Drowning

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Drowning is defined as respiratory impairment from being in or under a liquid.[1] It is further classified by outcome into: death, ongoing health problems, and no ongoing health problems.[1] Drowning itself is quick and silent, although it may be preceded by distress which is more visible.[2]

Drowning

Vasily Perov: *The drowned*, 1867 painting

Specialty	Critical care medicine

Generally, in the early stages of drowning, very little water enters the lungs: a small amount of water entering the trachea causes a muscular spasm that seals the airway and prevents the passage of both air and water until unconsciousness occurs. This means a person drowning is unable to shout or call for help, or seek attention, as they cannot obtain enough air. The instinctive drowning response is the final set of autonomic reactions in the 20–60 seconds before sinking underwater, and to the untrained eye can look similar to calm safe behavior.[2][3] Lifeguards and other persons trained in rescue learn to recognize drowning people by watching for these movements.[2] If the process is not interrupted, loss of consciousness due to hypoxia is followed rapidly by cardiac arrest. At this stage, the process is still usually reversible by prompt and effective rescue and first aid. Survival rates depend strongly on the duration of immersion.

In 2013, there were about 1.7 million cases of drowning.[4] Unintentional drowning is the third leading cause of unintentional injury resulting in death worldwide. In 2013, it was estimated to have resulted in 368,000 deaths, down from 545,000 deaths in 1990.[5] Of these deaths, 82,000 occurred in children less than five years old.[5] It accounts for 7% of all injury related deaths (excluding those due to natural disasters), with 91% of these deaths occurring in low-income and middle-income countries.[6] Drowning occurs more frequently in males and the young.[7] The rate of drowning in populations around the world varies widely according to their access to water, the climate and the national swimming culture. Most drownings are preventable.

Contents

Terminology

Drowning

Respiratory impairment from being in or under a liquid.[1][8]

Old terminology

There are several terms which were in general use, but are no longer recommended.

Active drowning

People, such as non-swimmers and the exhausted or hypothermic at the surface, who are unable to hold their mouth above water and are suffocating due to lack of air. Instinctively, people in such cases perform well-known behaviors in the last 20–60 seconds before being submerged, representing the body's last efforts to obtain air.[1][8] Notably, such people are unable to call for help, talk, reach for rescue equipment, or alert swimmers even feet away, and they may drown quickly and silently close to other swimmers or safety.[2]

Dry drowning

Drowning in which no water enters the lungs[1][8]

Near drowning

Drowning which is not fatal[1][8]

Wet drowning

Drowning in which water enters the lungs[1][8]

Passive drowning

People who suddenly sink or have sunk due to a change in their circumstances. Examples include people who drown in an accident, or due to sudden loss of consciousness or sudden medical condition.[8]

Secondary drowning

Physiological response to foreign matter in the lungs due to drowning causing extrusion of liquid into the lungs (pulmonary edema) which adversely affects breathing[1][8]

Silent drowning

Drowning without a noticeable external display of distress.[1][9]

Signs and symptoms

Drowning is most often quick and unspectacular. Its media depictions as a loud, violent struggle have much more in common with distressed non-swimmers, who may well drown but have not yet begun to do so. In particular, an asphyxiating person is seldom able to call for help.[2] The instinctive drowning response covers many signs or behaviors associated with drowning or near-drowning:

- Head low in the water, mouth at water level
- Head tilted back with mouth open
- Eyes glassy and empty, unable to focus
- Eyes open, with fear evident on the face
- Hyperventilating or gasping
- Trying to swim in a particular direction but not making headway
- Trying to roll over on the back to float
- Uncontrollable movement of arms and legs, rarely out of the water.

Frank Pia, a lifeguard and researcher of rescue techniques and drowning, notes that drowning begins at the point a person is unable to keep their mouth above water; inhalation of water takes place at a later stage.[10] Most people demonstrating the instinctive drowning response do not show obvious prior evidence of distress.[10]

Cause

Approximately 90% of drownings take place in freshwater (rivers, lakes and swimming pools) and 10% in seawater. Drownings in other fluids are rare, and often relate to industrial accidents. In New Zealand's early colonial history, so many settlers died while trying to cross rivers that drowning was known as "The New Zealand death".[11]

People have drowned in as little as 30 mm of water lying face down.[12] Children have drowned in baths, buckets and toilets; inebriates or those under the influence of drugs have died in puddles.

Drowning can also happen in ways that are less well known:

- Ascent blackout, also called deep water blackout – caused by latent hypoxia during ascent from depth, where the partial pressure of oxygen in the lungs under pressure at the bottom of a deep free-dive is adequate to support consciousness but drops below the blackout threshold as the water pressure decreases on the ascent. It usually strikes upon arriving near the surface as the pressure approaches normal atmospheric pressure.[13]

Children have drowned in buckets and toilets.

- Shallow water blackout – caused by hyperventilation prior to swimming or diving. The primary urge to breathe is triggered by rising carbon dioxide (CO_2) levels in the bloodstream.[14] The body detects CO_2 levels very accurately and relies on this to control breathing.[14] Hyperventilation reduces the carbon dioxide content of the blood but leaves the diver susceptible to sudden loss of consciousness without warning from hypoxia. There is no bodily sensation that warns a diver of an impending blackout, and victims (often capable swimmers swimming under the surface in shallow water) become unconscious and drown quietly without alerting anyone to the fact that there is a problem; they are typically found on the bottom.

- Secondary drowning – Inhaled fluid can act as an irritant inside the lungs. Physiological responses to even small quantities include the extrusion of liquid into the lungs (pulmonary edema) over the following hours, but this reduces the ability to exchange air and can lead to a person "drowning in their own body fluid". Certain poisonous vapors or gases (as for example in chemical warfare), or vomit can have a similar effect. The reaction can take place up to 72 hours after a near drowning incident, and may lead to a serious condition or death.

Risk factors

Populations groups at risk:[15]

- In the US:
  - Children and young adults: Drowning rates are highest for children under 5 years of age and persons 15–24 years of age.
  - Males: Nearly 80% of people who die from drowning are male.
  - Minorities: The fatal unintentional drowning rate for African Americans between 2005 and 2009 was significantly higher than that of whites across all ages. The fatal drowning rate of African American children of ages from 5 to 14 is almost three times that of white children in the same age range, and 5.5 times higher in swimming pools. These disparities might be associated with lack of basic swimming skills in some minority populations.

Behavioral and physical factors:[15][16]

- In the US:
  - Use of alcohol increases the risk of drowning. Among adolescents and adults, alcohol use is involved in almost a quarter of emergency department visits for drowning.
  - Inability to swim: Participation in formal swimming lessons can reduce the risk of drowning among children aged 1 to 4 years.
  - Free access to water: Effective barriers prevent young children from gaining access to the water
  - Ineffective supervision: Drowning can occur anywhere there is water, and even in the presence of lifeguards.
  - Risk can vary with location depending on age. Children between 1 and 4 usually drown in home swimming pools. Drownings in natural water settings increase with age. More than half of drownings among those 15 years and older occurred in natural water environments.
  - Failure to wear life jackets or personal flotation devices was implicated in 88% of the boating related drownings in the US during 2010.
  - For persons with seizure disorders, drowning is the most common cause of death by unintentional

injury, largely in the bathtub.

Pathophysiology

Drowning can be considered as going through four stages:[17]

1. Breath-hold under voluntary control until the urge to breathe due to hypercapnia becomes overwhelming
2. Fluid is aspirated into the airways and/or swallowed
3. Cerebral anoxia stops breathing and aspiration
4. Cerebral injury due to anoxia becomes irreversible

Oxygen deprivation

A conscious person will hold his or her breath (see Apnea) and will try to access air, often resulting in panic, including rapid body movement. This uses up more oxygen in the blood stream and reduces the time to unconsciousness. The person can voluntarily hold his or her breath for some time, but the breathing reflex will increase until the person tries to breathe, even when submerged.[18]

The breathing reflex in the human body is weakly related to the amount of oxygen in the blood but strongly related to the amount of carbon dioxide (see Hypercapnia). During apnea, the oxygen in the body is used by the cells, and excreted as carbon dioxide. Thus, the level of oxygen in the blood decreases, and the level of carbon dioxide increases. Increasing carbon dioxide levels lead to a stronger and stronger breathing reflex, up to the *breath-hold breakpoint*, at which the person can no longer voluntarily hold his or her breath. This typically occurs at an arterial partial pressure of carbon dioxide of 55 mm Hg, but may differ significantly from individual to individual and can be increased through training.

The breath-hold break point can be suppressed or delayed either intentionally or unintentionally. Hyperventilation before any dive, deep or shallow, flushes out carbon dioxide in the blood resulting in a dive commencing with an abnormally low carbon dioxide level; a potentially dangerous condition known as hypocapnia. The level of carbon dioxide in the blood after hyperventilation may then be insufficient to trigger the breathing reflex later in the dive and a blackout may occur without warning and before the diver feels any urgent need to breathe. This can occur at any depth and is common in distance breath-hold divers in swimming pools. Hyperventilation is often used by both deep and distance free-divers to flush out carbon dioxide from the lungs to suppress the breathing reflex for longer. It is important not to mistake this for an attempt to increase the body's oxygen store. The body at rest is fully oxygenated by normal breathing and cannot take on any more. Breath holding in water should always be supervised by a second person, as by hyperventilating, one increases the risk of shallow water blackout because insufficient carbon dioxide levels in the blood fail to trigger the breathing reflex.[19][20]

A continued lack of oxygen in the brain, hypoxia, will quickly render a person unconscious usually around a blood partial pressure of oxygen of 25–30 mmHg.[20] An unconscious person rescued with an airway still sealed from laryngospasm stands a good chance of a full recovery. Artificial respiration is also much more effective without water in the lungs. At this point the person stands a good chance of recovery if attended to within minutes. More than 10% of drownings may involve laryngospasm, but the evidence suggests that it is not

usually effective at preventing water from entering the trachea. The lack of water found in lungs during autopsy does not necessarily mean there was no water at the time of drowning, as small amounts of freshwater are readily absorbed into the bloodstream. Hypercarbia and hypoxia both contribute to laryngeal relaxation, after which the airway is effectively open through the trachea. There is also bronchospasm and mucous production in the bronchi associated with laryngospasm, and these may prevent water entry at terminal relaxation.[21]

The hypoxemia and acidosis caused by asphyxia in drowning affect various organs. There can be central nervous system damage, cardiac arhythmias, pulmonary injury, reperfusion injury, and multiple-organ secondary injury with prolonged tissue hypoxia.[22]

A lack of oxygen or chemical changes in the lungs may cause the heart to stop beating. This cardiac arrest stops the flow of blood and thus stops the transport of oxygen to the brain. Cardiac arrest used to be the traditional point of death but at this point there is still a chance of recovery. The brain cannot survive long without oxygen and the continued lack of oxygen in the blood combined with the cardiac arrest will lead to the deterioration of brain cells causing first brain damage and eventually brain death from which recovery is generally considered impossible. The brain will die after approximately six minutes without oxygen at normal body temperature, but hypothermia of the central nervous system may prolong this.

The extent of central nervous system injury to a large extent determines the survival and long term consequences of drowning, In the case of children, most survivors are found within 2 minutes of immersion, and most fatalities are found after 10 minutes or more.[22]

Water aspiration

If water enters the airways of a conscious person, the person will try to cough up the water or swallow it, often inhaling more water involuntarily. When water enters the larynx or trachea, both conscious and unconscious persons experience laryngospasm, in which the vocal cords constrict, sealing the airway. This prevents water from entering the lungs. Because of this laryngospasm, in the initial phase of drowning, water generally enters the stomach and very little water enters the lungs. Though laryngospasm prevents water from entering the lungs, it also interferes with breathing. In most persons, the laryngospasm relaxes some time after unconsciousness and water can then enter the lungs causing a "wet drowning". However, about 7–10% of people maintain this seal until cardiac arrest.[18] This has been called "dry drowning", as no water enters the lungs. In forensic pathology, water in the lungs indicates that the person was still alive at the point of submersion. Absence of water in the lungs may be either a dry drowning or indicates a death before submersion.[23]

Aspirated water that reaches the alveoli destroys the surfactant, which causes pulmonary oedema and decreased lung compliance which compromises oxygenation in affected parts of the lungs. This is associated with metabolic acidosis, and secondary fluid and electrolyte shifts. During alveolar fluid exchange, diatoms present in the water may pass through the alveolar wall into the capillaries to be carried to internal organs. Presence of these diatoms may be diagnostic of drowning.

Fresh water is hypotonic and hyponatremic relative to blood, so causes osmotic diffusion of water into the blood and sodium to the alveoli leading to hypovolemia and haemodilution with haemolysis, hypnonatremia, and hyperkalemia,[24] The resulting elevation of plasma K+ (potassium) level and depression of Na+ (sodium) level

alter the electrical activity of the heart, which can cause ventricular fibrillation. In animal experiments this effect was shown to be capable of causing cardiac arrest in 2 to 3 minutes. Acute renal failure can also result from hemoglobin from the burst blood cells accumulating in the kidneys, and cardiac arrest can also result if cold fresh water taken into the bloodstream sufficiently cools the heart.

Sea water is hypertonic relative to blood, so water diffuses from blood into the water in the alveoli, and the electrolytes diffuse into the blood, leading to hypovolemia, haemoconcentration and hypernatremia. The laboratory blood tests may show these shifts, which may be diagnostically useful.[24] In animal experiments the thicker blood requires more work from the heart leading to cardiac arrest in 8 to 10 minutes.

Autopsies on drowned persons show no indications of these effects and there appears to be little difference between drownings in salt water and fresh water. After death, rigor mortis will set in and remains for about two days, depending on many factors, including water temperature.

Cold water immersion

Submerging the face in water cooler than about 21 °C (70 °F) triggers the diving reflex, common to air-breathing vertebrates, especially marine mammals such as whales and seals. This reflex protects the body by putting it into *energy saving* mode to maximize the time it can stay under water. The strength of this reflex is greater in colder water and has three principal effects:

- *Bradycardia*, a slowing of the heart rate by up to 50% in humans.
- *Peripheral vasoconstriction*, the restriction of the blood flow to the extremities to increase the blood and oxygen supply to the vital organs, especially the brain.
- *Blood Shift*, the shifting of blood to the thoracic cavity, the region of the chest between the diaphragm and the neck, to avoid the collapse of the lungs under higher pressure during deeper dives.

The reflex action is automatic and allows both a conscious and an unconscious person to survive longer without oxygen under water than in a comparable situation on dry land. The exact mechanism for this effect has been debated and may be a result of brain cooling similar to the protective effects seen in patients treated with deep hypothermia.[25][26]

The actual cause of death in cold or very cold water is usually lethal bodily reactions to increased heat loss and to freezing water, rather than any loss of core body temperature. Of those who die after plunging into freezing seas, around 20% die within 2 minutes from cold shock (uncontrolled rapid breathing and gasping causing water inhalation, massive increase in blood pressure and cardiac strain leading to cardiac arrest, and panic), another 50% die within 15 – 30 minutes from cold incapacitation (loss of use and control of limbs and hands for swimming or gripping, as the body 'protectively' shuts down the peripheral muscles of the limbs to protect its core),[27] and exhaustion and unconsciousness cause drowning, claiming the rest within a similar time.[28] A notable example of this occurred during the sinking of the *Titanic*, in which most people who entered the –2 °C (28 °F) water died within 15–30 minutes.[29]

> [S]omething that almost no one in the maritime industry understands. That includes mariners [and] even many (most) rescue professionals: It is impossible to die from hypothermia in cold water unless you are wearing flotation, because without flotation – you won't live long enough to become hypothermic.
>
> — Mario Vittone, lecturer and author in water rescue and survival[27]

Heat transfers very well into water, and body heat is therefore lost extremely quickly in water compared to air,[30] even in merely 'cool' swimming waters around 70F (~20C).[28] A water temperature of 10 °C (50 °F) can lead to death in as little as one hour, and water temperatures hovering at freezing can lead to death in as little as 15 minutes.[28] This is because cold water can have other lethal effects on the body, so hypothermia is not usually a reason for drowning or the clinical cause of death for those who drown in cold water.

Hypothermia (and also cardiac arrest) present a risk for *survivors* of immersion, as for survivors of exposure; in particular the risk increases if the survivor, feeling well again, tries to get up and move, not realizing their core body temperature is still very low and will take a long time to recover.

Most victims of cold-water drowning do not develop hypothermia quickly enough to decrease cerebral metabolism before ischemia and irreversible hypoxia occur. The neuroprotective effects appear to require water temperatures below about 5 °C.[31]

Diagnosis

The World Health Organization in 2005 defined drowning as "the process of experiencing respiratory impairment from submersion/immersion in liquid".[1] This definition does not imply death, or even the necessity for medical treatment after removal of the cause, nor that any fluid enters the lungs. The WHO further recommended that outcomes should be classified as: death, morbidity, and no morbidity.[1] There was also consensus that the terms wet, dry, active, passive, silent, and secondary drowning should no longer be used.[1]

Experts differentiate between distress and drowning.

- Distress – people *in trouble*, but who still have the ability to keep afloat, signal for help and take actions.
- Drowning – people *suffocating* and in *imminent danger of death within seconds*.

Management

Prevention

Water safety

Most drowning is preventable. It has been estimated that more than 85% of drownings could have been prevented by supervision, training in water skills, technology, regulation and public education.[8]

Surveillance

Many pools and designated bathing areas either have lifeguards, a pool safety camera system for local or remote monitoring, or computer-aided drowning detection. However, bystanders play an important role in drowning detection and either intervention or the notification of authorities by phone or alarm.

The acronym *RID* was originated by Frank Pia to summarize important reasons why lifeguards may be unaware of a drowning. The term stands for "failure to recognize the struggle, the intrusion of non-lifeguard duties upon lifeguards' primary task-preventive lifeguarding, and the distraction from surveillance duties".[32] In his paper on the RID factors,[32] Pia makes a number of observations on the role, and the required behavior and training of lifeguards, as well as the importance of administrators directing lifeguards to this role and avoiding double tasking them (due to the very brief time of 20 – 60 seconds required for drowning to occur). He ended by summarizing the role of lifeguards as guardians of life, and that they should be directed exclusively to this duty and none other, while on surveillance, due to the high value placed on human life.

Buddy system/safety divers

Rescue

Many people who are drowning manage to save themselves, or are assisted by bystanders or professional rescuers. Less than 6% of people rescued by lifeguards need medical attention, and only 0.5% need CPR. The statistics are not as good for rescue by bystanders, but even there, a minority require CPR.

Rescue involves bringing the person's mouth and nose above the water surface. A drowning person may cling to the rescuer and try to pull himself out of the water, submerging the rescuer in the process. Rescuers should avoid endangering themselves unnecessarily and where possible should provide assistance from a safe position, such as a boat, or by providing flotation or a means of towing from a distance.[8]

Where it is necessary to approach a panicking person in deep water, it is advised that the rescuer approach with a buoyant object, or from behind, twisting the person's arm on the back to restrict movement. If the rescuer does get pushed under water, they can dive downwards to escape.

After a successful approach, negatively buoyant objects such as a weight belt are removed. The priority is then to transport the person to the water's edge in preparation for removal from the water. The person is turned on their back with a secure grip used to tow from behind. If the person is cooperative they may be towed in a similar fashion held at the armpits. If the person is unconscious they may be pulled in a similar fashion held at the chin and cheeks, ensuring that the mouth and nose are well above the water.

Rescue, and where necessary, resuscitation, should be started as early as possible for best results. If conscious, the person should be taken out of the water as soon as possible. In-water resuscitation may increase the chances of a favourable result by a factor of about three, if there will be any delay in getting the person out of the water, but the necessary skills require training. Only rescue ventilation is practicable in the water, chest compressions require a suitable platform, so in-water assessment of circulation is pointless. If the person does not respond after a few breaths, cardiac arrest may be assumed, and getting them out of the water becomes the priority.[8]

Special care has to be taken for people with suspected spinal injuries, and a back board (spinal board) may be needed for the rescue. In water, CPR is ineffective, and the goal should be to bring the person to a stable ground quickly and then to start CPR.[33]

First aid

The checks for responsiveness and breathing are carried out with the person horizontally supine. If unconscious but breathing, the recovery position is appropriate. If not breathing, rescue ventilation is necessary. Drowning can produce a gasping pattern of apnea while the heart is still beating, and ventilation alone may be sufficient, as the heart may be basically healthy, but hypoxic. The airway-breathing-circulation (ABC) sequence should be followed, rather than starting with compressions as is typical in cardiac arrest,[34] as the basic problem is lack of oxygen. Five initial breaths are recommended, as the initial ventilation may be difficult because of water in the airways which can interfere with effective alveolar inflation. Thereafter a sequence of two breaths and 30 chest compressions is recommended, repeated until vital signs are re-established, the rescuers are unable to continue, or advanced life support is available.[8]

Attempts to actively expel water from the airway by abdominal thrusts, Heimlich maneuver or positioning head downwards should be avoided as there is no obstruction by solids, and they delay the start of ventilation and increase the risk of vomiting, with a significantly increased risk of death, as aspiration of stomach contents is a common complication of resuscitation efforts.[8][35]

Treatment for hypothermia may also be necessary. Because of the diving reflex, people submerged in cold water and apparently drowned may revive after a relatively long period of immersion.[36] Rescuers retrieving a child from water significantly below body temperature should attempt resuscitation even after protracted immersion.[36]

Advanced pre-hospital care

Administration of oxygen at 15 litres per minute by face mask or bag valve mask is often sufficient, but tracheal intubation with mechanical ventilation may be necessary. Suctioning of pulmonary oedema fluid should be balanced against the need for oxygenation. The target of ventilation is to achieve 92% to 96% arterial saturation and adequate chest rise. Positive end-expiratory pressure will generally improve oxygenation. Drug administration via peripheral veins is preferred over endotracheal administration. Hypotension remaining after oxygenation may be treated by rapid crystalloid infusion.[8] Cardiac arrest in drowning usually presents as asystole or pulseless electrical activity. Ventricular fibrillation is more likely to be associated with complications of pre-existing coronary artery disease, severe hypothermia, or the use of epinephrine or norepinephrine.[8]

Prognosis

Drowning victims who arrive at a hospital with spontaneous circulation and breathing usually recover with good outcomes.[36] Early provision of basic and advanced life support improve probability of positive outcome.[8]

Longer duration of submersion is associated with lower probability of survival and higher probability of permanent neurological damage.[36]

Duration of submersion	Risk of death or severe long term neurological impairment[8]
0–5 min	10%
6–10 min	56%
11–25 min	88%
>25 min	nearly 100%
Signs of brain-stem injury predict death or severe neurological consequences	

Contaminants in the water can cause bronchospasm and impaired gas exchange, and can cause secondary infection with delayed severe respiratory compromise.[36]

Low water temperature can cause ventricular fibrillation, but hypothermia during immersion can also slow the metabolism, allowing a longer hypoxia before severe damage occurs.[36] Hypothermia which reduces brain temperature significantly can improve outcome. A reduction of brain temperature by 10 °C decreases ATP consumption by approximately 50%, which can double the time that the brain can survive.[8]

The younger the victim, the better the chances of survival.[36] In one case, a child submerged in cold (37 °F (3 °C)) water for 66 minutes was resuscitated without apparent neurological damage.[36] However, over the long term significant deficits were noted, including a range of cognitive difficulties, particularly general memory impairment, although recent magnetic resonance imaging (MRI) and magnetoencephalography (MEG) were within normal range.[37]

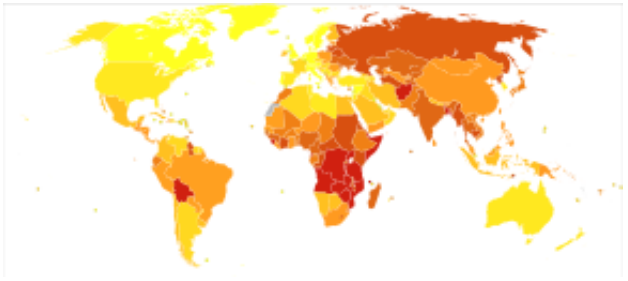
Children

Drowning is a major worldwide cause of death and injury in children. Long term neurological outcomes of drowning cannot be predicted accurately during the early stages of treatment and although survival after long submersion times, mostly by young children, has been reported, many survivors will remain severely and permanently neurologically compromised after much shorter submersion times. Factors affecting probability of long term recovery with mild deficits or full function in young children include the duration of submersion, whether advanced life support was needed at the accident site, the duration of cardiopulmonary resuscitation, and whether spontaneous breathing and circulation are present on arrival at the emergency room.[38]

Data on long-term outcome are scarce and unreliable. Neurological examination at the time of discharge from hospital does not accurately predict long term outcomes. Some victims who suffered from severe brain injury and were transferred to other institutions died months or years after the drowning and are recorded as survivors. Non-fatal drownings have been estimated as two to four times more frequent than fatal drownings.[38]

Epidemiology

In 2013 drowning was estimated to have resulted in 368,000 deaths down from 545,000 deaths in 1990.[5] with more than 20 times that many non-fatal incidents.[40] It the third leading cause of death from unintentional trauma after traffic injuries and falls.[41]



Drowning deaths per million persons in 2012

- 0-8
- 9-14
- 15-21
- 22-25
- 26-36
- 37-53
- 54-63
- 64-79
- 80-103
- 104-182

In many countries, drowning is one of the leading causes of death for children under 12 years old. In the United States in 2006, 1100 people under 20 years of age died from drowning.[42] Typically the United Kingdom suffers 450 drownings per year or 1 per 150,000 of population whereas the United States suffers 6,500 drownings or around 1 per 50,000 of population. In Asia, according to a study by The Alliance for Safe Children, suffocation and drowning were the most easily preventable causes of death for children under five years of age;[43][44] a 2008 report by the organization found that in Bangladesh, for instance, 46 children drown each day.[45]

Males are more likely to be overconfident of swimming abilities and to take risks and are 4 times more likely to have submersion injuries.[40]

In the fishing industry the largest group of drownings is associated with vessel disasters in bad weather, followed by man-overboard incidents, and boarding accidents at night, in foreign ports, or under the influence of alcohol.[40] Scuba diving deaths are estimated at 700 to 800 per year, associated with inadequate training and experience, exhaustion, panic, carelessness and barotrauma.[40]

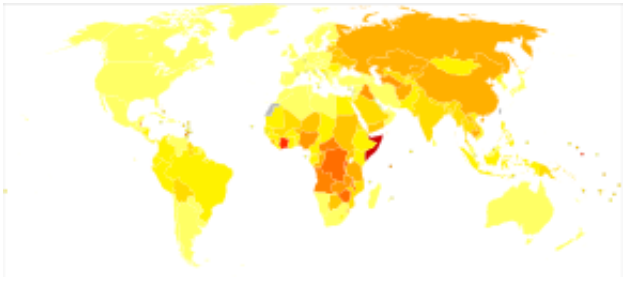
United States

In the United States, it is the second leading cause of death (after motor vehicle crashes) in children 12 and younger.[7]

People who drown are more likely to be male, young or adolescent.[7] Surveys indicate that 10% of children under 5 have experienced a situation with a high risk of drowning. Worldwide, about 175,000 children die through drowning every year.[46] The causes of drowning cases in the US from 1999 to 2006 are as follows:[47]

31.0% Drowning and submersion while in natural water
27.9% Unspecified drowning and submersion
14.5% Drowning and submersion while in swimming pool
9.4% Drowning and submersion while in bathtub
7.2% Drowning and submersion following fall into natural water

6.3% Other specified drowning and submersion
2.9% Drowning and submersion following fall into swimming p
0.9% Drowning and submersion following fall into bathtub



Disability-adjusted life year for drowning per 100,000 inhabitants in 2004.[39]

- no data
- < 100
- 100–150
- 150–200
- 200–250
- 250–300
- 300–350
- 350–400
- 400–450
- 450–500
- 500–600
- 600–700
- > 700

Forensic pathology

Forensic diagnosis of drowning is considered one of the most difficult in forensic medicine. External examination and autopsy findings are often non-specific, and the available laboratory tests are often inconclusive or controversial. The purpose of investigation is generally to distinguish whether the death was due to immersion, or whether the body was immersed post mortem. The mechanism in acute drowning is hypoxemia and irreversible cerebral anoxia due to submersion in liquid.[24]

Drowning would be considered as a possible cause of death when the body was recovered from a body of water, or in close proximity to a fluid which could plausibly have caused drowning, or when found with the head immersed in a fluid. A medical diagnosis of death by drowning is generally based on excluding all other possible causes of death by means of a complete autopsy and toxicology tests. Indications of drowning are seldom completely unambiguous, and may include bloody froth in the airway, water in the stomach, cerebral oedema and petrous or mastoid haemorrhage. Some evidence of immersion may be unrelated to the cause of death, and lacerations and abrasions may have occurred before or after immersion or death.[17]

Diatoms should normally never be present in human tissue unless water was aspirated, and their presence in tissues such as bone marrow suggests drowning, but they are present in soil and the atmosphere and samples may easily be contaminated. An absence of diatoms does not rule out drowning as they are not always present in water.[17] A match of diatom shells to those found in the water may provide supporting evidence of the place of death.[24] Drowning in salt water can leave significantly different concentrations of sodium and chloride ions in the left and right chambers of the heart, but this will dissipate if the person survived for some time after the aspiration or CPR was attempted,[17] and have been described in other causes of death.[24]

Most autopsy findings relate to asphyxia and are not specific to drowning. The signs of drowning are degraded by decomposition. Large amounts of froth will be present around the mouth and nostrils and in the upper and lower airways in freshly drowned bodies. The volume of froth is generally much greater in drowning than from other origins. Lung density may be higher than normal but normal weights are possible after cardiac arrest reflex or vaso-vagal reflex. The lungs may be over inflated and waterlogged, filling the thoracic cavity, and the surface may have a marbled appearance, with darker areas associated with collapsed alveoli interspersed with

paler aerated areas. Fluid trapped in the lower airways may block the passive collapse that is normal after death. Haemorrhagic bullae of emphysema may be found. These are related to rupture of alveolar walls. These signs are suggestive of drowning, but not conclusive.[24]

Capital punishment

In Europe, drowning was used as capital punishment. During the Middle Ages, a sentence of death was read using the words "*cum fossa et furca*", or "with pit and gallows".[48]

Drowning survived as a method of execution in Europe until the 17th and 18th centuries.[49] England had abolished the practice by 1623, Scotland by 1685, Switzerland in 1652, Austria in 1776, Iceland in 1777, and Russia by the beginning of the 1800s. France revived the practice during the French Revolution (1789–1799) and was carried out by Jean-Baptiste Carrier at Nantes.[50]

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External links

Classification • Canadian	**ICD-10**: T75.1 (http://apps.who.int/classifications/icd10/browse/2016/en#/T75.1) · **ICD-9-CM**: 994.1 V · T · D (http://www.icd9data.com/getICD9Code.ashx?icd9=994.1) · **DiseasesDB**: 3957 (http://www.diseasesdatabase.com/ddb3957.htm)
External resources	**MedlinePlus**: 000046 (https://www.nlm.nih.gov/medlineplus/ency/article/000046.htm) · **eMedicine**: emerg/744 (http://www.emedicine.com/emerg/topic744.htm)

Red Cross: Drowning Research: Drownings in Canada, 10 Years of Research Module 2 – Ice & Cold

Water Immersion (http://www.redcross.ca/cmslib/general/ws_final_m2_english2006_04_19.pdf)

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