# 10.3.4 Drowning 1691

# 10.3.4 Drowning 1691

10.3.4 Drowning 1691 Frostbite Human tissues freeze at around –2 °C. Ice forms outside cells but the remaining extracellular fluid becomes hyperosmolar and hence severe intracellular dehydration occurs. This denatures proteins. Vascular endothelial cells are particularly vulnerable, and following rewarming, small blood vessels may leak plasma and then become blocked by red cell sludge and clot. Additional ischaemic necrosis is then superimposed on the frost damage. Frozen tissues appear hard and white and are anaesthetic. Rewarming leads to pain and swelling, often accompanied by blis- tering. Deep-freezing results in irreversible necrosis but appear- ances can be misleading, and early amputation of digits should be avoided. If still frozen, rewarming is best achieved rapidly by using immersion in water at 40–42°C, although any thawing should be avoided if refreezing is likely. Once thawed, treatment is similar to that used for burns with prevention of infection paramount. Generous analgesia is required. FURTHER READING Dexter WW (1990). Hypothermia. Safe and efficient methods of rewarming the patient. Postgrad Med, 88, 55–8, 61–4. Giesbrecht GG (2000). Cold stress, near drowning and accidental hypothermia: a review. Aviat Space Environ Med, 71, 733–52. Granberg PO (1997). Cold injury. In: Chant ADB, Barros D'Sa AAB (eds) Emergency vascular practice, pp. 119–34. Hodder Arnold, London. Hamlet MP (1988). Human cold injuries. In: Pandolf KB, Sawka MN, Gonzalez R (eds) Human performance physiology and environ- mental medicine at terrestrial extremes, pp. 435–66. Benchmark, Indianapolis, IN. Stroud MA (1993). Environmental temperature and physiological function. In: Ulijaszek SJ, Strickland SS (eds) Seasonality and human ecology, pp. 38–53. Cambridge University Press, Cambridge. 10.3.4 Drowning Peter J. Fenner ESSENTIALS Drowning is a major preventable cause of death, most frequently in children and in developing countries. Aspiration (whether of salt or fresh water) is usual in drowning and near-drowning (known as nonfatal, or submersion injury) and leads to cardiac arrest within a few minutes. Death or severe neurological impairment occurs after submersion for more than 5–10 min, but much longer durations may be tolerated in hypothermic conditions. Prevention Precautions include proper supervision of children in recreation areas such as swimming pools, beaches, and river banks, and of young children and epileptics in baths. Personal flotation devices (life jackets) are the best preventive strategy in boating activities. Prevention and rescue efforts of life-savers are effective in swimming pools and on patrolled beaches. Clinical features Prognosis cannot reliably be predicted, but cardiovascular status is a better prognostic indicator than neurological presentation. Patients who are neurologically responsive at the scene of immersion, in sinus rhythm and with reactive pupils, have good outcomes. Those who are asystolic on arrival at hospital and remain comatose for more than 3 h have a poor prognosis unless they are hypothermic. Patients with a normal chest radiograph on admission usually survive. Management The factors that influence outcome are

(1) immediate management— including rapid rescue; laying the victim on their side for assessment of the airway and breathing to assist drainage of any excess water from the airways and lungs; prompt and effective bystander cardiopulmonary resuscitation, using supplemental oxygen if available, preferably with oxygen of highest concentration possible (e.g. bag–valve–mask) and an oropharyngeal airway, endotracheal tube, or laryngeal mask airway in comatose victims (if suitably skilled personnel are present). (2) Hospital management—important elements are (a) ventilatory support to main- tain adequate arterial oxygenation, which may involve the use of extra- corporeal membrane oxygenation and/or cardiopulmonary bypass in refractory cases; (b) colloid resuscitation, (c) recognition and treatment of complications (e.g. secondary pneumonia). Definition Drowning has most recently been defined as 'the process of experi- encing respiratory impairment from submersion/immersion in liquid'. Outcomes of drowning should be classified as death, mor- bidity, and no morbidity. Recent guidelines suggest that the term 'submersion injury' or nonfatal drowning should replace 'near- drowning', although the latter is still commonly used. The lack of a universally agreed standard definition makes it difficult to evaluate the results of studies of drowning and submersion, particularly as drowning remains difficult to diagnose at autopsy. Mortality and morbidity Acute prolonged hypoxia causes haemodynamic effects, cerebral damage, and death. Neurological morbidity in survivors of near- drowning includes difficulties with learning, memory, attention and planning, and cerebral palsy. A large study of childhood immersions has shown that approximately 70% of survivors have no neuro- logical deficit, 30% have some deficit; 3% will live in a permanent vegetative state. Epidemiology The estimated incidence of drowning is 0.5  million per year, making it the fourth most common fatal injury worldwide in the

SECTION 10 Environmental medicine, occupational medicine, and poisoning 1692 global burden of disease. It is the seventh leading cause of death from unintentional injury in all ages and the second leading cause in children aged 1–14 years. Incidences of drowning are highest in children up to 4 years old. In infants and toddlers under 12 months, bathtub and bucket immersions are the highest cause of drowning. Ten per cent (10%) of fatal bucket or tub immersions are attrib- utable to child abuse. Smooth and slippery bathtubs are particu- larly dangerous and bathtub seats are unsafe, particularly if infants are left unattended. Worldwide, drowning rates in young children, many of whom are unsupervised, have decreased little, despite po- tentially effective preventive strategies such as fencing of swimming pools, providing education appropriate to the particular circum- stances, or increased surveillance. Although there are few such pre- ventive strategies for older children, drowning rates have declined dramatically in the last decade. Developing countries have the highest rates of drowning. Thirty- eight per cent (38%) of the world's drownings occur in the Western Pacific region and Africa, where the drowning mortality rate is 13.1 per 100 000 population per year. Children aged 5–14 years suffer the highest mortality rate. Children under the age of 5 years have the highest drowning mortality rate for both sexes. The mother's age and literacy and family income are identified as risk factors. In Bangladesh, drowning has been shown to be a major cause of child- hood mortality: among 1- to 4-year-olds; there are 156 fatal drown- ings/100 000 population per year. Younger males were at greatest risk of drowning in rural areas, mainly in ditches and ponds. In China, estimated drowning mortality rates for all age groups were 29.8/100 000/year for boys and 29.6 for girls. In the United States of America in 2000, more than 1400 children younger than 20 years drowned. It is the seventh leading cause of unintentional injury deaths for all ages, the second leading cause of all deaths from injury in children aged 1–14 years and the third most common cause of fatality in people under 15 years (after car accidents and asphyxia). Many drownings occur during recre- ation in swimming pools, spas, hot tubs, lakes, rivers, or oceans. Approximately 53% of victims needed hospitalization or transfer for more specialized care. Drowning rates were highest among children up to 4 years old. Worldwide, ocean drownings are less common than freshwater drownings, probably because fewer children swim unsupervised in the ocean, and increasing numbers now swim on patrolled beaches in more-developed countries, where prevention and the rescue efforts of life-saving associations have proved effective. Rate of drowning varies with climate, availability of beaches, lakes, and other natural and artificial water sources, provision of life-saving services, improvements in designs and rules for water craft, and the use of life jackets. Rock fishing carries a high risk of drowning and near-drowning. A genetic basis has been suggested for unexplained drowning or near-drowning. Ethnicity White American children aged 1–4 years drown twice as often as African-American children of the same age. These accidents usu- ally happen in residential swimming pools. Conversely, in the age group 5–19 years, African-Americans drown more often than white Americans. Australian aboriginal children drown more often than nonindigenous children. Worldwide, fatal drowning is generally more prevalent in indigenous races than in others. Alcohol Alcohol affects vision, balance, movement, and reasoning and is a major risk factor for drowning in adolescent and adult swimmers, water craft operators, and passengers, who fall overboard while in- toxicated. At the time of rescue, resuscitation, or death, 25–50% of adult and adolescent victims of drowning had some exposure to alcohol. Pathophysiology Aspiration is usual in drowning. Earlier figures had suggested that approximately 10–15% of victims of drowning had not aspirated water but recent figures show an incidence of only 2%. In these cases, death may result from laryngeal spasm and asphyxia during submersion. Early animal studies in anaesthetized dogs showed that spontaneous respiratory efforts continued for around 60 s after im- mersion. Complete cardiac arrest supervenes after 4.5 min (mean 262 s). Recent Chinese bronchoscopic studies in anaesthetized dogs whose lungs were filled with seawater showed that the bronchi fill with bronchoalveolar fluid, causing increasing blood lactate dehydrogenase-L and alkaline phosphatase levels. Electron micros- copy shows injuries to type II alveolar epithelial cells, thickened re- spiratory mucosa, and platelet adherence. Haemodynamic effects following inspiration of liquid are similar. There is a rapid fall in cardiac output, while pulmonary capil- lary wedge pressure, central venous pressure, and pulmonary vas- cular resistance increase. Reduction in the dynamic compliance of the lungs is similar, following inspiration of all types of solutions. However, aspiration of large volumes of hypertonic seawater draws fluid into the lung from the circulation by osmosis, resulting in fluid- filled, nonventilated, but perfused alveoli incapable of normal gas exchange while aspiration. Conversely, aspiration of large amounts of hypotonic freshwater may cause sufficient absorption of fluid into the circulation from the alveoli to cause both acute hypervolaemia and haemolysis. Within 1 h, pulmonary oedema develops, resulting in a decrease in circulating blood volume. Early studies suggested that 85% of human drowning victims aspirated 22 ml/kg of water or less, but it has been estimated that about 10% of body weight of water may be absorbed from the lungs during freshwater drowning. Since the brain has a limited ability to maintain adenosine tri- phosphate levels anaerobically when cerebral blood flow is reduced, it suffers irreparable damage within 4–6 min. Death or severe neuro- logical impairment occurs after submersion of more than 5–10 min. However, in hypothermic conditions, brain activity may be restored after up to 60 min of submersion apnoea. Bystanders’ estimates of submersion time are usually inaccurate. Hypothermia (See Chapter 10.3.3.) A low body temperature generally indicates the severity of the drowning incident. Sudden immersion in ice water causes a reflex cardiorespiratory response, called ‘cold shock’, causing an initial gasp and hyperventilation despite hypocapnia and also hypertension. Continuous aspiration of cold water results in rapid core cooling, while the circulation is intact. Such victims may survive with little or no neurological deficit after long submersion with extreme hypoxia. After submersion for a maximum of 10 min in

 water at 16°C, a good outcome can be predicted in 96.6% of victims. New evidence supports the use of mild hypothermia for periods of 12–24 h in comatose drowned victims. A 6-year-old boy, who presented with a rectal temperature of 16.4°C after a 65-min sub- mersion, survived, apparently neurologically intact when his blood was rewarmed in increments of 3°C over 96 min. However, later neuropsychological testing revealed cognitive difficulties, espe- cially global memory impairment, despite the fact that MRI and magnetoencephalography were normal. In adults, success is less common. A notable exception was a 31-year-old man with a core temperature of 23°C who had been asystolic for 80 min, but was warmed by cardiopulmonary bypass and recovered. Despite discouraging data from animal studies, recent reports suggest that in hypothermic submersion-associated cardiac ar- rest, adrenaline and vasopressin may help to achieve the vaso- pressor response needed to restore spontaneous circulation prior to rewarming. This treatment could obviate prolonged mechanical cardiopulmonary resuscitation, or the use of extracorporeal circula- tion. It has proved effective in restoring spontaneous circulation, but one patient died of multiorgan failure 15 h later. In warm-water drowning there appears to be no statistically significant correlation between duration of submersion and survival. Causes
of drowning Drowning occurs in many different situations: after accidental im- mersion in people with little or no swimming ability, with head and neck injury, following cardiac and neurological emergencies (including epilepsy), as a result of alcohol and drugs, metabolic disease (including hypoglycaemia), and even child abuse and murder. In countries with long coastlines and many bathing beaches, drowning is common and is often caused by swimmers being caught in 'rip currents' (also known as 'rips') (large vol- umes of water returning back out to sea after onshore wave action) (Fig. 10.3.4.1); there is no such entity as the frequently suggested 'undertow'. Swimmers in difficulty may be able to shout for help but, contrary to public opinion, those who are drowning do not. Most drowning victims adopt a characteristic vertical position in the water—legs hanging vertically, head tilted back for quick ex- halation and inhalation before bobbing underwater, with no time or sufficient breath to call for help. After only 20–60 s, victims may submerge permanently. Clinical features Prognostic indicators None of the recent developments in assessment, treatment, or equipment has improved survival rates among submersion victims. Prevention and rapid rescue remain the most effective means of re- ducing the toll. The key to a successful outcome and return to pro- ductive, full life is early bystander cardiopulmonary resuscitation, early and aggressive advanced life support methods (Fig. 10.3.4.2), induced hypothermia when appropriate, careful rewarming, including extracorporal membrane oxygenation, and extracorporal warming where needed. However, up to 25% of drowning victims presenting to the hospital emergency department will die and a further 6% suffer neurological sequelae. The prognosis cannot Fig. 10.3.4.1 Australians swimming in the sea at Petrel Cove near Victor Harbour despite notice warning of rip currents. Courtesy of D A Warrell.

 be predicted from the initial clinical presentation, laboratory, or electrophysiological examinations, but those with a normal chest radiograph on admission usually survive; $Pao_2$ may not relate to radiographic appearances. Although the cause and pathophysio- logical changes of pulmonary insufficiency vary depending on the type and volume of fluid aspirated, serum electrolyte and haemo- globin

concentrations (or haematocrit) do not predict survival. Cardiovascular status This is a better guide to outcome than neurological status. Mortality is high in victims with circulatory arrest on admission, but those in sinus rhythm with reactive pupils, who are neurologically re- sponsive at the scene of immersion, have good outcomes. Those who are asystolic on arrival at hospital and remain comatose for more than 3 h have a poor prognosis unless they are hypothermic. Rapid hypothermia from sudden submersion in cold water (see Chapter 10.3.3) carries a relatively good prognosis, compared to in- sidious hypothermia developed during prolonged submersion that results in cardiac arrest. Neurological status Victims who are alert when medical help arrives have a survival rate approaching 100%, whereas the prognosis in those who are coma- tose with fixed, dilated pupils is poor. Among victims with impaired consciousness, 87% will survive without neurological defects and 2% with minor defects, while 11% will die. Approximately 40–50% of victims who are comatose on arrival have incapacitating brain damage. Those with no spontaneous limb movements and abnormal brain stem function 24 h after the accident have a poor neurological outcome. A modified Glasgow Coma Score is helpful in evaluating neuro- logical injury. A score of 5 or less predicts a mortality risk of over 80%. Pupil reactivity at the time of arrival differentiates survivors from fatalities but could not differentiate between those with minor or incapacitating neurological deficits. Fixed, dilated pupils or total flaccidity are associated with a high mortality. Victims with any motor activity, even posturing or seizures, in the immediate postresuscitation period had a higher incidence of intact survival, but abnormal posturing that persisted or recurred after 12–24 h in- dicated a high probability of severe brain damage. An abnormal CT scan in the initial 36 h following an immersion incident is associated with a dismal prognosis. MRI with qualitative and quantitative MR spectroscopy data may allow a more accurate prognosis. The gravity of the early clinical state, the estimated duration of cardiorespiratory arrest, and the severity of the hypothermia, seiz- ures, and paroxysmal electroencephalogram (EEG) activity do not determine the severity of submersion injury encephalopathy. Early EEG patterns with moderate background activity, sleep patterns, response to auditory and painful stimulations, and numerous β- rhythms suggest a good outcome, whereas bad outcomes are sug- gested by high voltage, rhythmic δ-waves; biphasic sharp waves; monotonous EEG, ‘burst-suppression’ pattern, and absence of β- rhythms. Children who show no spontaneous movements and have abnormal brainstem function 24 h after submersion injury are likely to suffer severe neurological deficits or death. Treatment Victims of submersion injury must be treated immediately for venti- latory insufficiency, hypoxia, and the resulting acidosis. A successful outcome depends on early effective resuscitation at the scene and on competent intensive life support. In-water resuscitation is effective within 5 mins of the shore, or longer, if the victim shows signs of in- creased activity after the initial breaths of the shore. Immediate Laying victims on their side for assessment of the airway and breathing will assist drainage of any excess water from the airways and lungs (Fig. 10.3.4.2). If necessary, on-site cardiopulmonary re- suscitation should be started as soon as possible using supplemental oxygen if available, preferably in the highest concentration (e.g. (a) (b) Fig. 10.3.4.2 (a, b) Cardiopulmonary resuscitation including defibrillation being carried out on the beach by Australian surf
life-savers, in a man who suffered a cardiac arrest while swimming. Courtesy of P J Fenner.

 bag–valve–mask). An oropharyngeal airway, endotracheal tube, or laryngeal mask airway should be inserted in comatose victims, if suitably skilled personnel are present. Pulse oximetry is helpful. Vomiting and regurgitation are significant risks during early resus- citation. Respiratory and cardiopulmonary arrest may occur after an apparently successful rescue, mandating close, uninterrupted monitoring, and the early administration of oxygen to all immersion victims. At the hospital On arrival at the hospital, after a clear airway and cardio-circulatory support have been established, arterial blood gas tensions and pH should be measured. The pH of the blood will indicate whether there is a residual metabolic acidosis after a substantial period of hypoxia. Mechanical ventilation may be necessary with positive end- expiratory pressure, or continuous positive airway pressure to main- tain arterial oxygen pressure above 10 kPa with an inspired oxygen fraction below 0.6. After both freshwater and seawater aspiration, large volumes of intravenous colloid are usually needed while circulating blood volume and cardiac output are estimated. Freshwater aspiration is more likely to cause pulmonary oedema. A central venous catheter or pulmonary artery catheter helps to assess the effective circulating blood volume to guide fluid therapy. Failure of response to intra- vascular replacement with 20 ml/kg of colloid is an indication for starting inotropes. Steroid and prophylactic antibiotic therapy do not appear to increase the chance of survival. Inpatient treatment Extracorporeal membrane oxygenation has been proved to be ef- fective after drowning. Patients with severe hypoxaemia may have irreversible cerebral ischaemia. A  3-year-old drowned girl in re- fractory cardiorespiratory arrest was successfully resuscitated using cardiopulmonary bypass, and then extracorporeal membrane oxy- genation for 4 days. Despite a prolonged period in a vegetative state, she later made an almost complete neurological recovery. If adult respiratory distress syndrome occurs, it is usually within 6 h of admission. There is evidence that alveolar epithelial barrier function is well preserved even after aspiration of large quantities of hypertonic salt water. Surfactant has been used with some suc- cess in refractory respiratory failure in near-drowning, but it is expensive. The risk of secondary pneumonia is high, especially when mech- anical ventilation has been used. Although prophylactic antibiotics are not recommended, broad-spectrum antibiotics may be required. Mild reversible renal impairment is rare. Initial serum creatinine, marked metabolic acidosis, abnormal urinalysis, or significant blood lymphocytosis are markers of impending acute renal failure. Prevention of drowning Swimming pools and natural bodies of water are the greatest risk to young children. Preventive measures include public media educa- tion and campaigns, parental education and supervision, training in cardiopulmonary resuscitation, better safety standards, and safety devices such as the fencing of swimming pools. The number of pool drownings in Brisbane, Australia, decreased after legislation made pool-fencing compulsory. Strategies for the prevention of drowning should also consider hazards in rural areas. Multilingual notices on public beaches are important (Fig. 10.3.4.3) but are often ignored (Fig. 10.3.4.1). Swimming ability and safety skills of young children can be im- proved by training. Education of the public is essential. In Australian surf, only 17% of rescues and resuscitations, up to 95% of them suc- cessful, occurred within patrolled areas, while 55% (62% of them successfully) occurred outside patrolled areas. Resuscitation success rates fell with increasing distance from patrolled areas. Among non- boating drownings in Australia, 4.7% are among overseas tourists, 89% of whom drown in the ocean. An adult should supervise all epileptic children and infants aged under 3 while they are in the bath. Currently, up to 89% of children aged 35 to 59 months and 6% of those younger than 3 years of age are bathed without adult supervision. Drownings associated with boating and personalized water craft can be prevented by using life jackets (personal flotation devices), but as many as 50% of boaters do not use them. Efforts to increase their use should target adolescents, adults, and boating enthusiasts, especially those using motor boats. In Alaska’s commercial fishing industry, specific measures designed to prevent drowning after ves- sels have capsized and sunk have proved successful. In most age groups, more men drown than women. This probably reflects men’s overestimation of their abilities, and perhaps greater alcohol consumption. Middle-aged men dominate the group who die of cardiac events (mostly on the surface) (Fig. 10.3.4.2). Fatalities from breath-holding hypoxia during diving tend to occur in young males. Hyperventilation to increase breath-hold time is a dangerous practice that should be discouraged. Drownings are rare at super- vised water parks, thanks to the large number of lifeguards on duty. Fig. 10.3.4.3 Multilingual talking sign warning of dangers on an Australian beach. Courtesy of P J Fenner.

---

Revision #1
Created 2026-01-22 16:37:12 UTC by Omar Ayman
Updated 2026-01-22 16:37:12 UTC by Omar Ayman