10 coded drowning deaths were reported in Australia, with international tourists accounting for 25% of drowning deaths at beaches.[7] In Brazil, 6000 drowning deaths are recorded annually, more than 75% of which occur in open freshwater (rivers, lakes, and ponds).[8] Drowning remains the second leading cause of death among 1- to 9-year-old children in Brazil, and third among 10- to 19-year-olds.

Drowning data from the African continent are limited, and are based upon modelling rather than reporting.[9] Similarly, data collection in south and southeast Asia is poor.[10]

Aetiology

Inability to keep the airway above the surface of the water precipitates a drowning episode. This may occur due to lack of physical ability, or inability to cope with environmental conditions (e.g., temperature, waves, currents, or depth). Falls, boating accidents, or motor vehicle accidents and medical comorbidities (seizures, stroke, intoxication, or cardiac disease) may cause physical or mental incapacitation, leading to drowning. Complications of drowning are related to hypoxaemia induced by asphyxiation from submersion, and lung injury from aspiration.

Pathophysiology

The drowning process, from submersion or immersion to cardiac arrest, usually occurs in seconds to a few minutes. In unusual situations, such as rapid hypothermia, this process can last for up to 1 hour.[11]

In less than 2% of cases, laryngospasm may be present when the victim starts to inhale water.[12] [13] Airway obstruction results in impaired oxygenation and ventilation, leading to apnoea, hypoxaemia, and loss of consciousness. Hypoxic cardiac arrest generally occurs after a period of bradycardia and pulseless electrical activity, and not by means of ventricular fibrillation.[14] [15] In most instances of drowning-related cardiac arrest, the heart tissue is relatively healthy and ceases perfusion due to hypoxic insult.[16] [17]

The clinical picture is determined by the reactivity of the airways and the amount of water that has been aspirated, but not by the type of water (salt or fresh). Aspiration of water leads to surfactant destruction and wash-out in the alveoli, and to hypoxia. The effect of the osmotic gradient on the alveolar-capillary membrane can disrupt the integrity of the membrane, increase its permeability, and exacerbate fluid, plasma, and electrolyte shifts.[14] Regional or generalised pulmonary oedema result, which may alter oxygen exchange.[3] [16] [14] [18] As little as 1 to 3 mL/kg of water aspiration produces profound alterations in pulmonary gas exchange and decreases pulmonary compliance by 10% to 40%.[14] The combined effects of fluid in the lungs, loss of surfactant, and increased capillary-alveolar permeability can result in decreased lung compliance, increased right-to-left shunting in the lungs, atelectasis, and alveolitis.[14]

Primary prevention

It has been estimated that 80% to 90% of all drownings are preventable.[13] [31] People prone to seizures or cardiac arrhythmias should swim only with an observant partner. Alcohol should be avoided during all water sports, boating, or swimming activities. Parents should always supervise young children when bathing or swimming. Pool enclosures and early swimming lessons can also prevent accidental drowning in childhood.

Measures for all ages include:

- Be aware of personal limitations, and always swim in a lifeguard-supervised area or with someone able to help you
- Ask the lifeguard for safe places to swim or play
- Read and follow warning signs posted on the beach and around the pool
- Do not drink alcohol or eat a heavy meal before swimming
- Do not dive into shallow water or water of unknown depth
- Weak or non-swimmers should wear life jackets in and around water and when boating
- Learn to swim
- Do not attempt to rescue a drowning person unless you have specific training.

For infants, toddlers, and young children:

- Ensure 100% 'touch' supervision in or around water by a parent or adult capable of performing a rescue (i.e., within arm's reach)
- Use appropriate garden and pool fencing
- Avoid inflatable swimming aids because they may instil a false sense of security
- Be sure that swimming pools have 2 drains fitted with anti-vortex covers (to prevent hair or appendages becoming entangled in the drain mechanism)
- Infants and young children should wear life jackets in and around water.

For teenagers and adults:

- Swim with others and always in the lifeguards' area
- Avoid alcohol or drug consumption while in and around water
- Consider pre-existing medical conditions (e.g., epilepsy) when engaging in water activities.

For older adults:

- Consider medical issues and medication side effects when engaging in water activities
- Practise safe entry and exit from bath, and use handrails and non-slip mats
- Communicate with family or carer when bathing.

Case history

Case history #1

A 22-year-old man is found floating face-down in a stagnant pond after binge drinking earlier that day. There were no witnesses to his drowning, and the duration of his submersion is unclear. When pulled from the pond he is not breathing. There is no palpable carotid pulse and he is cold to the touch. Cardiopulmonary resuscitation is started and emergency medical services arrive to transfer him to the nearest hospital.

Step-by-step diagnostic approach

While the cause of drowning is often related to swimming ability and prevailing environmental conditions, other causes (e.g., cardiac event, seizure, hypoglycaemia, trauma, overdose/intoxication, suicide/homicide) should be excluded based upon patient history and scene information.

Information from the scene, patient history, and examination can be useful in determining severity of injury, treatment plan, and prognosis.

Scene information

- Was the drowning episode witnessed?
- If witnessed, approximate duration of submersion
- Approximate temperature of water
- Initial mental status
- Bystander resuscitation efforts
- Time to emergency medical services arrival, and emergency services interventions

Patient history

- Strong risk factors
  - Age (0-4 years old)
  - Lack of awareness of water hazard risks
  - Male
  - Alcohol or drug intake
  - Swimming alone/diving
- Weak risk factors
  - Cardiac disease
  - Seizure disorder

Patient examination

- Mental status (Glasgow Coma Score [GCS], alertness/orientation)
- Vital signs including temperature
- Pulmonary exam
- Evidence of trauma

Drowning episode history and examination information

Created by BMJ Knowledge Centre

Primary examination

Hypoxaemia is the primary cause of morbidity and mortality. Apnoea or impaired oxygenation will lead to poor outcomes. Patients who are pulseless when removed from the water have a poor outcome if return of spontaneous circulation is not quickly obtained with initial ventilations.

Hypothermia

Severe hypothermia (body temperature <30ºC) may be associated with marked depression of critical body functions such that the patient may appear dead during initial assessment. Resuscitation guidelines recommend that CPR should be continued unless the victim is unquestionably dead. Patients should not be considered dead until successful warming has been provided.[32] [33] [34]

Despite this, hypothermia is a sign of prolonged exposure and carries a poor prognosis. In rare cases, hypothermia may confer neuroprotection to those falling into icy water.[11]

Investigations

Pivotal information is obtained from the scene and the examination of the patient. Other testing is non-specific and primarily aids in determining drowning severity and response to treatment. Laboratory testing in critically ill patients serves to elucidate precipitating events and to monitor systemic hypoxaemia.

Those with suspected cervical spine injury usually exhibit obvious signs of trauma or have a witnessed event consistent with a high-risk mechanism. Patients with a witnessed submersion without traumatic mechanism should not undergo routine spinal motion restriction.

If cervical spine injury cannot be readily excluded, a validated clinical tool such as the NEXUS Criteria for C-spine Imaging or the Canadian C-Spine Rule may be used to determine whether imaging is required.

Risk factors

Strong

age (0-4 years)

- Rates of fatal and non-fatal drowning are highest among children <4 years of age.[19] [20]

male sex

- Drowning is 5 times more common in males than in females.[21] [22]

alcohol or drug intake

- Alcohol intoxication is commonly implicated in drowning incidents.[22] [23] [24] Its role in drowning primarily relates to alcohol's ability to impair judgement, orientation, reflexes, and motor activity. Similarly, any other substance abuse can impair judgement, alertness, and coordination, resulting in drowning incidents.

swimming alone/diving

- High-risk behaviours such as swimming alone and diving, in addition to alcohol and drug use, have been associated with increased risk of drowning death, especially in males.[25]

lack of awareness of water hazard risks

- Improper evaluation of high-risk swimming conditions contributes to an increased risk of submersion injury.

lack of swimming ability

- The ability to swim may lead to increased exposure to water or increased risk-taking in water. There is a paucity of evidence demonstrating a causal relationship between the ability to swim and reduced risk of drowning death. In rural Bangladesh, however, a structured swimming programme significantly reduced fatal drowning in children.[26]

Weak

cardiac disease

- Older adults are at higher risk for drowning death secondary to cardiac events in the water.[27] Additionally, channelopathies such as prolonged QT syndrome have been associated with an increased risk of drowning death.[28]

seizure disorder

- A seizure while in or around water may lead to drowning. Evidence suggests an increased risk of drowning for individuals with seizure disorders.[29] [30]

History & examination factors

Key diagnostic factors

presence of risk factors (common)

- Strong risk factors include young age, male sex, alcohol and drug use, and lack of swimming ability.

respiratory impairment (common)

- Drowning results from primary respiratory impairment from submersion/immersion in a liquid.[2] [35]

evidence of submersion or immersion (common)

- Drowning results from primary respiratory impairment from submersion/immersion in a liquid.[2] [35]

Diagnostic tests

1st test to order

Test	Result
pulse oximetry/arterial blood gases • Pulse oximetry is pivotal in determining drowning severity and need for treatment. Arterial blood gas measurements may be preferred in cases of hypothermia, where peripheral vasoconstriction may make pulse oximetry difficult.	**hypoxaemia**
chest x-ray • While chest x-ray does not correlate directly with outcome, early parenchymal abnormalities usually predict respiratory decompensation and need for mechanical ventilation.[36] Early infiltrates are often water or pneumonitis, and not infectious pneumonia.	**pulmonary infiltrate/ acute respiratory distress syndrome**
basic metabolic panel • Electrolyte disturbances have been reported, but they have been of no clinical significance. • Acute kidney injury has been reported, most commonly in grade 6 patients who were successfully resuscitated. • Hypoglycaemia may cause loss of consciousness or seizure, which could lead to drowning.	**abnormal in the presence of metabolic or electrolyte abnormalities**

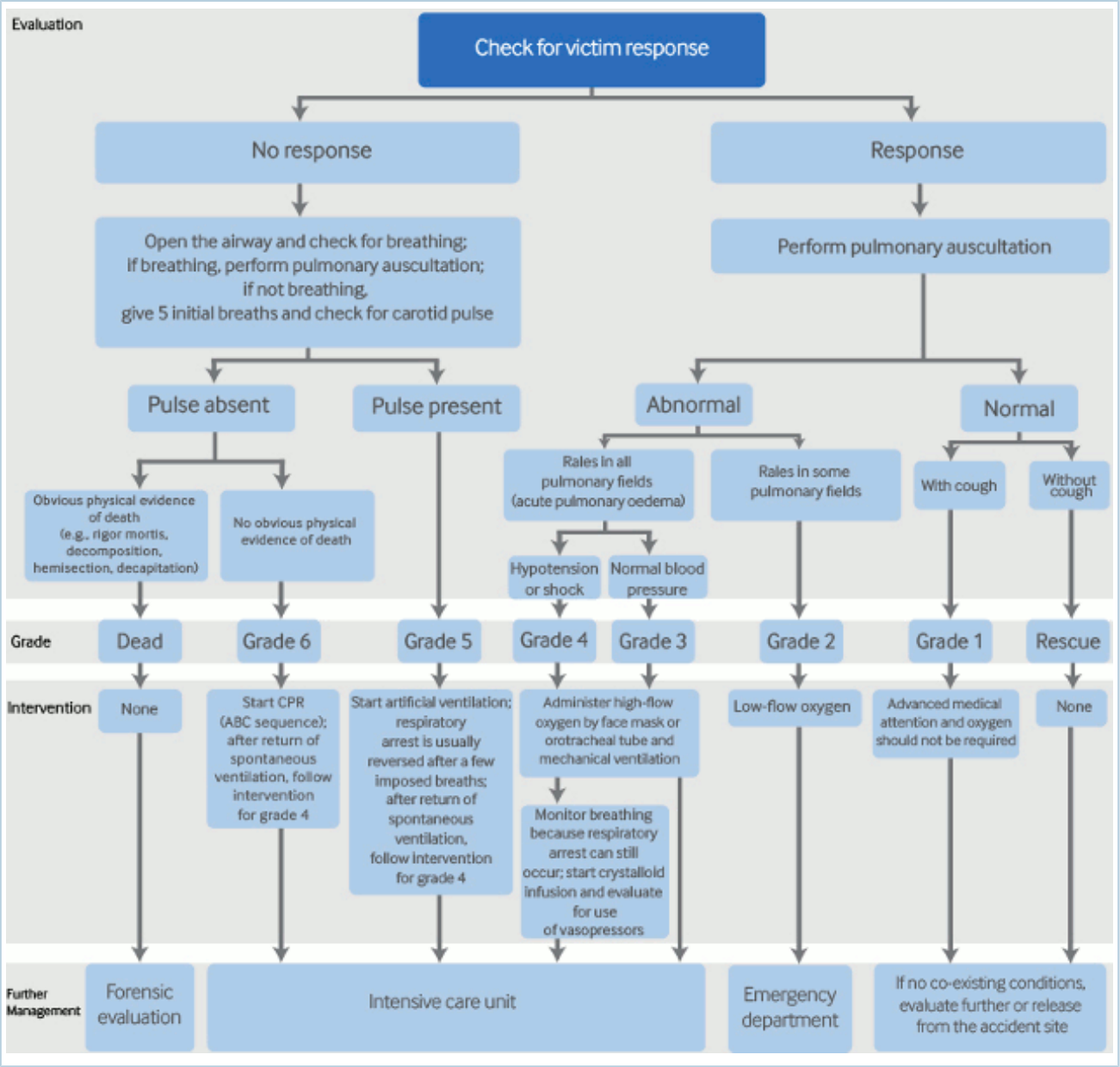
Other tests to consider

Test	Result
cervical spine CT • Incidence of cervical spine injury is low in drowning patients.[37] [38] Those with injuries have obvious signs of trauma; patients witnessed to have no preceding trauma prior to a drowning should not undergo cervical spine imaging. • If cervical spine injury cannot be readily excluded, a validated clinical tool such as the NEXUS Criteria for C-spine Imaging or the Canadian C-Spine Rule may be used to determine whether imaging is required.	**may show cervical spine vertebral misalignment, fracture, and pre-vertebral soft-tissue swelling**
creatine kinase • Prolonged struggle can lead to rhabdomyolysis. This may cause or worsen kidney injury.	**may be elevated**
serum alcohol and urine drugs of abuse • Alcohol and illicit drug levels may assist in determining the cause of the drowning.	**positive in the setting of intoxication**
ECG • Evidence of myocardial infarction may assist in determining the cause of a drowning in those at risk.	**ST-segment elevation of at least 1 mm in 2 or more contiguous leads; non-specific ST-T wave changes or ischaemic changes**
serum cardiac biomarkers • Evidence of myocardial infarction may assist in determining the cause of a drowning in those at risk.	**elevated in the presence of myocardial infarction**
anticonvulsant medication levels • Individuals with a history of seizures are at a higher risk for drowning death. • Medication levels may assist in determining cause of drowning.	**variable; levels may be sub-therapeutic**

Diagnostic criteria

Drowning severity classification[16] [39] [17] [40]

A drowning severity classification has been developed, separating drowning patients into 6 grades based on the initial examination. Each grade has an associated mortality risk and treatment recommendations.



Drowning classification system

Adapted from Orlowski JP, Szpilman D. Drowning. Rescue, resuscitation, and reanimation. Pediatr Clin North Am. 2001;48:627-646. Used with permission

[BMJ Best Practice: drowning classification system (high-resolution)]

Step-by-step treatment approach

The "Drowning Chain of Survival" refers to a series of interventions that, when put into action by lay persons or professionals, may reduce morbidity and mortality associated with drowning.[16] [41]

The links of the chain are as follows:

- Prevention - be safe in and around water
- Recognise distress - ask someone to call for help
- Provide flotation - to prevent submersion
- Remove from the water - only if safe to do so
- Provide care as needed - seek medical attention.

Drowning Chain of Survival

Szpilman et al. Creating a drowning chain of survival. Resuscitation. 2014;85:1149-1152. Used with permission

Severity of injury, as determined by the drowning severity classification,[16] [39] dictates the initial treatment approach. The primary focus is the timely reversal of systemic hypoxaemia to prevent secondary neurological injury.

Water rescue

The following links of the Drowning Chain of Survival are pertinent:

- Recognise distress and call for help.
- Provide flotation to stop the process of drowning. A responder who is not properly trained in advanced water rescue should never enter the water to attempt a rescue. If possible, reaching/ throwing an object or manoeuvring a craft to the victim is safest.
- Remove the victim from the water in as near a horizontal position as possible, with the airway open.

For the unconscious victim, in-water ventilation by trained individuals increases the likelihood of neurologically intact discharge from hospital.[42] If there is no response to in-water ventilation, the victim should be assumed to be in cardiac arrest.

Cardiopulmonary resuscitation (CPR) with chest compression and ventilation should be initiated once the victim is out of the water.

Routine spinal motion restriction is not indicated for the majority of drowning victims because the incidence of cervical spine injury is extremely low.[37] [38] If cervical spine injury is suspected, the

cervical spine may be held in mid-line, but attempts at further motion restriction with cervical spine collars or long spine boards should never impede resuscitative efforts.

Pre-hospital disposition

Grade 1 patients (conscious and alert; cough with normal lung auscultation) may be considered for release from care at the scene if, after 10 to 15 minutes of careful observation, they meet all of the following criteria:[43]

- No cough
- Normal rate of breathing
- Normal circulation as measured by pulse in strength and rate and/or blood pressure
- Normal colour and skin perfusion
- No shivering
- Fully conscious, awake, and alert.

Patients who fulfil these criteria should be offered education regarding water safety prior to release, and advised not to drive a vehicle during the next 24 hours.

Although delayed lung complications are rare, drowning victims should be advised to seek medical advice immediately if they develop cough, breathlessness, fever, or any other worrying symptom in the ensuing 8-hour period.

Victims of drowning who require any form of resuscitation (including solely rescue breathing) should be taken to the emergency department for evaluation and monitoring, even if they appear to be alert and demonstrate effective cardiorespiratory function at the scene.[33]

Airway management

All drowning patients, except those with normal oxygenation (grade 1, conscious and alert; cough with normal lung auscultation), should receive supplemental oxygen. The goal is to deliver the highest concentration of oxygen possible, with the method determined by patient condition.

- Patients who are protecting their airway with mildly laboured breathing may be trialled with oxygen by face mask at a rate of 15 litres of oxygen per minute, with a goal of SaPO2 between 92% and 96%.[40] [44] If the patient's ventilatory status, mental state, or SaPO2 decline, continue to endotracheal intubation (ETI).
- Patients who are protecting their airway with increased breathing effort requiring support, and who are mentating sufficiently to follow commands, may be trialled on non-invasive positive pressure ventilation. If the patient does not improve or there is clinical deterioration, continue to ETI.
- Patients not protecting their airway or not performing adequate ventilations should be oxygenated via mouth-to-mouth, mouth-to-mask (pocket mask), or bag-valve mask (BVM) as a bridge to ETI.
- If ETI is performed, mechanical ventilation should follow ventilation strategies similar to acute respiratory distress syndrome ventilation.[40]
- If ETI equipment is not available, or airway assessment suggests that ETI is likely to be difficult, a supraglottic device may be used. If the supraglottic device does not result in sufficient ventilation (e.g., because drowning can cause reduced pulmonary compliance requiring high inflation pressures),[32] remove the device and continue BVM ventilations or proceed to ETI should it become available.[40]

- If advanced care is close by and BVM ventilations are adequate to maintain SaPO2 >95%, BVM ventilations may be continued as a bridge to ETI at the advanced care centre.

Hypothermia

Severe hypothermia (body temperature <30°C) may be associated with marked depression of critical body functions such that the patient may appear dead during initial assessment. Resuscitation guidelines recommend that CPR should be continued unless the victim is unquestionably dead. Patients should not be considered dead until successful warming has been provided.[32] [33] [34]

Despite this, case reports of drowning patients surviving prolonged submersion in icy water and cardiac arrest are rare, and typically involve small children.[11] In the majority of cases, hypothermia carries a poor prognosis.

Patients should undergo passive and active re-warming as indicated by the patient's condition and available resources:

- Passive re-warming (including removing wet clothing, and drying and covering the patient) is the preferred treatment option for mild cases.
- Active external re-warming is indicated for moderate to severe hypothermia. In addition to covering the patient with warm blankets, forced warm air is applied directly to the patient's body. The use of a Bair-Hugger warmer is a good example.
- Active internal re-warming, used alone or in combination with active external re-warming, is the most aggressive strategy. Techniques include airway re-warming with humidified oxygen at 40°C (104°F), warmed intravenous fluids, and peritoneal lavage. Extracorporeal blood warming is the most effective method and increases core body temperature by 1°C to 2°C (1.8°F to 3.6°F) every 3 to 5 minutes.[45]

All drowning patients with cardiac arrest should be actively re-warmed to achieve return of spontaneous circulation (ROSC).[32] If ROSC is successful, and local protocols and resources allow, current recommendations call for re-warming the patient to 32°C to 34°C (89.6°F to 93.2°F) and maintaining that temperature for at least 24 hours.[46] If the patient's temperature is >34°C (>93.2°F), recommendations call for targeted temperature management.[47]

Cardiopulmonary resuscitation (CPR)

Grade 6 patients (cardiopulmonary arrest) should be given 5 rescue breaths before beginning chest compressions.[40] This is to address the primary issue of hypoxaemia.[40] CPR should follow with a breath to compression ratio of 30:2 for adults and 15:2 for children.[32] If an automated or manual defibrillator is available, it may be applied as long as this does not impede positive pressure ventilations and high-quality CPR; the majority of drowning cardiac arrest patients will be in pulseless electrical activity or asystole.[48]

Advanced Cardiac Life Support medications should be administered per local protocols, with the understanding that reversal of hypoxaemia is the priority.

Patient disposition following initial management

Patient disposition is determined by initial drowning severity classification[16] [39] and response to treatment.

- Grade 1 patients (conscious and alert; cough with normal lung auscultation) who present at the emergency department can be observed off oxygen for a few hours and released if vital signs, symptoms, lung examination, and mentation remain normal.[16] [49] [50]
- Grade 2 to 6 patients (where grade 2 patients have rales in some pulmonary fields) should all be transported to advanced care.

    - Grade 2 patients who arrive at an emergency department and improve with treatment can be observed off oxygen for 6 to 8 hours and released if vital signs, symptoms, lung examination, and mentation remain normal.[16] [49] [50] If continued oxygen is required, vital signs or mentation are not normalised, or if patient/family home resources are not adequate for discharge, the patient should be admitted to a non-critical unit.
    - Grade 3 to 6 patients (where grade 3 patients have acute pulmonary oedema) should be admitted to the intensive care unit.

Supportive therapies

Cardiac dysfunction with low cardiac output is common immediately after severe drowning cases, especially after the return of spontaneous circulation.[14] This may cause hypotension, which can be corrected with oxygenation, rapid crystalloid infusion, and restoration of normal body temperature. Echocardiography can help to guide the clinician in titrating inotropic agents, vasopressors, or both, if volume crystalloid replacement has failed.[40] Urine output should be monitored.

There is no evidence to support the use of any specific fluid therapy for salt- or freshwater drowning, or for the use of diuretics or water restriction in drowning pulmonary oedema.[14]

Treatment details overview

Consult your local pharmaceutical database for comprehensive drug information including contraindications, drug interactions, and alternative dosing. (see Disclaimer)

Presumptive (summary)		
Patient group	**Tx line**	**Treatment**
all patients	**1st**	**water rescue**
	adjunct	**in-water resuscitation**
	adjunct	**cervical spine considerations**

Acute (summary)		
Patient group	**Tx line**	**Treatment**
grade 1 (cough with normal lung auscultation)	**1st**	**observation**

Acute (summary)		
■ with hypothermia	plus	re-warming
grade 2 (rales in some pulmonary fields)	1st	respiratory support and oxygen
■ with hypothermia	plus	re-warming
grade 3 (acute pulmonary oedema with no hypotension or shock)	1st	respiratory support and oxygen
■ with hypothermia	plus	re-warming
grade 4 (acute pulmonary oedema with hypotension or shock)	1st	respiratory support and oxygen
	adjunct	intravenous fluids ± vasopressor
■ with hypothermia	plus	re-warming
grade 5 (no spontaneous ventilation, carotid pulse present)	1st	respiratory support and oxygen
	adjunct	intravenous fluids ± vasopressor
■ with hypothermia	plus	re-warming
■ failure to restore spontaneous breathing	plus	cardiopulmonary resuscitation (CPR)
grade 6 (cardiopulmonary arrest)	1st	cardiopulmonary resuscitation (CPR) ± advanced life support medications
	adjunct	intravenous fluids ± vasopressor
■ with hypothermia	plus	re-warming
■ return of spontaneous circulation (ROSC)	plus	respiratory support and oxygen

Treatment options

Presumptive

Patient group	Tx line	Treatment
all patients	1st	**water rescue** » Recognise distress and call for help. » Provide flotation to stop the process of drowning. Reaching, throwing, or dropping a buoyant object or manoeuvring a craft to the victim is preferred. » Lay persons and rescuers without specialised training in water rescue should never enter the water to attempt a rescue. » The victim should be removed from the water in as near a horizontal position as possible, with the airway open. » On land, the victim should be placed supine with trunk and head at the same level.
	adjunct	**in-water resuscitation** » For an unconscious victim, in-water ventilation by trained individuals can increase the likelihood of neurologically intact discharge from hospital.[42] » If there is no response to in-water ventilation (up to 5 mouth-to-mouth ventilations only), the victim should be assumed to be in cardiac arrest. Cardiopulmonary resuscitation (CPR) with chest compression and ventilation should be initiated once the victim is out of the water.
	adjunct	**cervical spine considerations** » Routine spinal motion restriction is not indicated for the majority of drowning victims because the incidence is extremely low.[37] [38] » If cervical spine injury is suspected, the cervical spine may be held in mid-line, but attempts at further motion restriction with cervical spine collars or long spine boards should never impede resuscitative efforts. » Those with confirmed cervical spine injury have obvious history, or signs of significant trauma.

Acute

Patient group	Tx line	Treatment
grade 1 (cough with normal lung auscultation)	1st	**observation** » Respiratory support and oxygen should not be required.[40] Patients can typically be released from the scene with education. » Grade 1 patients (conscious and alert; cough with normal lung auscultation) who present at the emergency department can be observed off oxygen for a few hours and released if vital signs, symptoms, lung examination, and mentation remain normal.[16] [49] [50] » Although delayed lung complications are rare, drowning victims should be advised to seek medical advice immediately if they develop cough, breathlessness, fever, or any other worrying symptom in the ensuing 8-hour period.
with hypothermia	plus	**re-warming** » Passive re-warming (including removing wet clothing, and drying and covering the patient) is the preferred treatment option for mild cases. » Active external re-warming is indicated for moderate to severe hypothermia. In addition to covering the patient with warm blankets, forced warm air is applied directly to the patient's body. The use of a Bair Hugger is a good example.
grade 2 (rales in some pulmonary fields)	1st	**respiratory support and oxygen** » Deliver the highest concentration of oxygen available based on patient condition, with a goal of SaPO2 between 92% and 96%.[40] [44] This can often be achieved with nasal cannula or face-mask. » Consider an observation period of 6 to 8 hours in the emergency department. If the patient is off supplemental oxygen for that time, with normalised vital signs and mentation, and there are no other medical/traumatic conditions requiring further treatment, consider discharge with close follow-up.[49] [50] » If requiring supplemental oxygen, vital signs or mentation not normalised, poor follow-up, or if the patient/family is not comfortable returning home, admit the patient to a non-critical unit.

Acute

Patient group	Tx line	Treatment
with hypothermia	plus	**re-warming** » Passive re-warming (including removing wet clothing, and drying and covering the patient) is the preferred treatment option for mild cases. » Active external re-warming is indicated for moderate to severe hypothermia. In addition to covering the patient with warm blankets, forced warm air is applied directly to the patient's body. The use of a Bair Hugger is a good example.
grade 3 (acute pulmonary oedema with no hypotension or shock)	1st	**respiratory support and oxygen** » Based on patient condition, deliver the highest concentration of oxygen available via non-invasive or invasive ventilation. » Non-invasive positive pressure ventilation (NIPPV) may be considered if the patient's mental status allows and the airway is clear of vomit and secretions. If the patient does not improve after a short course of NIPPV, quickly convert to endotracheal intubation (ETI).[51] [52] » ETI is ideal, but may be challenging to implement due to copious airway fluids. Efforts to clear the airway should be limited as they will often be futile. » Given the similar clinical course, recommendations call for following acute respiratory distress syndrome-focused ventilation strategies.[40] » Positive end-expiratory pressure (PEEP) should be added initially at a level of 5 cm H2O. Increase by 2 to 3 cm H2O increments, if possible, until the desired intrapulmonary shunt (QS:QT) of 20% or less, or the ratio of arterial oxygen partial pressure to fractional inspired oxygen (PaO2:FiO2) of 250 or more, is achieved. PEEP level should be left unchanged for 48 hours to permit adequate surfactant regeneration and consequent alveolar recruitment before weaning is attempted. Early weaning from the ventilator may cause the return of pulmonary oedema with the need for re-intubation, a prolonged hospital stay, and further morbidity.[40] » Admit to intensive care unit.

Acute

Patient group	Tx line	Treatment
with hypothermia	plus	**re-warming** » Passive re-warming (including removing wet clothing, and drying and covering the patient) is the preferred treatment option for mild cases. » Active external re-warming is indicated for moderate to severe hypothermia. In addition to covering the patient with warm blankets, forced warm air is applied directly to the patient's body. The use of a Bair Hugger is a good example.
grade 4 (acute pulmonary oedema with hypotension or shock)	**1st**	**respiratory support and oxygen** » Based on patient condition, deliver the highest concentration of oxygen available via non-invasive or invasive ventilation. » Non-invasive positive pressure ventilation (NIPPV) may be considered if the patient's mental status allows and the airway is clear of vomit and secretions. If the patient does not improve after a short course of NIPPV, quickly convert to endotracheal intubation (ETI).[51] [52] » ETI is ideal, but may be challenging to implement due to copious airway fluids. Efforts to clear the airway should be limited as they will often be futile. » Given the similar clinical course, recommendations call for following acute respiratory distress syndrome-focused ventilation strategies.[40] » Positive end-expiratory pressure (PEEP) should be added initially at a level of 5 cm H2O. Increase by 2 to 3 cm H2O increments, if possible, until the desired intrapulmonary shunt (QS:QT) of 20% or less, or the ratio of arterial oxygen partial pressure to fractional inspired oxygen (PaO2:FiO2) of 250 or more, is achieved. PEEP level should be left unchanged for 48 hours to permit adequate surfactant regeneration and consequent alveolar recruitment before weaning is attempted. Early weaning from the ventilator may cause the return of pulmonary oedema with the need for re-intubation, a prolonged hospital stay, and further morbidity.[40] » Admit to intensive care unit.

Acute

Patient group	Tx line	Treatment
	adjunct	**intravenous fluids ± vasopressor** » Reversal of hypoxia and/or hypothermia may resolve hypotension. Intravenous crystalloid infusion may be required. » Breathing should be monitored as respiratory arrest can still occur.[40] » Refractory hypotension may require vasopressors. **Primary options** » noradrenaline (norepinephrine): 0.01 to 3 micrograms/kg/minute intravenous infusion, titrate according to response **OR** **Primary options** » adrenaline (epinephrine): 0.05 to 1 micrograms/kg/minute intravenous infusion, titrate according to response
with hypothermia	plus	**re-warming** » Passive re-warming (including removing wet clothing, and drying and covering the patient) is the preferred treatment option for mild cases. » Active external re-warming is indicated for moderate to severe hypothermia. In addition to covering the patient with warm blankets, forced warm air is applied directly to the patient's body. The use of a Bair Hugger is a good example.
grade 5 (no spontaneous ventilation, carotid pulse present)	1st	**respiratory support and oxygen** » Initial treatment of apnoeic patients with a palpable pulse is by way of mouth-to-mouth (feasible), or mouth-to-mask (pocket-mask, usually not feasible), or bag-valve mask. » Respiratory arrest is usually reversed after several imposed breaths.[40] » Endotracheal intubation is ideal, but may be challenging to implement due to copious airway fluids. Efforts to clear the airway should be limited as they will often be futile. » Given the similar clinical course, recommendations call for following acute

Acute

Patient group	Tx line	Treatment
		respiratory distress syndrome-focused ventilation strategies.[40] » Positive end-expiratory pressure (PEEP) should be added initially at a level of 5 cm H2O. Increase by 2 to 3 cm H2O increments, if possible, until the desired intrapulmonary shunt (QS:QT) of 20% or less, or the ratio of arterial oxygen partial pressure to fractional inspired oxygen (PaO2:FiO2) of 250 or more, is achieved. PEEP level should be left unchanged for 48 hours to permit adequate surfactant regeneration and consequent alveolar recruitment before weaning is attempted. Early weaning from the ventilator may cause the return of pulmonary oedema with the need for re-intubation, a prolonged hospital stay, and further morbidity.[40] » Admit to intensive care unit.
	adjunct	**intravenous fluids ± vasopressor** » Reversal of hypoxia and/or hypothermia may resolve hypotension. Intravenous crystalloid infusion may be required. » Breathing should be monitored as respiratory arrest can still occur.[40] » Refractory hypotension may require vasopressors. If the patient is severely hypothermic, cardioactive medications can reach toxic levels if given repeatedly. For these reasons, intravenous drugs are often withheld if the patient's core body temperature is <30°C (<86°F). If the core body temperature is >30°C (>86°F), intravenous medications may be administered but with increased intervals between doses.[33] **Primary options** » noradrenaline (norepinephrine): 0.01 to 3 micrograms/kg/minute intravenous infusion, titrate according to response **OR** **Primary options** » adrenaline (epinephrine): 0.05 to 1 micrograms/kg/minute intravenous infusion, titrate according to response
■ **with hypothermia**	**plus**	**re-warming**

Acute

Patient group	Tx line	Treatment
		» Severe hypothermia (body temperature <30°C) may be associated with marked depression of critical body functions such that the patient may appear dead during initial assessment. Resuscitation guidelines recommend that CPR should be continued unless the victim is unquestionably dead. Patients should not be considered dead until successful warming has been provided.[32] [33] [34] » Passive re-warming (including removing wet clothing, and drying and covering the patient) is the preferred treatment option for mild cases. » Active external re-warming is indicated for moderate to severe hypothermia. In addition to covering the patient with warm blankets, forced warm air is applied directly to the patient's body. The use of a Bair Hugger is a good example. » Active internal re-warming techniques include airway re-warming with humidified oxygen at 40°C (104°F), warmed intravenous fluids, and peritoneal lavage. Extracorporeal blood warming is the most effective method and increases core temperature by 1°C to 2°C (1.8°F to 3.6°F) every 3 to 5 minutes.[45]
failure to restore spontaneous breathing	**plus**	**cardiopulmonary resuscitation (CPR)** » Administer 5 initial ventilations followed by 30 chest compressions to a drowning victim who does not present with obvious physical evidence of death (e.g., rigor mortis, decomposition, hemisection, decapitation). » CPR should follow with a breath to compression ratio of 30:2 for adults and 15:2 for children.[32] » If an automated or manual defibrillator is available, it may be applied as long as this does not impede high-quality CPR. » If endotracheal intubation is performed, utilise continuous compressions with a breath every 6 seconds.[32] » The stomach should be decompressed using a gastric tube.[32]
grade 6 (cardiopulmonary arrest)	**1st**	**cardiopulmonary resuscitation (CPR) ± advanced life support medications**

Acute

Patient group	Tx line	Treatment
		» A majority of drowning cardiac arrest patients will be in pulseless electrical activity or asystole.[48] » Administer 5 initial ventilations followed by 30 chest compressions to a drowning victim who does not present with obvious physical evidence of death (e.g., rigor mortis, decomposition, hemisection, decapitation). » CPR should follow with a breath to compression ratio of 30:2 for adults and 15:2 for children.[32] » If an automated or manual defibrillator is available, it may be applied as long as this does not impede high-quality CPR. » If endotracheal intubation is performed, utilise continuous compressions with a breath every 6 seconds.[32] » The stomach should be decompressed using a gastric tube.[32] » Consider Advanced Cardiac Life Support medications as indicated, especially adrenaline. If the patient is severely hypothermic, cardioactive medications can reach toxic levels if given repeatedly. For these reasons, intravenous drugs are often withheld if the patient's core body temperature is <30°C (<86°F). If the core body temperature is >30°C (>86°F), intravenous medications may be administered but with increased intervals between doses.[33] Amiodarone may be used for refractory ventricular tachycardia/ventricular fibrillation. **Primary options** » adrenaline (epinephrine): 1 mg intravenously every 3-5 minutes **OR** **Primary options** » amiodarone: 300 mg intravenously as a single dose
	adjunct	**intravenous fluids ± vasopressor** » Reversal of hypoxia and/or hypothermia may resolve hypotension. Intravenous crystalloid infusion may be required. » Breathing should be monitored as respiratory arrest can still occur.[40]

Acute

Patient group	Tx line	Treatment
		» Refractory hypotension may require vasopressors. If the patient is severely hypothermic, cardioactive medications can reach toxic levels if given repeatedly. For these reasons, intravenous drugs are often withheld if the patient's core body temperature is <30°C (<86°F). If the core body temperature is >30°C (>86°F), intravenous medications may be administered but with increased intervals between doses.[33] **Primary options** » noradrenaline (norepinephrine): 0.01 to 3 micrograms/kg/minute intravenous infusion, titrate according to response **OR** **Primary options** » adrenaline (epinephrine): 0.05 to 1 micrograms/kg/minute intravenous infusion, titrate according to response
■ **with hypothermia**	**plus**	**re-warming** » Severe hypothermia (body temperature <30°C) may be associated with marked depression of critical body functions such that the patient may appear dead during initial assessment. Resuscitation guidelines recommend that CPR should be continued unless the victim is unquestionably dead. Patients should not be considered dead until successful warming has been provided.[32] [33] [34] » For prolonged submersion, submersion in cold water, or if the patient is deemed to be hypothermic, passive and active re-warming measures should be administered.[32] » Active external re-warming is indicated for moderate to severe hypothermia. In addition to covering the patient with warm blankets, forced warm air is applied directly to the patient's body. The use of a Bair Hugger is a good example. » Active internal re-warming techniques include airway re-warming with humidified oxygen at 40°C (104°F), heating intravenous fluids, and peritoneal lavage. Extracorporeal blood warming is the most effective method and increases core temperature by 1°C to 2°C (1.8°F to 3.6°F) every 3 to 5 minutes.[45]

Acute

Patient group	Tx line	Treatment
		» If local protocols and resources allow, current recommendations call for sustained re-warming of the patient to 32°C to 34°C (89.6°F to 93.2°F) and maintaining that temperature for at least 24 hours.[46] If the patient's temperature is >34°C (>93.2°F), recommendations call for targeted temperature management.[47]
return of spontaneous circulation (ROSC)	**plus**	**respiratory support and oxygen** » Ventilation is likely to require ongoing support following ROSC, whether through mouth-to-mouth, mouth-to-mask (pocket mask), bag-valve mask (BVM), or an advanced airway inserted during cardiopulmonary resuscitation. Some patients may remain dependent on rescue breathing until spontaneous ventilation becomes more efficient. » Endotracheal intubation (ETI) is ideal, but may be challenging to implement due to copious airway fluids. Efforts to clear the airway of vomit, water, or expelled pulmonary fluid should be limited as they will often be futile and delay needed interventions. » If ETI equipment is not available, or airway assessment suggests that ETI is likely to be difficult, a supraglottic device may be used. If the supraglottic device does not result in sufficient ventilation (e.g., because of reduced pulmonary compliance requiring high inflation pressures),[32] remove and continue BVM ventilations or proceed to ETI should it become available.[40] » If ventilations cannot be given due to airway obstruction (uncommon), an attempt to quickly roll the patient and apply suction can be made with the goal of rapidly resuming ventilations. » Although there is insufficient evidence to support a specific target oxygen saturation or PaCO2 during and after resuscitation, hypoxaemia and hypercarbia should be avoided. » Given the similar clinical course, recommendations call for following acute respiratory distress syndrome-focused ventilation strategies.[40] » Positive end-expiratory pressure (PEEP) should be added initially at a level of 5 cm H2O. Increase by 2 to 3 cm H2O increments, if possible, until the desired intrapulmonary shunt (QS:QT) of 20% or less, or the ratio of

Acute

Patient group	Tx line	Treatment
		arterial oxygen partial pressure to fractional inspired oxygen (PaO2:FiO2) of 250 or more, is achieved. PEEP level should be left unchanged for 48 hours to permit adequate surfactant regeneration and consequent alveolar recruitment before weaning is attempted. Early weaning from the ventilator may cause the return of pulmonary oedema with the need for re-intubation, a prolonged hospital stay, and further morbidity.[40] » Admit to intensive care unit.

Recommendations

Monitoring

Long-term follow-up after drowning is determined by the degree of neurological recovery. Patients with full recovery rarely require additional outpatient monitoring. However, patients with some impairment can benefit from rehabilitation, depending on the severity of functional impairment after hospital discharge. Alcohol rehabilitation programmes should be offered to patients with alcohol abuse. Genetic counselling should be pursued for patients with newly diagnosed genetic-associated cardiac arrhythmias.

Patient instructions

Patients should return for re-evaluation if they develop difficulty breathing, chest pain, productive cough, or fevers, as this may suggest delayed onset of pneumonia. Patients with a predisposing condition, such as epilepsy or cardiac arrhythmias, should not swim without supervision.

Complications

Complications	Timeframe	Likelihood
anoxic brain injury	**short term**	**low**
Most late deaths and long-term sequelae of drowning are neurological in origin. Adequate oxygenation and cerebral perfusion post rescue may prevent or limit neurological damage.[57] The likelihood of anoxic-ischaemic cerebral insult is low in grade 1 to 5 drownings, but high in grade 6 (cardiopulmonary arrest).		
cardiac dysfunction	**short term**	**low**
Cardiac dysfunction with low cardiac output is common immediately after severe drowning episodes, especially after the return of spontaneous circulation.[14] This may cause hypotension, which can be corrected with oxygenation, rapid crystalloid infusion, and restoration of normal body temperature. Vasopressors should only be used in refractory hypotension after a trial with crystalloids.		
pneumonia	**short term**	**low**
Bacterial colonisation at the site of the drowning (e.g., river, sea) is not generally sufficient to promote pneumonia in the immediate post drowning period.[57] Pneumonia is often misdiagnosed because of the early radiographic appearance of water in the lungs, and the presence of leukocytosis and low-grade fever, which are physiological responses to the stress of the event. The incidence of ventilator-associated pneumonia increases to 34% to 52% in the third or fourth day of hospitalisation when pulmonary oedema is resolving.[58] Prophylactic antibiotics are not recommended.[59]		
acute respiratory distress syndrome (ARDS)-like syndrome	**short term**	**low**
A clinical picture similar, but not identical, to ARDS is common after significant drowning episodes (grades 3 to 6).[53] Management is similar to that of other patients with ARDS.[40] [53]		
electrolyte disturbances	**short term**	**low**

FOLLOW UP

Complications	Timeframe	Likelihood
Electrolyte disturbances have been reported in the literature, primarily in patients who drowned in water with an abnormally high salt concentration, such as the Dead Sea. No study has found these disturbances to be clinically significant.[60]		
metabolic acidosis	**short term**	**low**
Metabolic acidosis occurs in the majority of drowning patients transferred to the emergency department.[40] The acidosis should be corrected when pH is lower than 7.2, or bicarbonate is less than 12 mEq/L, despite adequate ventilatory support.		
cervical spine injury	**short term**	**low**
Retrospective analyses suggest that the incidence of in-water cervical spine injury is low (0.009% to <0.5%).[37] [38] Studies are, however, limited.[37] [38] [65]		
acute kidney injury	**variable**	**low**
Acute kidney injury, resulting from hypovolaemic shock, hypoxaemia, rhabdomyolysis, and lactic acidosis, may occur secondary to drowning.[36] In severe cases, patients have required haemodialysis.[61] [62] [63] [64]		

Prognosis

Of drowning cases graded 1 to 5, 95% return home without sequelae.[16] Mortality among grade 6 cases has been reported at 93%.[16]

Of grade 6 drowning cases fully resuscitated, only 7% to 11% recover fully or partially (Cerebral Performance Categories Scale CPC 1 and CPC 2).[16] [40] [42] Studies have established that outcome is almost entirely determined by the duration of submersion.[53] Additionally, a low Glasgow Coma Scale score, lack of pupillary response, acidosis, and hypotension are all associated with increased morbidity and mortality.[54] [55] To date, most studies on the subject are based on weak evidence, and prognostic tools lack validation.[54]

The following points are consistent throughout most studies:

- Submersion time is the most important prognostic factor. Known submersion time <10 minutes is a good prognostic factor and >25 minutes is a poor prognostic factor.[54]
- Successful resuscitation without sequelae is rare, but possible, following prolonged submersion in cold or icy water (anecdotally, some people may survive extended submersion in warm water without sequelae).[16] [11] [56]
- Most patients who are awake and alert on arrival at the emergency department, or whose mentation improves to near-normal early in treatment, have good neurological outcomes.[49] [50]

Treatment guidelines

Europe

European Resuscitation Council guidelines for resuscitation 2015: Section 4. Cardiac arrest in special circumstances

Published by: European Resuscitation Council **Last published:** 2015

Resuscitation guidelines

Published by: The Resuscitation Council (UK) **Last published:** 2015

Unintentional injuries in the home: interventions for under 15s

Published by: National Institute for Health and Care Excellence **Last published:** 2010

Trauma emergencies: the immersion incident

Published by: Joint Royal Colleges Ambulance Liaison Committee **Last published:** 2007

International

International Life Saving Federation position statements

Published by: The International Life Saving Federation **Last published:** 2016

North America

Wilderness Medical Society practice guidelines for the prevention and treatment of drowning

Published by: The Wilderness Medical Society **Last published:** 2016

2015 American Heart Association guidelines for cardiopulmonary resuscitation and emergency cardiovascular care. Part 10: special circumstances of resuscitation

Published by: American Heart Association **Last published:** 2015

Online resources

1. BMJ Best Practice: drowning classification system (high-resolution) *(external link)*

Key articles

References

1. van Beeck EF, Branche CM, Szpilman D, et al. A new definition of drowning: towards documentation and prevention of a global public health problem. Bull World Health Organ. 2005;83:853-856. Full text Abstract

2. Idris AH, Berg RA, Bierens J, et al; American Heart Association. Recommended guidelines for uniform reporting of data from drowning: the "Utstein style". Circulation. 2003;108:2565-2574. Full text Abstract

3. World Health Organization. Global report on drowning: Preventing a leading killer. 2014. http://www.who.int/ (last accessed 22 August 2017). Full text

4. Lu TH, Lunetta P, Walker S. Quality of cause-of-death reporting using ICD-10 drowning codes: a descriptive study of 69 countries. BMC Med Res Methodol. 2010;10:30. Full text Abstract

5. Centers for Disease Control and Prevention. WISQARS (Web-based Injury Statistics Query and Reporting System) fatal injury reports, national, regional and state, 1981-2015: drowning. February 2017. https://www.cdc.gov/ (last accessed 22 August 2017). Full text

6. Moutafi A, Petridou E. The burden of drowning: issues in selected countries - Europe. In: Bierens JJ, ed. Handbook on drowning: prevention, rescue, and treatment. Berlin: Springer-Verlag; 2014:101-105.

7. Ozanne-Smith J. The burden of drowning: issues in selected countries - Australia and New Zealand. In: Bierens JJ, ed. Handbook on drowning: prevention, rescue, and treatment. Berlin: Springer-Verlag; 2014:107-110.

8. Szpilman D. Analyses of drowning deaths in Brazil over the last 34 years reveal a sharp decline. World Conference on Drowning Prevention program and proceedings, Malaysia; 2015:60. Full text

9. Kobusingye O, Bowman B. The burden of drowning: issues in selected countries - Africa. In: Bierens JJ, ed. Handbook on drowning: prevention, rescue, and treatment. Berlin: Springer-Verlag; 2014:111-113.

10. Labrique A, Hyder A. The burden of drowning: issues in selected countries - South and Southeast Asia. In: Bierens JJ, ed. Handbook on drowning: prevention, rescue, and treatment. Berlin: Springer-Verlag; 2014:119-122.

11. Tipton MJ, Golden FS. A proposed decision-making guide for the search, rescue and resuscitation of submersion (head under) victims based on expert opinion. Resuscitation. 2011;82:819-824. Abstract

12. Szpilman D, Elmann J, Cruz-Filho FE. Dry-drowning - fact or myth? Book of abstracts. World Congress on Drowning, Amsterdam; 2002:65.

REFERENCES

13. Lunetta P, Modell JH, Sajantila A. What is the incidence and significance of "dry-lungs" in bodies found in water? Am J Forensic Med Pathol. 2004;25:291-301. Abstract

14. Orlowski JP, Abulleil MM, Phillips JM. The hemodynamic and cardiovascular effects of near-drowning in hypotonic, isotonic, or hypertonic solutions. Ann Emerg Med. 1989;18:1044-1049. Abstract

15. Grmec S, Strnad M, Podgorsek D. Comparison of the characteristics and outcome among patients suffering from out-of-hospital primary cardiac arrest and drowning victims in cardiac arrest. Int J Emerg Med. 2009;2:7-12. Full text Abstract

16. Szpilman D. Near-drowning and drowning classification: a proposal to stratify mortality based on the analysis of 1,831 cases. Chest. 1997;112:660-665. Abstract

17. Orlowski JP, Szpilman D. Drowning. Rescue, resuscitation, and reanimation. Pediatr Clin North Am. 2001;48:627-646. Abstract

18. Modell JH, Moya F, Newby EJ, et al. The effects of fluid volume in seawater drowning. Ann Intern Med. 1967;67:68-80. Abstract

19. Matthews BL, Andrew E, Andronaco R, et al. Epidemiology of fatal and non-fatal drowning patients attended by paramedics in Victoria, Australia. Int J Inj Contr Saf Promot. 2017;24:303-310. Abstract

20. Felton H, Myers J, Liu G, et al. Unintentional, non-fatal drowning of children: US trends and racial/ethnic disparities. BMJ Open. 2015;5:e008444. Full text Abstract

21. Dietz PE, Baker SP. Drowning: epidemiology and prevention. Am J Public Health. 1974;64:303-312. Full text Abstract

22. Clemens T, Tamim H, Rotondi M, et al. A population based study of drowning in Canada. BMC Public Health. 2016;16:559. Full text Abstract

23. Peden AE, Franklin RC, Leggatt PA. The hidden tragedy of rivers: a decade of unintentional fatal drowning in Australia. PLoS One. 2016;11:e0160709. Full text Abstract

24. Peden AE, Franklin RC, Leggatt PA. Alcohol and its contributory role in fatal drowning in Australian rivers, 2002-2012. Accid Anal Prev. 2017;98:259-265. Abstract

25. Quan L. Review of risk factors. In: Bierens JJ, ed. Handbook on drowning: prevention, rescue, and treatment. Berlin: Springer-Verlag; 2014:123-126.

26. Rahman F, Bose S, Linnan M, et al. Cost-effectiveness of an injury and drowning prevention program in Bangladesh. Pediatrics. 2012;130:e1621-e1628. Full text Abstract

27. Papadodima SA, Sakelliadis EI, Kotretsos PS, et al. Cardiovascular disease and drowning: autopsy and laboratory findings. Hellenic J Cardiol. 2007;48:198-205. Full text Abstract

28. Tester DJ, Medeiros-Domingo A, Will ML, et al. Unexplained drownings and the cardiac channelopathies: a molecular autopsy series. Mayo Clin Proc. 2011;86:941-947. Full text Abstract

29. Bell GS, Gaitatzis A, Bell CL, et al. Drowning in people with epilepsy: how great is the risk? Neurology. 2008;71:578-582. Abstract

30. Chang CY, Lu TH, Cheng TJ. Trends in reporting injury as a cause of death among people with epilepsy in the U.S., 1981-2010. Seizure. 2014;23:836-843. Full text Abstract

31. Quan L, Pilkey D, Gomez A, et al. Analysis of paediatric drowning deaths in Washington State using the child death review (CDR) for surveillance: what CDR does and does not tell us about lethal drowning injury. Inj Prev. 2011;17(Suppl 1):i28-i33. Abstract

32. Truhlár A, Deakin CD, Soar J, et al; Cardiac Arrest in Special Circumstances Collaborators. European Resuscitation Council Guidelines for Resuscitation 2015: Section 4. Cardiac arrest in special circumstances. Resuscitation. 2015;95:148-201. Abstract

33. Lavonas EJ, Drennan IR, Gabrielli A, et al. Part 10: Special circumstances of resuscitation: 2015 American Heart Association guidelines update for cardiopulmonary resuscitation and emergency cardiovascular care. Circulation. 2015;132(18 Suppl 2):S501-S518. Full text Abstract

34. The Resuscitation Council (UK). Resuscitation guidelines. 2015. https://www.resus.org.uk (last accessed 22 August 2017). Full text

35. Idris AH, Bierens JJLM, Perkins GD, et al. 2015 revised Utstein-style recommended guidelines for uniform reporting of data from drowning-related resuscitation: an ILCOR advisory statement. Resuscitation. 2017;118:147-158.

36. Gregorakos L, Markou N, Psalida V, et al. Near-drowning: clinical course of lung injury in adults. Lung. 2009;187:93-97. Abstract

37. Watson RS, Cummings P, Quan L, et al. Cervical spine injuries among submersion victims. J Trauma. 2001;51:658-662. Abstract

38. Szpilman D, Brewster C, Cruz-Filho FE. Aquatic cervical spine injury - how often do we have to worry? Oral presentation. World Congress on Drowning, Netherlands; 2002.

39. Szpilman D, Elmann J, Cruz-Filho FE. Drowning classification: a revalidation study based on the analysis of 930 cases over 10 years. Book of abstracts. World Congress on Drowning, Amsterdam; 2002:66.

40. Szpilman D, Bierens JJ, Handley AJ, et al. Current concepts: drowning. N Engl J Med. 2012;366:2102-2110. Full text Abstract

41. Szpilman D, Webber J, Quan L, et al. Creating a drowning chain of survival. Resuscitation. 2014;85:1149-1152. Abstract

42. Szpilman D, Soares M. In-water resuscitation - is it worthwhile? Resuscitation. 2004;63:25-31. Abstract

43. International Life Saving Federation. Position statements: medical help. 2016. http://www.ilsf.org/ (last accessed 22 August 2017). Full text

REFERENCES

44. Kochanek PM, Bayir H. Titrating oxygen during and after cardiopulmonary resuscitation. JAMA. 2010;303:2190-2191. Abstract

45. McCullough L, Arora S. Diagnosis and treatment of hypothermia. Am Fam Physician. 2004;70:2325-2332. Full text Abstract

46. Nolan JP, Soar J, Cariou A, et al; European Society of Intensive Care Medicine. European Resuscitation Council and European Society of Intensive Care Medicine 2015 guidelines for post-resuscitation care. Intensive Care Med. 2015;41:2039-2056. [Erratum in: Intensive Care Med. 2016;42:488-489.] Abstract

47. World Congress on Drowning. Final recommendations of the 2002 World Congress on Drowning. 2017. http://www.ilsf.org/ (last accessed 22 August 2017). Full text

48. Dyson K, Morgans A, Bray J, et al. Drowning related out-of-hospital cardiac arrests: characteristics and outcomes. Resuscitation. 2013;84:1114-1118. Abstract

49. Causey AL, Tilelli JA, Swanson ME. Predicting discharge in uncomplicated near-drowning. Am J Emerg Med. 2000;18:9-11. Abstract

50. Noonan L, Howrey R, Ginsburg CM. Freshwater submersion injuries in children: a retrospective review of seventy-five hospitalized patients. Pediatrics. 1996;98:368-371. Abstract

51. Dottorini M, Eslami A, Baglioni S, et al. Nasal-continuous positive airway pressure in the treatment of near-drowning in freshwater. Chest. 1996;110:1122-1124. Abstract

52. Michelet P, Bouzana F, Charmensat O, et al. Acute respiratory failure after drowning: a retrospective multicenter survey. Eur J Emerg Med. 2017;24:295-300. Abstract

53. Szpilman D, Orlowski JP. Sports related to drowning. Eur Respir Rev. 2016;25:348-359. Full text Abstract

54. Quan L, Bierens JJ, Lis R, et al. Predicting outcome of drowning at the scene: A systematic review and meta-analyses. Resuscitation. 2016;104:63-75. Abstract

55. Son KL, Hwang SK, Choi HJ. Clinical features and prognostic factors in drowning children: a regional experience. Korean J Pediatr. 2016;59:212-217. Full text Abstract

56. Szpilman D. A case report of 22 minutes submersion in warm water without sequelae. In: Bierens JJ, ed. Handbook on drowning: prevention, rescue, and treatment. Berlin: Springer-Verlag; 2006:375-376.

57. Orlowski JP. Drowning, near-drowning, and ice-water submersions. Pediatr Clin North Am. 1987;34:75-92. Abstract

58. Van Berkel M, Bierens JJ, Lie RL et al. Pulmonary oedema, pneumonia and mortality in submersion victims; a retrospective study in 125 patients. Intensive Care Med. 1996;22:101-107. Abstract

59. Wood C. Towards evidence based emergency medicine: best BETs from the Manchester Royal Infirmary. BET 1: prophylactic antibiotics in near-drowning. Emerg Med J. 2010;27:393-394. Abstract

60. Saidel-Odes LR, Almog Y. Near-drowning in the Dead Sea: a retrospective observational analysis of 69 patients. Isr Med Assoc J. 2003;5:856-858. Abstract

61. Bierens JJ, Lunetta P, Tipton M, et al. Physiology of drowning: a review. Physiology (Bethesda). 2016;31:147-166. Full text Abstract

62. Seong EY, Rhee H, Lee N, et al. A case of severe acute kidney injury by near-drowning. J Korean Med Sci. 2012;27:218-220. Full text Abstract

63. Hegde SN, Anupama YJ. Acute renal failure secondary to rhabdomyolysis following near-drowning in sea water. J Assoc Physicians India. 2003;51:512-513. Abstract

64. Opdahl H. Survival put to the acid test: extreme arterial blood acidosis (pH 6.33) after near drowning. Crit Care Med. 1997;25:1431-1436. Abstract

65. Szpilman D. Aquatic cervical and head trauma: nobody told me it could be a jump in the darkness! Oral presentation, paper 290. World Conference on Drowning Prevention program and proceedings, Danang, Vietnam; 2011:153.

Images

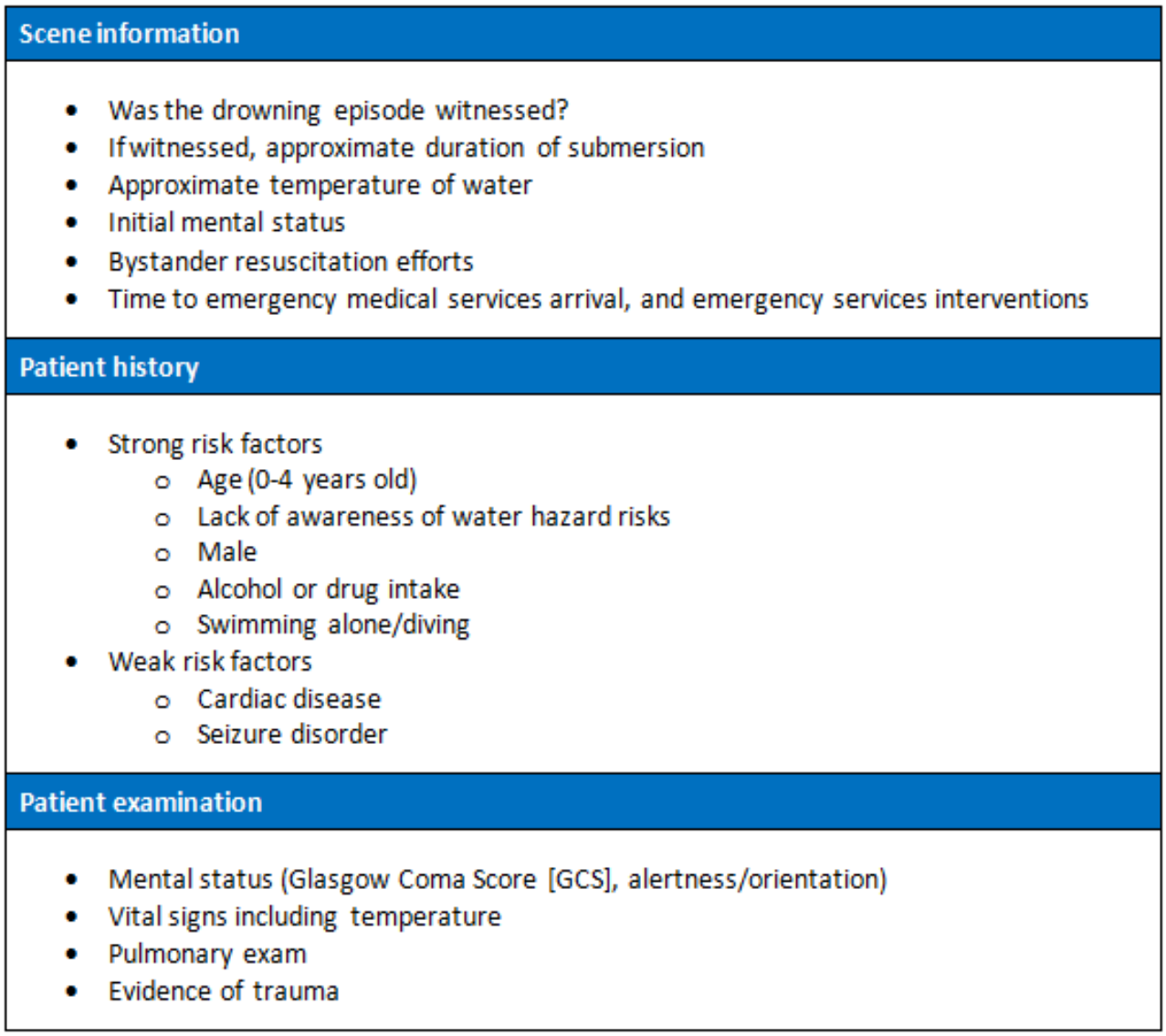


Figure 1: Drowning episode history and examination information

Created by BMJ Knowledge Centre

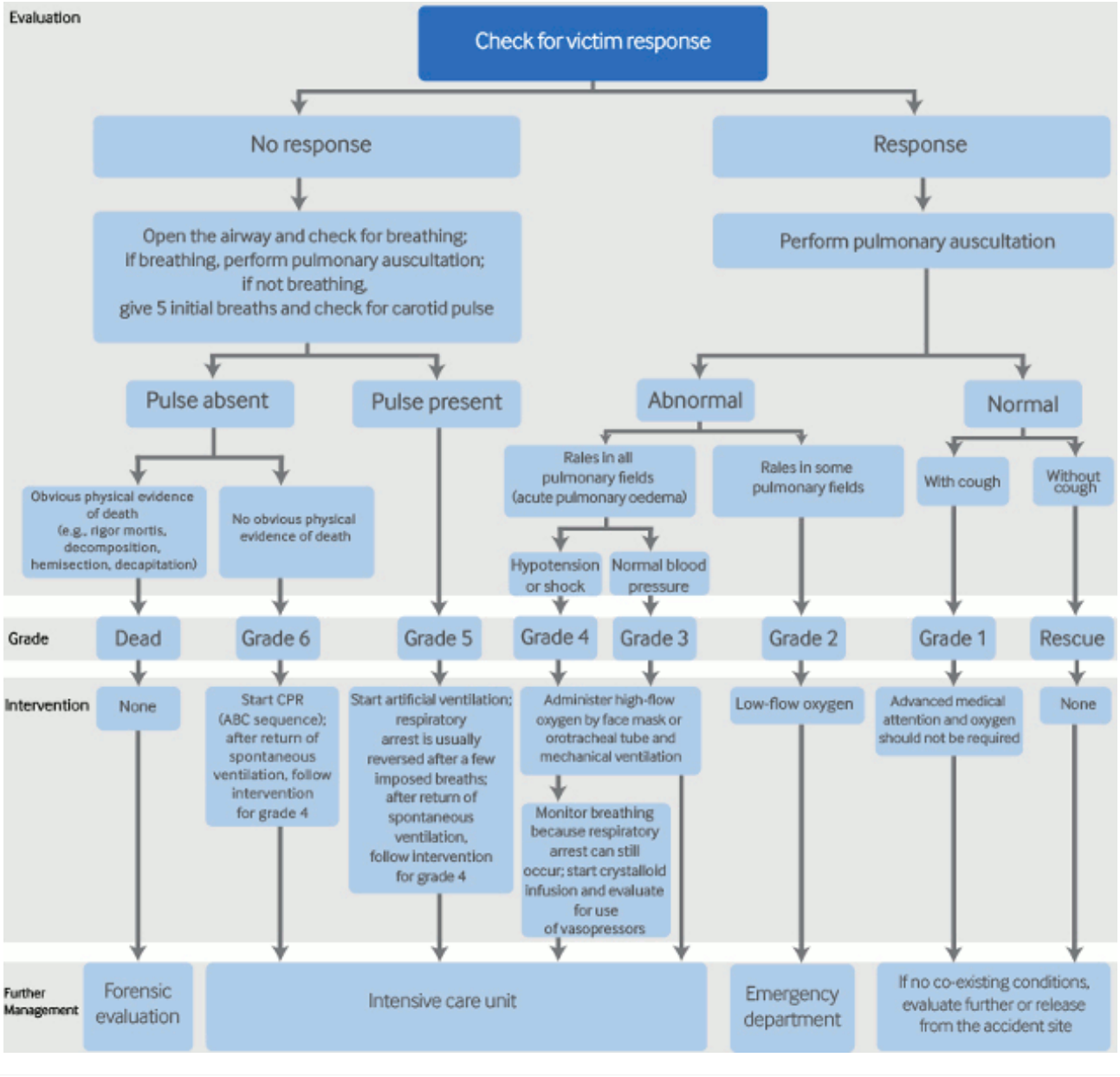


Figure 2: Drowning classification system

Adapted from Orlowski JP, Szpilman D. Drowning. Rescue, resuscitation, and reanimation. Pediatr Clin North Am. 2001;48:627-646. Used with permission

Figure 3: Drowning Chain of Survival

Szpilman et al. Creating a drowning chain of survival. Resuscitation. 2014;85:1149-1152. Used with permission

IMAGES

Disclaimer

This content is meant for medical professionals situated outside of the United States and Canada. The BMJ Publishing Group Ltd ("BMJ Group") tries to ensure that the information provided is accurate and up-to-date, but we do not warrant that it is nor do our licensors who supply certain content linked to or otherwise accessible from our content. The BMJ Group does not advocate or endorse the use of any drug or therapy contained within nor does it diagnose patients. Medical professionals should use their own professional judgement in using this information and caring for their patients and the information herein should not be considered a substitute for that.

This information is not intended to cover all possible diagnosis methods, treatments, follow up, drugs and any contraindications or side effects. In addition such standards and practices in medicine change as new data become available, and you should consult a variety of sources. We strongly recommend that users independently verify specified diagnosis, treatments and follow up and ensure it is appropriate for your patient within your region. In addition, with respect to prescription medication, you are advised to check the product information sheet accompanying each drug to verify conditions of use and identify any changes in dosage schedule or contraindications, particularly if the agent to be administered is new, infrequently used, or has a narrow therapeutic range. You must always check that drugs referenced are licensed for the specified use and at the specified doses in your region. This information is provided on an "as is" basis and to the fullest extent permitted by law the BMJ Group and its licensors assume no responsibility for any aspect of healthcare administered with the aid of this information or any other use of this information.

View our full Website Terms and Conditions.

Contributors:

// Authors:

David Szpilman, MD

Diretor Médico da Sobrasa
Ten Cel BM Médico RR - Corpo de Bombeiros Militar do Rio de Janeiro, Defesa Civil Municipal do Rio de Janeiro, Membro Fundador - International Drowning Research Alliance - IDRA, Rio de Janeiro, Brazil
DISCLOSURES: DS is an author of several references cited in this topic.

Justin Sempsrott, MD, FAAEM

Executive Director: Lifeguards Without Borders
Medical Director: International Surf Lifesaving Association, Medical Director: Starfish Aquatics Institute, Medical Director: Innovative Attraction Management Starguard Elite, Board of Directors: Safer 3 Water Safety Foundation, Staff: Global Outreach Doctors, Jacksonville Beach, FL
DISCLOSURES: JS has acted as a paid medical expert for cases related to emergency medicine and drowning. JS has accepted honoraria of up $1000 to speak at aquatics or EMS conferences on the topic of drowning resuscitation; however, he has engaged in no product endorsement and received no honoraria from device/pharma makers.

Andrew Schmidt, DO, MPH

Assistant Professor
Department of Emergency Medicine, University of Florida College of Medicine - Jacksonville, Medical Director, Jacksonville Beach Ocean Rescue, Deputy Medical Director, Trauma One, Jacksonville, FL
DISCLOSURES: AS declares that he has no competing interests.

// Acknowledgements:

Dr David Szpilman, Dr Justin Sempsrott, and Dr Andrew Schmidt would like to gratefully acknowledge Dr Bhakti K. Patel and Dr D. Kyle Hogarth, previous contributors to this topic. BKP and DKL declare that they have no competing interests.

// Peer Reviewers:

Ajeet G. Vinayak, MD

Assistant Professor of Internal Medicine
Department of Medicine, Division of Pulmonary and Critical Care Medicine, Charlottesville, VA
DISCLOSURES: AGV declares that he has no competing interests.