Drowning and immersion injury

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Abstract

Drowning is a process resulting in primary respiratory impairment from submersion/immersion in a liquid medium. It is a frequent cause of unintentional injury deaths and public health initiatives to prevent drowning are important as there are no specific interventions proven to improve outcomes in drowning victims. Risk factors for drowning include inadequate supervision, recreational or occupational access to water, risk-taking behaviour and underlying medical conditions. Pathophysiological events in the process of drowning are secondary to hypoxaemia that results from the immersion injury. The major determinant of outcome after drowning is the degree of hypoxic neurological insult and subsequent recovery. Management priorities in the drowning victim include rescue from the water and basic life support with an emphasis on rescue breaths. Compression-only cardiopulmonary resuscitation is not recommended in drowning victims. Supportive critical care is directed towards optimizing oxygenation and circulation, and preventing complications. Temperature control is important as hypothermia complicates drowning and may limit the efficacy of resuscitative attempts when severe. Therapeutic hypothermia may be considered in the treatment of unconscious survivors of drowning. Survival rates after cardiac arrest due to drowning are poor, and patients who are unconscious on admission to hospital have a guarded prognosis.

Keywords Drowning; hypothermia; hypoxic encephalopathy; immersion; resuscitation; submersion

Royal College of Anaesthetists CPD matrix: 1B03, 1B04, 2C04, 2F01, 3A10

Learning objectives

After reading this article you should be able to:

- describe the epidemiology and pathophysiology of drowning
- state the management priorities for the drowning victim at the scene and in hospital
- identify the clinical features associated with poor neurological outcome in the drowning victim

Definition

'Drowning is a process resulting in primary respiratory impairment from submersion/immersion in a liquid medium. …The victim may live or die after this process, but whatever the outcome, he or she has been involved in a drowning incident'.[1] Previously used descriptions including near-drowning, wet and dry drowning and secondary drowning are potentially confusing and these terms are no longer recommended.

Epidemiology

Drowning is the third leading cause of unintentional injury deaths worldwide, and in developed countries is responsible for 0.6–1.2 deaths per 100,000 per year.[2] There are up to 4 times as many non-fatal events requiring hospital treatment. The incidence is high in children less than 5 years old, with a second peak in late adolescence and early adulthood. Males are 2–4 times more likely to die from drowning than females. Globally it is estimated that 450,000 people drown annually, with 97% of drownings occur in low- and middle-income countries.[3]

Infants often drown in bathtubs, and non-accidental injury must be considered. Young children commonly drown in swimming pools, while older children and adults tend to drown in rivers, lakes or the ocean during recreational activities such as boating or diving.

Risk factors for drowning include younger age (0–4 years), inability to swim, a lack of pool fencing and inadequate supervision. Conditions increasing the risk of drowning in open water include currents, rips, waves and cold water temperatures. Intoxication with alcohol or drugs contributes to at least 10–30% of drownings particularly in older age groups. Tourists have a higher risk of drowning than locals. Strategies to prevent drowning are listed in Box 1.

Medical conditions associated with an increased risk of drowning include epilepsy, arrhythmias, cardiomyopathies, coronary artery disease, cerebrovascular disease, diabetes mellitus, and depression. Possibly 30% of unexplained drownings may be due to arrhythmias in the context of cardiac channelopathies causing long QT syndrome or catecholaminergic polymorphic ventricular tachycardia.[4]

Factors affecting survival may include age, water temperature, submersion duration, whether the drowning was

Prevention of drowning

Prevention is the best way to reduce the burden of drowning, as there are few effective treatments. It is estimated that up to 80% of drownings are preventable.

Legislation and education are targeted at:

- Mandatory self-closing and locking pool fencing
- Constant supervision of children in the water
- Reducing drug and alcohol consumption around water
- Wearing lifejackets in boats
- Learning to swim
- Swimming in areas patrolled by lifeguards
- Not swimming alone
- Learning cardiopulmonary resuscitation

Box 1

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witnessed, adequacy of cardiopulmonary resuscitation (CPR), time to arrival of the emergency medical services (EMS), and the initial cardiac rhythm upon EMS arrival.[5]

Pathophysiology[3,6,7]

The process of drowning begins with submersion or immersion of the airway in water, leading to breath-holding, panic, swallowing of water, aspiration and laryngospasm. Hypoxia and hypercapnia develop and unconsciousness ensues. Eventually the larynx relaxes, and fluid is aspirated into the lungs resulting in worsening hypoxia and a mixed metabolic and respiratory acidosis. Survivors probably aspirate less than 3–4 ml/kg fluid, which may be contaminated with sand, mud, vomit or other debris. It was previously thought that some victims had persistent laryngospasm resulting in 'dry drowning', but it is now considered more likely that these patients died from an alternative cause prior to submersion. The complex issues of hypothermia in drowning are discussed in below.

Cardiovascular

During drowning there is initially hypertension and tachycardia with activation of the sympathetic nervous system. However, worsening hypoxia, acidosis and hypothermia lead to bradycardia, pulmonary hypertension and decreased cardiac output. Atrial fibrillation and other arrhythmias may occur, ultimately progressing to pulseless electrical activity (PEA) and asystole. In patients with cardiac arrest due to drowning, an initial 'shockable' rhythm (ventricular fibrillation or pulseless ventricular tachycardia) is present in only about 5% of cases.[5]

Respiratory

Several mechanisms contribute to the development of alveolar oedema and acute respiratory distress syndrome (ARDS) occurring in up to 70% of symptomatic survivors of drowning. (see article on Acute Respiratory Distress Syndrome in *Anaesthesia & Intensive Care Medicine* 2013; 14(10): 472–474) These include the aspirated fluid itself, increased capillary permeability, negative pressure and neurogenic pulmonary oedema. Surfactant washout and dysfunction results in atelectasis, and the combined effect is decreased lung compliance, ventilation–perfusion mismatch and intrapulmonary shunting.

Neurological

Hypoxic brain injury is the leading cause of morbidity and mortality in drowning and begins within 5 minutes of inadequate cerebral oxygenation. The clinical spectrum ranges from confusion and disorientation to cerebral oedema with coma, seizures and death.

Fluid and electrolytes

Case reports, post mortem studies and dog experiments suggested that in fresh water drowning, water moves from the alveoli into capillaries, causing haemodilution and hyponatraemia. Conversely, with drowning in seawater, water moves from plasma into the alveoli, exacerbating the pulmonary oedema, and causing hypernatraemia and hypovolaemia. However, in humans who survive drowning, there is no clinically significant difference in volume status, electrolytes or lung function between patients drowning in fresh or salt water.[8] The volume of fluid aspirated is probably insufficient to cause significant volume or electrolyte effects.

Infective complications

Aspirated fluid may be contaminated with a variety of microorganisms, leading to infection in up to 50% of drownings. Aerobic Gram-positive organisms such as *Streptococcus* species and *Staphylococcus aureus* may be aspirated from the oropharynx. Aerobic Gram-negative organisms including *Pseudomonas*, *Aeromonas* and *Burkholderia pseudomallei* may contaminate fresh water, as may *Leptospira*. Fungal infections including delayed central nervous system infections from *Aspergillus* and *Pseudallescheria boydii* may complicate drowning, especially in immunocompromised patients.

Management[3,6,7]

Rescue and resuscitation

Rapid rescue from the water and basic life support at the scene are essential to survival. As cardiac arrest and neurological damage in drowning are due to hypoxia, the priorities in resuscitation are restoring oxygenation, ventilation and perfusion. Five rescue breaths are the first step in the resuscitation of drowning victims in the 2010 European Resuscitation Council Guidelines,[3] a distinction from the resuscitation of other out-of-hospital cardiac arrests. Detection of a pulse may be difficult, and CPR should be performed if the patient is unresponsive and not breathing normally, however 'compression-only CPR' is not appropriate in drowning victims. The risk of cervical spine injury is low,[9] and cervical spine protection is only required where the history or examination is suggestive of a neck injury (e.g. diving into shallow water) or severe trauma.[3]

Emergency department

Systematic physical examination should focus on the respiratory, cardiovascular and neurological systems. Dyspnoea, wheeze and crackles suggest aspiration, while the level of consciousness may have prognostic relevance. Examine for signs of trauma or other medical conditions. Consider decompression illness in scuba divers.

Monitoring should include pulse rate, electrocardiogram (ECG), pulse oximetry (SpO_2), blood pressure, and core temperature. More invasive monitoring such as arterial and central venous pressure monitoring should be considered in the unstable patient. Investigations include an arterial blood gas, full blood count, blood glucose, electrolytes, urea and creatinine, blood alcohol level and toxicology screen, 12-lead ECG and a chest X-ray. Unconscious patients should have a brain CT scan to exclude a primary neurological event or traumatic brain injury and to look for early complications of drowning.

Treatment remains focussed on optimizing oxygenation, cardiac output and temperature control. Supplemental oxygen, non-invasive ventilation or intubation may be required depending on the severity of the respiratory failure and the patient's level of consciousness. Patients may have significant hypovolaemia in the setting of pre-existing dehydration, capillary extravasation and the onset of the systemic inflammatory response syndrome (SIRS). Volume resuscitation and inotropes should be considered in the setting of significant haemodynamic instability. Nasogastric decompression may improve ventilation, haemodynamics and reduce the risk of aspiration.