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Drowning

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Contents

INTRODUCTION

Despite the vast improvement in understanding the pathophysiology and treatment of drowning over the last decades, it still represents a significant preventable public health issue[1, 2]. Obstacles include limited resources to respond to drowning incidents and delay in recognition due to some victims not indicating their need for assistance[3]

Humanity loses about half a million people to drowning each year[4], around half of these are children[5], and many of the other half are healthy young people[6].

Ninety-seven percent of these deaths occur in the low and middle income countries[7], which makes drowning the second cause of unnatural death after road traffic accidents in these countries[6].

Africa has the highest rate of drowning in the world. Although there are no consistent data for South Africa, some preliminary information from Lifesaving SA suggest similar trends to that of the United States of America with approximately 4000 deaths, 8000 hospitalizations, and 31000 emergency department visits per annum[3]. And only 1 in 4 incidents are reported[3].

Classification

Drowning is classified into 4 categories[6]

1. No evidence of inhalation of water

2. Evidence of inhalation of water and adequate ventilation

3. Evidence of inhalation of water and inadequate ventilation

4. Absent ventilation and circulation

Drowning outcomes may be classified as[3]:

- Drowning with mortality

- Drowning with morbidity

- Drowning without morbidity

Risk factors

The incidence in children aged 0-4 years is high, especially if they have been left with insufficient attention, or if in-house pools have no gates around them[7].

In adults, some conditions such as the inability to swim or background medical problems may predispose them to the risk of drowning[1]. Interestingly, tourists have shown increased risk of drowning compared to locals[7]. Male gender increases the risk 2 to 4 times when compared to females[7].

An estimated 30 % of unexplained drownings is thought to be caused by arrhythmias[7].

Table 1 below shows different risk factors for drowning, accompanied by some examples.

Neurological problems	**Cardiovascular problems**	**Trauma**	**Bad behaviors**	**Decreased awareness**
CVA Syncope Fits	Myocardial infarction Arrhythmias	Cervical injury Head injury	Homicide Suicide Child abuse	Alcohol Drugs Hypothermia

Table *1*: Risk Factors for Drowning [6]

Terminology

For the purpose of facilitation of communication, and to increase the co-ordination and consistency between different medical bodies; the **Utstein template** for categorizing drowning was adopted[4].

In 2002, The World Health Organization (WHO) defined *drowning* as: **The process of experiencing respiratory impairment from submersion/immersion in liquid[4].**

Submersion is when the person’s airway goes below the liquid.

Immersion is when the liquid splashes over the face[4].

The definition of *near drowning* as **survival of a patient for longer than 24 hours following submersion**, was questioned, because of some of these patients die later[7]– quoted by some authors as up to 25%[5].

The term *near-drowning* used to describe survivors was eventually abandoned in 2002 by the World Congress on Drowning[6]. The congress has also abandoned the term *dry drowning* which was thought to occur after profound hypoxia from laryngospasm or vagally mediated cardiac arrest[6]. In a large review of postmortem findings, death from drowning without liquid aspiration was rarely found[6]. Victims with dry lungs on autopsy were thought to have died from natural causes or trauma prior to airway submersion. [6] [6] [6]

Despite lab results in distinguishing between salt water and fresh water drowning, this did not formalize any importance in terms of pathophysiology or management of drowning[8].

The **Ustein template** considers the following as outdated idioms and advocates avoiding them[4, 8].

- Salt water drowning
- Fresh water drowning
- Wet drowning
- Dry drowning
- Active drowning
- Passive drowning or secondary drowning

Pathophysiology

Unless the victim is hypothermic, or the drowning happens in ice water, the full drowning process only takes seconds to minutes to progress to cardiac arrest[4, 9].

To be simplified, the drowning process can be divided into 4 stages:

1. **Breath holding**

When the submersion/immersion covers the victim's airway, the victim cannot breathe anymore. Consequently, he/she holds their breath deliberately [1, 5-7]. In children, this may be accompanied by the diving reflex – intense peripheral vasoconstriction and bradycardia[5].

2. **Laryngospasm**

Some liquid finds its way to the victim's airway, irritates the airway and leads to development of involuntary laryngospasm[1, 6, 7].

> **laryngospasm**: is a forceful involuntary spasm of the laryngeal muscles caused by sensory stimulation of the superior laryngeal nerve[10]

3. **Break of the spasm**

The victim, despite their active respiratory efforts, is unable to inhale or exhale any gas, which leads to hypoxemia, hypercapnia and acidosis. Eventually the consciousness level drops and the relaxation of laryngeal muscles occurs[1, 6].

4. **Aspiration**

Once the airway is open, the liquid gets into the patient's airway[6], and might be accompanied by vomitus, mud or sand[4, 11].

The effects of the aspirate on the lungs may vary according to the amount, content and duration of the aspiration[1].

Hypoxia is the main single factor leading to death; hypercapnia and acidosis are secondary factors [3]. The initial hypoxemia is caused by apnea. Thereafter, hypoxemia is due to the ventilation-perfusion mismatch caused by the aspiration[11].

Hypothermia can be a protective factor, giving the victim a better chance of survival[1]. It decreases the consumption of oxygen in the brain, which slows the rate of cellular anoxia and ATP depletion. It decreases the electrical and metabolic brain activities[4].

> The oxygen consumption decreases by around 5% for every 1 Celsius degree drop of temperature, in a range of 37° to 20° C(4)

Effects Of Drowning On Different Body Systems

Cardiovascular system

The initial tachycardia and the rise in blood pressure that develop due to sympathetic nervous system stimulation changes to bradycardia and hypotension as a result of hypoxia and acidosis [4, 7, 9].

The most common rhythm in the arrested drowning victims was found to be unshockable – asystole or electromechanical dissociation. Ventricular tachycardia and ventricular fibrillation represents only about 5% of arrested victims[7, 12].

ECG changes include bradycardia, complete heart block, and appearance of a J wave[5].

Hypovolaemic shock can occur due to systemic and pulmonary extravasation of fluid or cold diuresis. Following resuscitation, a SIRS response with vasodilatation may occur[5].

Respiratory system

As mentioned above, aspiration has harmful consequences in the lungs. It may wash out surfactant leading to atelectasis, or increase the permeability of the alveolar capillary membrane leading to pulmonary edema[6]. Secondarily, the lung suffers a significant ventilation perfusion mismatch and decreased lung compliance[6].

Radiographic changes in survivors include three patterns[11]:

1. Normal chest x-ray
2. Peri-hilar pulmonary edema
3. Diffuse bilateral pulmonary edema

Blood gas interpretation may be complicated, as hypothermia causes increase solubility of oxygen and carbon dioxide and significant hypoxaemia may be missed. P_aCO_2 and pH should be corrected to normothermia to guide interventions[5].

In the majority of survivors, the lung abnormalities resolve within 3-5 days. If infiltrates persist, then the acute respiratory distress syndrome or a superimposed chest infection could be the cause[11]. Pneumonitis may occur from aspiration of chlorinated swimming pool water or vomitus[5]. Sand aspiration has been documented in some cases. It can be seen as a radio-dense material in either the chest x-ray or the chest computerized tomography[11].

Management of the hypoxia requires oxygen and may require lung-protective ventilation. If neurological injury is present, permissive hypercapnia may be contra-indicated[5].

Haemoglobin, electrolytes and volume status

Early animal experimental studies found that drowning in fresh water results in haemolysis, haemodilution and hyponatremia. In comparison, postmortem examinations of the animals drowned in salt water, showed pulmonary edema, increase in sodium levels and hypovolemia[7].

In humans, unless the drowning occurred in the Dead Sea where the water is highly concentrated[1, 13], survivors of drowning are unlikely to get significant differences in electrolyte and fluid status, or respiratory dysfunction; if drowning occurred in either fresh or salty water[7]. This is probably because the amount of the liquid aspirated in the survivor's lungs is less than that required to induce such differences[7].

The aspiration of both kinds of water (despite being different in osmotic gradient effect), results in disruption of the alveolar capillary membrane, which leads to enhancement of fluid and plasma shifts by raising the membrane permeability[4].

Central nervous system

The main reason for the morbidity and mortality in drowning is the hypoxic brain insult[7], which may lead to cerebral oedema and cell death[6]. This injury happens within 4.10 minutes in the hippocampus, basal ganglia and cerebral cortex[11]. The injury varies from simple confusion or disorientation to serious convulsions, coma or death; according to the duration and level of hypoxia[7].

Renal system

Hypoxaemia, myoglobinaemia and hypoperfusion are believed to be mechanisms for the renal failure that may happen after drowning[4, 6].

Treatment

Pre hospital resuscitation

Ensure the urgency in removing the patient from water, but without endangering yourself. Throwing a rope or life jacket to the awake patient is reasonable. Call for help[3, 4, 8, 12]. Do not attempt in-water resuscitation unless you are well trained[3, 4, 8]. Chest compression in deep water is not advised[3, 4].

Spinal injury incidence is rare, unless the suspicion is high – such as rocky beach or shallow water[4]. The delay in taking the patient out of the water for stabilization of the spine is poorly justified [2, 4, 6, 7, 12].

Once the patient is out of water, check the patient's response and breathing and follow the basic life support in the traditional ABC order as immediate priorities are airway management, oxygenation and ventilation[3, 4, 6]. Clear the airway and provide 5 rescue mouth-to-mouth breaths if no ventilation equipment is available[6]. Dry the patient and remove wet clothes[3, 5]. If available, place AED pads if on dry areas[12]. Compression-only-CPR is not appropriate in drowning victims[7].

If available, collateral history may give clues regarding possible medical reasons for the drowning[12]. The earlier the CPR the better the chances of survival, if other factors are neutralized[6, 12].

Severely hypotensive patients may not respond to defibrillation. In these cases, focus should be on effective chest compressions and rewarming[3]. Arrange transfer to the nearest hospital[5]. Continue CPR in the supine position, or put the patient in the lateral position to avoid aspiration if CPR is no longer required[12]. Vascular access is not usually indicated in the field[3].

In hospital resuscitation

Evaluate the airway breathing and circulation[4, 5].

Apply 100 oxygen via non-rebreather mask or non-invasive positive pressure ventilation if Glasgow Coma Scale is greater than 8[7, 12]. An arterial blood gas may be useful to determine if the need for oxygen and/or ventilation[3]. Intubation might be necessary in the arrested or low consciousness level patients, or those who are still hypoxic despite the non-invasive methods of oxygenation[7].

Rewarm the patient[6], and provide intravenous fluids[7]. Empty the stomach using a naso-gastric tube[4].

Restoration of normal body temperature is an important part of initial management. As mentioned earlier, defibrillation attempts in a hypothermic patient may be unsuccessful [5].

Passive	Warm environment > 30 Celsius Rewarm wet clothing Insulating cover
Active, External	Conduction methods, eg. warmed pads Convection methods, eg. forced air warming blanket Radiant methods, eg. radiant heater Secondary decrease in core temperature may occur due to peripheral vasodilation
Active, Internal	Humidified warm inspired gases Warmed IV fluids Body cavity lavage, eg. bladder, peritoneal, gastric Intravascular thermal regulation system Extracorporeal methods: - Hemodialysis - Cardiopulmonary bypass

Different methods of rewarming are listed in table 2 below. Even with rewarming, restoration of the myocardium to a defibrillatable temperature may not be achieved[5].

Table *2*: Rewarming Methods [6]

Initial chest x-ray[3], empirical antibiotics[3], and steroid treatment[6, 8] are not recommended. Antibiotics should only be considered in situations with persistent fever and increased sputum production(3).

Procalcitonin measurements may help make the decision on whether to commence antibiotics[3]. Routine electrolyte examination in the drowning patient has not been shown to have any added value[8].

Patients can be observed in the emergency department for 6 hours[8].

Indications for admission include[4, 5]:

- Low blood pressure
- Low consciousness level or confusion
- Hypoxia
- Abnormal respiratory sounds
- Severe cough
- Signs of pulmonary edema

In patients with prolonged cardiac arrest, a decision will need to be made regarding continuation of resuscitation. Clinical features associated with death or poor neurological outcome, depicted in table 3 below, may assist in decision making[3].

Multiple clinical features can predict death or poor outcome, also shown in table 3[7].

Clinical features of drowning associated with death or poor neurological outcome[3]
Submersion greater than 5-10 minutes
Resuscitation not attempted for more than 10 minutes after rescue
More than 25 minutes of resuscitation
Glasgow Coma Score less than 5 or unreactive pupils on arrival to hospital
Pulseless and apneic on arrival to hospital
pH < 7.10 on initial arterial blood gas

Table *3*

If the patient remains unconscious after resuscitation, therapeutic temperature management with targets of 32 – 34°C for 12 – 24 hours has been suggested to improve neurological outcomes[4-6]. However, the literature about therapeutic temperature management is still unclear[3].

Prevention of secondary brain injury (ie. 30˚head up tilt, low normocapnia, maintenance of cerebral perfusion pressure greater than 70mmHg, glucose and seizure control) should be undertaken[5].

Methods such as artificial surfactant, inhaled nitric oxide, and partial liquid ventilation for treating the pulmonary pathology require further investigation before being recommended practice[4].

Table 4 shows factors that determine surviving the drowning[(5)].

Victim age
Liquid temperature
Duration in liquid
Witnessed/unwitnessed drowning
Quality ofCPR
Time to resuscitation start
Rhythm at resuscitation start

Table 4: Survival Determinants[(5)]

Prediction of outcomes can be assisted by using prognostic tools. Hypoxia is the main predictor of outcome. Submersion time has an exponential negative relationship with survival. Mortality in patients surviving to hospital can still be greater than 93%(3). Thirty percent of survivors may have adverse neurological outcomes[(7)].

The Orlowski Score (Table 5) can be used in paediatric patients to determine prognosis[(3)].

Predictions Of Mortality In Paediatric Drowning	
Prognostic factor	Orlowski score
Age >3 years Estimated maximum submersion time > 5 minutes No attempts at resuscitation for >10 minutes after rescue Comatose on arrival in emergency department Arterial blood gas ≤ 7.10	1 point awarded for each unfavorable prognostic factor. Score of ≤ 2= 90% chance of recovery. Score of ≥3 = 5% chance of recovery

Table 5: The Orlowski score[(3)]

Prevention

Since drowning is associated with poor outcomes[3], with no specific interventions proven to improve outcomes[7], much focus should be placed on preventative strategies[3]. Up to 80% of drowning incidents are thought to be preventable[7].

Suggested strategies include:

- Protection of children by encouraging the use of fences and gates to encircle pools. Pool covers and barriers are currently unregulated in South Africa[3]
- Adequate signage at dangerous beaches

- Allocation of lifeguards in swimming areas
- Wearing life-jackets on boats
- Survival swimming could be integrated into life skills programs at schools[3]
- Teaching the public how to do cardiorespiratory resuscitation
- Increasing the awareness regarding the dangers of swimming after consuming alcohol or recreational drugs[4, 7]

CONCLUSION

Drowning is a major public health issue, which is preventable. The best manner to prevent it is through effective education and training. Although drowning claims a large number of the young population around the world, numerous lives are saved every year by trained lifeguards, paramedics, and doctors.

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