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Impact and Epidemiology of drowning in a pediatric population. The Emergency Department experience of Gaslini Hospital, in Genoa: a retrospective study between 2010 and 2021.

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Considerate la vostra semenza:
fatti non foste a viver come bruti
ma per seguir virtute e canoscenza

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Introduction

Definition of drowning

The term drowning is actually defined as "*a process resulting in primary respiratory impairment from submersion/immersion in a liquid medium. Implicit in this definition is that a liquid/air interface is present at the entrance of the victim's airway, preventing the victim from breathing air. The victim may live or die after this process, but whatever the outcome, he or she has been involved in a drowning incident*.". This definition was developed after an extensive debate, which underlined the lack of clear terminology used in the past. To solve these problems in 2002 there was the first World Congress on Drowning. (1) Before that discussion the literature used to separate fatal and nonfatal events as well as cases with or without aspiration, using the following terms:

-drowning without aspiration: death because of respiratory obstruction or asphyxia due to submersion in a liquid medium;
-drowning with aspiration: death due to the both previous processes;
- near drowning without aspiration: survival after experiencing asphyxia due to submersion in a liquid fluid;
- near drowning with aspiration: survival following fluid aspiration.

Experts found out that these definitions, which mixed the events with outcomes were difficult to use in surveillance and epidemiological reviews, resulting in underestimation of the phenomenon. The current definition has been finally developed using the Utstein Approach by consensus experts, which classified also drowning outcomes as: death, morbidity and no morbidity. (2) The first guidelines about drowning terminology were published in 2003 in order to uniform reporting data related to drowning; after more than 10 years there was the Second International Utstein-style consensus conference on drowning that revised the template for reporting data from drowning research. Some items listed in the first edition were removed as well as some data items were converted from supplementary to core or the other way around, with new emphasis on measurement of quality of resuscitation, neurological outcomes. (3)

The process starts when 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 is interrupted, and this is called a "nonfatal drowning". If the victim dies at any time, this is a fatal drowning. Any water-distress incident without evidence of respiratory impairment (i.e. without aspiration) should be considered a water rescue and not a drowning. There is also consensus that the terms wet, dry, active, passive, silent and secondary drowning should no longer be used. (4)

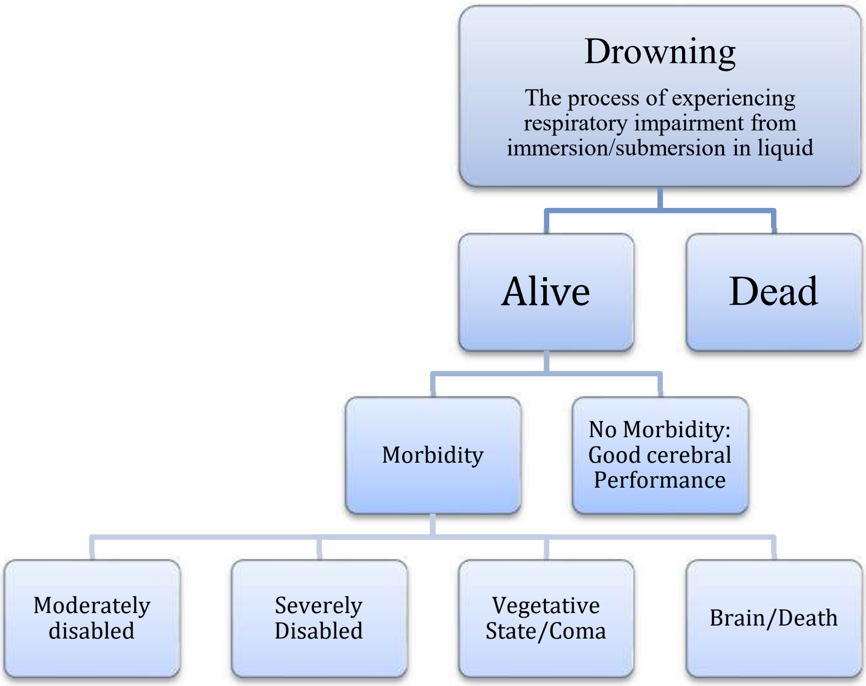

Figure 1 : *Possible scheme for tracking outcomes. Adapted from Circulation: Cardiovascular Quality and Outcomes Volume 10, Issue 7, July 2017*

Epidemiology

It is known that drowning is a major public health issue that is usually neglected despite of its warning global impact. It was estimated that it is responsible for 372 000 deaths a year worldwide, excluding drownings in natural disasters and due to transport incidents, "*approximately 42 drowning deaths every hour every day*", making it the third unintentional injury killer worldwide.

Drowning rates in low and middle- income countries are more than 90% of the total, up to 3.4 times greater than those in the high-income countries. Regardless of the economic development of the country, drowning often hits the poorest and least-educated people who live in rural settings (especially around water), and communities with the least resources to safely adapt to the risks around them. There are also differences in fatal drowning rates between population subgroups in high income countries: children and young people from racial ethnic minority groups face a greater risk. (5)

Despite the lack of data collection and surveillance, the highest drowning death rates in the world are estimated to be in African countries. A retrospective descriptive study used existing administrative records on drowning cases that took place in Uganda from January 2016 to June 2018 considering 60 districts: 1435 drowning cases were recorded, including fatal and non-fatal events; after data deduplication, unique drowning cases were 1283 (89% of recorded cases; 1160 fatal, 123 non-fatal). Focusing on the setting, lakeside districts were the setting of 70% of drowning events, while the remaining (30%) happened in non-lakeside districts. When demographic traits were known, male fatal victims (n=876, 85%) were more if compared to the female one, and the average age was 24 years of age. In lakeside districts, 81% of fatal cases with a known activity at the time of drowning involved boating. (6)

Characteristics of drowning victims may vary significantly from national data, depending on the area involved.

A descriptive retrospective study investigated the epidemiology of pediatric drowning patients presenting to a large Southern US Children's Hospital from 2016 to 2019. 162 patients met the inclusion criteria for the study. Submersion events were most common among children between 1 and 5 years of age and 58% is the rate of male patients. Pools were the setting for 78% of drowning injuries. cardiopulmonary resuscitation is performed in the 54% of victims. Sixty-four percent of patients required hospitalization after the injury. (7)

In the USA, there were almost 13,000 emergency department visits related to drowning injuries a year and about 3,500 deaths. In Brazil, which make up the two-thirds the population of the

United States, drowning numbers for far fewer hospital visits but about twice as many deaths. Different percentage has been seen in Rio de Janeiro where an analysis of the 46,060 cases of rescue in 10 years from 1991 to 2000 showed that medical assistance was needed in only 930 cases (2%). The rates are probably due to the highly effective and specialized prehospital service provided at 3 drowning resuscitation centres staffed with medical doctors. (4)

In 2017 The Global Burden of Diseases (GBD), Injuries and Risks Factors Study, found out that, considering YLLs (years of life lost), drowning has the second highest YLLs after road injuries, among the unintentional injuries category, since drowning is more common within early ages. YLLs are defined as the difference between life expectancy and the age at which the death occurs, making it an important measure of drowning mortality. The same GBD study shows a reduction in the estimated annual global drowning rate of 17% from 2007 to 2017, but the drowning burden is not evenly distributed such as some countries achieving greater reduction than others. (8) Moreover the recent study on the burden of unintentional drowning did not include intentional drowning which is actually part of the drowning profile. (9)

Hsieh W-H conducted the first study that compares drowning mortality rates according to intent-specific versus all intents combined, providing a more exhaustive picture of the phenomenon of drowning. within a country. It was a population-based descriptive cross-sectional study of 32 Economic Co-operation and Development OECD countries . Focusing on accidental intent, the countries with the highest drowning mortality rates (deaths per 100000 population) were Estonia (3.53), Japan (3.49) and Greece (2.40); Ireland (0.96), Belgium (0.96) and Korea (0.89) for intentional self-harm ; Austria (0.57), Korea (0.56) and Hungary (0.44) considering undetermined intent while Japan (4.35), Estonia (3.70) and South Korea (2.73) for all intents combined. Regarding the drowning mortality rates, the rankings of a country vary depending on whether the all-intents-combined approach or the intent-specific approach is used. The findings of this study indicate a large variation in the practice of classifying the undetermined intent of drowning deaths across countries so that valid international comparisons of intent-specific drowning mortality rates is limited. (10)

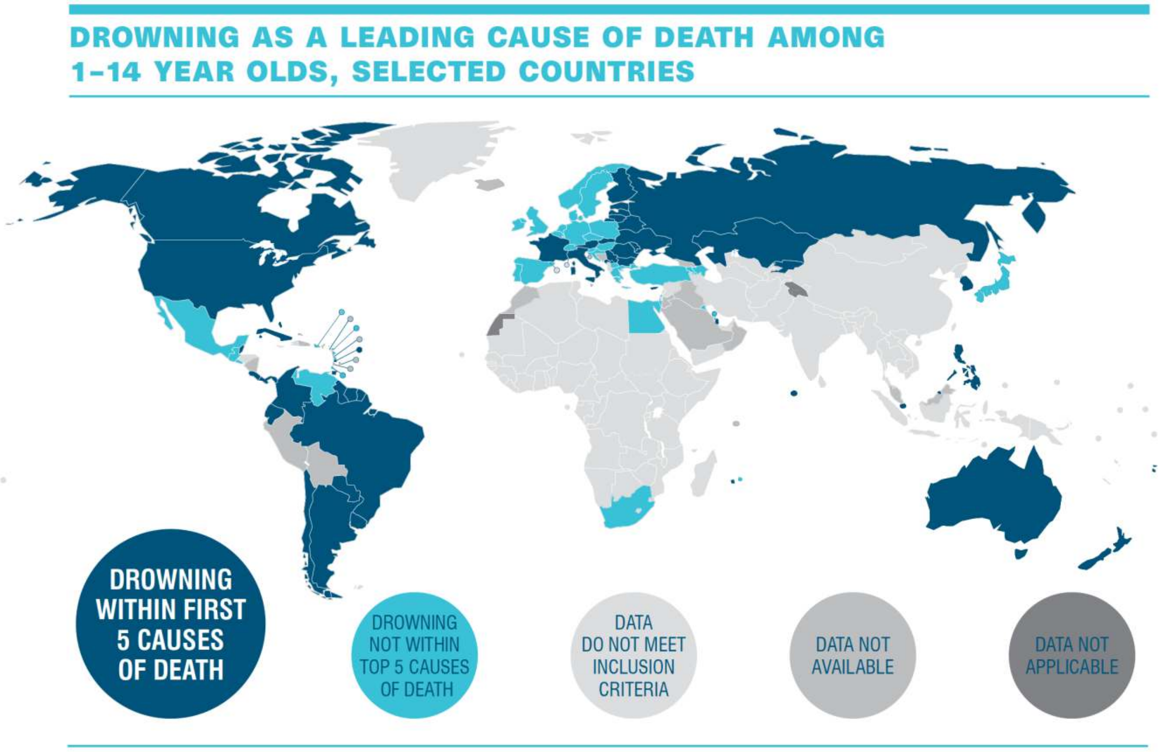

Figure 2 : *Analysis of mortality data submitted to WHO shows drowning is one of the top five causes of death for people aged 1–14 years for 48 of the 85 countries where data meet inclusion criteria."World Health Organization. Global report on drowning: preventing a leading killer. 2014"*

Populations With Increased Drowning Risk

The circumstances and the rates vary by **age and gender**. There are two peak incidence: the first one in the 0- to 4- year age group, with children 12 to 36 months of age at the highest risk, and the second one in adolescence. Males are at greater risk of drowning than females up to 1 year of age, but among the adolescents the gap increases since the rate is roughly 10 times higher for boys. (11)

Children's vulnerability changes with age but wherever there is water, there is the threat of drowning. Children aged under 12 months are less mobile and entirely dependent on caregivers; They can drown very quickly and in very little water, and also in water containers that may not be perceived as risks (for example, in a bucket or a toilet). Children who are mobile but too young to recognize danger or to get out of water are at risk, especially in the absence of barriers and close supervision. (5) A paper focused on Australian drowning injuries in infants and toddlers reviews drowning **death patterns and risk factors**, revealing that children aged 0-4 years are the most vulnerable group: nationally, their drowning rates is 50% higher than for the 5-9 age group and 130% higher than for the 10-14 age group. Their curiosity, the limited insight of potential danger and the little or absent capacity to take care for themselves are probably the main reasons. Moreover, some of their physiological characteristics are involved as their higher centre of gravity, their weak musculature and the developing balance and co-ordination systems.

Also **socio-economic status** has been investigated as a risk for infant drowning but the results are conflicting. Anecdotal evidence suggests that wealthy families and those living in cities with high swimming pool have greater risk, while earlier studies report that children from poor families are 4.1 times more likely to die for drowning events. Several reports suggest also that children of older mother, which means over the age of 30, are more likely to drown than children of younger mother: the connection may be explained by the lack of supervision due to their chance to have more children and competing demands. (12)

Adolescents tend to be more independent and are more likely to adopt risky behaviour around water, including consuming **alcohol.** The role of alcohol in drowning during aquatic recreational activities has been extensively investigated: alcohol consumption increases the likelihood of immersion resulting in drowning associated with aquatic recreational activities and that risk increases with increasing blood alcohol concentration. The rate of drowning victims with a measurable blood alcohol concentration varies by 30% to 70% among people who drown while involved in aquatic recreational activities. As suggested by the few available studies, a blood alcohol level of 0.10 g/100 ml, associated with recreational boating, may increases the risk of death about 10 times compared with sober people involved in the same activities. The percentage of drowning deaths attributed to alcohol consumption has been exstimated between 10% and 30%. (13) (5)

As far as **underlying medical conditions concerned**, drowning is the most common cause of death from unintentional injury for people with epilepsy, and epileptics children are at greater risk of drowning, whether in bathtubs or in swimming pools. The relative risk of fatal and nonfatal drowning in epileptics patients varies by age, severity of illness, degree of exposure to water and supervision level but is 7.5- to 10 times higher than that in children without seizures. (14) (15)

Children affected by autism spectrum disorder face also an increased risk of drowning, especially those younger than 15 years old. The risk depends also on the degree of intellectual disability. Regarding the behaviours reported as leading to drowning, Wandering is the most commonly reported, accounting for nearly 74% of fatal drowning events among autistic children. (16) (17)

Many victims of drowning fatalities are lay-people attempting to rescue another and these “non-expert” rescuer roles carry a risk that can be fatal. Despite the widespread expert opinion that an **untrained bystander**, who witnesses an incident, should not enter the water, it is common that the lay-rescuer enters the water and contacts the victim without any flotation equipment, which means that the rescuer is likely to drown while trying to help the victim. (18)

Focusing on the **intentional drowning deaths**, risk factors are actually under-explored as a recent Australian review highlighted. This review identifies only older age, female gender and Psychoactive substances use as a risk factor for suicidal drowning deaths underlining the lack of investigation about this topic. (9)

Pathophysiology and clinical presentation

Understanding the drowning process leads to the most accurate diagnosis, treatment and prognosis.

At the beginning, a variable quantity of fluid enters the oropharynx and is ejected, if possible. If water cannot be spitted out or swallowed, the person holds the breath consciously; then, the internal boost to inspire becomes irrepressible and fluid reaches the airways, stimulating the cough reflex or laryngospasm (rarely, it occurs in less than 2% of the events).

If the drowning process continues, a cascade of events may happens: both salt water and fresh water cause similar surfactant loss and they lead to the consumption of the alveolar-capillary membrane. This increases its permeability and exacerbates shifting of fluid, plasma, and electrolytes into the alveoli. The result of the damage is one of regional or generalized **pulmonary edema**, which takes to gas exchange impairments in the lungs, disturbing oxygen exchange and resulting in a rise of arterial pH and in a drop of partial pressure of oxygen.

These may lead to decreased lung compliance, bronchospasm, increased right-to-left shunting in the lungs, atelectasis, alveolitis, hypoxemia, and cerebral hypoxia.

If the person is not rescued, aspiration of water continues, and hypoxemia leads to loss of consciousness and apnea within seconds to a few minutes, followed by **cardiac arrest**. As a consequence, a period of tachycardia followed by bradycardia and pulseless electrical activity occurs, due to hypoxemic cardiac insult usually leading to asystole. The whole mechanism, from water distress to cardiac arrest, takes a few minutes even though, in rare situation, such as rapid hypothermia, it can go on for more than one hour. (19)

"*Drowning is a process of aspiration leading to hypoxia and eventually cardiac arrest. However, it is not synonymous with death: it can be interrupted* ." (4)

There are clinical differences between submersion and immersion.

Immersion

Hot-water Immersion

A minority of drowning events takes place in hot-water such as tubs, while pouring hot water over the head, or during diving or competitive swimming in warm water.

Thermoregulation during hot-water immersion (HWI) is different if compared to thermoregulation in hot ambient air. In ambient air, body cooling is possible mainly by sweat evaporation: This phase-change, from a liquid to a gaseous state, cools the body. In HWI, the high humidity limited evaporation of sweat above the water. When skin temperature increases, cutaneous warm thermoreceptors located in sensory nerve endings interact with keratinocytes through the spinal dorsal horn and trigeminal nerve, to hypothalamic thermoregulatory centers. Autonomic efferent information is forwarded to the skin and causes, among other effects, cutaneous vasodilatation. Under normal circumstances, external hydrostatic pressure takes to in bradycardia. In HWI, however, the temperature effects overcome this because decreased peripheral vascular resistance raises heart rate. Increased heart rate may trigger ventricular arhythmias, potentially hazardous in combination with peripheral vasodilatation and increased blood viscosity. (20)

Cold-Water Immersion

Most drownings occur at water temperatures below the point of thermoneutrality, which is 35°C. After a fall into cold water, any intention to hold the breath can be overcome by cold shock. Cold receptors answer include gasping, hyperventilation, increased cardiac output, peripheral vasoconstriction, and hypertension. These responses can increase metabolic rate, which decreases breath-hold time during initial immersion: breakpoint of breath-holding would be reached earlier, due to the hypoxic and hypercapnic thresholds. Maximum breath-hold time generally is 60 –90 seconds at a comfortable air temperature and is reduced to just a few seconds in water colder than 15°C.

With regard to drowning, the most significant consequence of hypothermia is the loss of consciousness (LOC) with deep body cooling. This prevents individuals from undertaking physical activity to maintain a clear airway The progressive signs and symptoms are shivering (36°C), confusion, disorientation, introversion (35°C), amnesia (34°C), cardiac arrhythmias (33°C), clouding of consciousness (33-30°C), LOC (30°C), ventricular fibrillation (VF) (28°C), and death (25°C). Below a cardiac temperature of 28°C, the heart may suddenly and spontaneously arrest.

The decreased oxygen demand of cold cells and organs causes decreased respiratory and heart rates. As a result, vital signs will be difficultly detected at the scene. Tendon reflexes are absent and the pupils dilated: the patient may appear dead.

Both the rate of cooling and the lowest deep body temperature compatible with life or consciousness vary significantly between individuals. Lastly, as for hypothermia, a reliable measure of deep body temperature is not always available at the field and sometimes in the emergency department, making the evaluation of hypothermia difficult. (20)

Submersion

Breath-Holding

Under normal circumstances in air, an initial interval occurs with little respiratory afferent activity and little effort required to maintain a breath-hold followed by an increasing drive for respiratory movement due to afferent neural input to the respiratory centers. The respiratory movement associated with rebreathing extends the breath-hold time until blood oxygen and carbon dioxide tensions lead to ventilation. Swallowing, through some movement of the respiratory musculature, can increase breath-hold time perhaps explaining why some drowning victims have water in their stomachs when rescued.

within ambient air, breakpoint alveolar PCO2 varies from 43 to 53 Torr and occurs 60 –90 s after breath-holding but The breath-holding time can be influenced by several factors so that the variation between individuals in maximum breath-hold time is large.

Known factors which decrease breath-holding duration include: alcohol intoxication, water temperature below 15°C, the cold shock response that intensifies respiratory drive and voluntary liquid aspiration such as occurs in suicides. (20)

Diving Response

The diving response is considered one of the most powerful autonomic responses, particularly in children, which can be triggered by apnea, facial immersion or their combination with a key role of cold water and a large ambient air-to-water temperature gradient

Research into diving birds, reptiles, mammals living in or underwater, and other hypoxia-tolerant animals shows that the diving response is an autonomic response that serves as an endogenous hypoxia defense mechanism to preserve life. The diving response is better developed and has a faster onset in diving mammals and children than in adult humans

Studies with infants reveal that, up to 6 months of age, all children have the ability to achieve the diving response with a reduction to 90% of all children at 12 months of age. (21)

It involves simultaneous activation of sympathetic and parasympathetic activation resulting in peripheral vasoconstriction, hypertension, and bradycardia. The diving response decreases metabolism selectively and overall oxygen consumption with a slower desaturation during apnea, mostly in the vasoconstricted tissues and heart, which result in the shift to anaerobic metabolism, leading to increased lactate. The simultaneous Increased carotid artery blood flow and vasodilatation in the brain improve cerebral perfusion. In addition, the diving response induces vagal-mediated bradycardia which adds to the oxygen-saving effects through decreased myocardial oxygen consumption. "*In the context of drowning, some consider the reflex fantastic physiology, others physiological fantasy*."

Bradycardia and hypertension may be indicators that the diving response has been active, informa- tion rarely available at the rescue site.

Despite these limitations, the diving response may have a role in the prevention of fatal drowning, especially in very young children. (20)

Upper Airway Reflexes

The upper airway, including the nose, pharynx, larynx, and extrathoracic portion of the trachea, has many reflexes relevant for life as the maintenance of an open airway and airway defense. Mild irritation of the laryngeal mucosa may lead to a laryngeal closure reflex in order to avoid materials entering the tracheobronchial tree. Laryngospasm is the closure of the aryepiglottic folds, false vocal cords, and true vocal cords.

During the drowning process, laryngospasm, also known as glottis spasm, may prevent the entrance of water into the lungs as mentioned in the earliest drowning studies to ex- plain why 10 –20% of all dead drowning victims had macroscopically dry lungs. However, this finding have been explained not only by laryngospasm but also by vago-vagal cardiac inhibition, pulmonary reflexes, absorption of aspirated fresh water into the circulation, and various reflexes triggered by contact of the body with water. Recent studies, as well as clinical observations, explained that if a laryngospasm may initially have occurred, it will cease to operate as a result of progressive hypoxia of the laryngeal muscles while under water breathing efforts are sustained. (20) (22) (23)

Aspiration of Water

The lung is the main vulnerable target affected by the drowning process. During laryngospasm, vigorous ventilatory movements against a closed glottis may mechanically damage the parenchyma. Further- more both hyper- tonic and hypotonic aspirated liquids leads to changes regarding the pulmonary surfactant and the alveolocapillary barrier resulting in systemic hypoxemia.

Hypotonic liquid, once alveoli have been reached, damages pulmonary surfactant getting a raise in the alveolar surface tension, with a simultaneous diminution of pulmonary compliance. It leads to alveolar instability and atelectasis that causes the ventilation-to-perfusion ratio impairment. A good part of the lung is not adequately ventilated so that more venous blood bypasses the lungs, and the shunt fraction increases.

Aspiration of hypertonic seawater promotes liquid movement from the plasma into the alveoli, which damages surfactant too. In both situations, the alveolar-capillary membrane integrity will be disrupted. Plasma enters the alveoli, avoiding normal gas ex- change and generating foam that further decreases pulmonary efficacy. (20)

Swallowing of Water

During the drowning process, swallowing water may increase the risk for vomiting, spontaneously or during resuscitation, eventually leading to aspiration of gastric content. Swallowing water may also contribute to life-threatening electrolyte disorders.

Coordination between breathing and swallowing, including soft palate elevation, epiglottis tilting, and airway reflexes inhibition prevents liquid aspiration, and the breathing is interrupted for about 1 second.

Focusing on drowning, uncontrolled premature entry of liquid into the pharynx can cause aspiration and swallowing, accentuated by a cough reflex. Stress, PCO2 raise, PO2 reduction, respiratory- and lung-volume changes, and unconsciousness impede coordination between swallowing and respiration resulting swallowing during inspiratory and expiratory phases, whichg leads to aspiration.

Although some drowning victims clearly have swallowed water, data are limited as to the incidence and clinical relevance, and whether differences exist between fatal and non-fatal drowning. (20)

Emesis

Emesis is defined as retroperistaltic activity from the small intestine, relaxation of the pyloric sphincter, downward contraction of the diaphragm with decreased intrathoracic pressure, increase in intra- abdominal pressure, contraction of the abdominal wall muscles, squeezing and contraction of the stomach with elevation of intragastric pressure and closure of the pylorus, relaxation of the esophageal sphincter, and expulsion of gastric contents. (20)

The rate of emesis occurrence in drowning is not clear and vary widely among studies. One study, reported 25–60% of drowning victims vomited (24) while another study revealed that emesis occurred in 86% of drowning victims who required cardiopulmonary resuscitation and in 50% of those who required no intervention (25).

During the drowning process, gastric contents can be aspirated into the airways, leading to pulmonary infection and chemical irritation. Vomiting can also interfere with pulmonary resuscitation. (20)

Electrolyte Disorders

Electrolyte disorders have been considered a major factor in drowning mortality previously while Current studies downsize their role. In the past, experimental models suggested Pathophysiological differences between freshwater or saltwater drowning while in most drowning victims, serum electrolyte changes have little significance. It may be due to the quick electrolyte balance restorement enabled by liquid redistribution within the body. Both hypo- and hypertonic liquid induce a ventilation/perfusion shift and hypoxemia and metabolic acidosis. These leads to myocardial depression, pulmonary vasoconstriction, and changes in capillary permeability that worsen pulmonary edema and the last common pathway is hypoxemia. (20)

In the majority of the injuries, drowning is not associated with clinically important electrolyte changes. In sporadic cases, such as in protracted immersion sea-water ingestion following the breath-holding breaking-point directly causes hypernatremia and serum sodium concentrations higher than 145 mM have been detected in pediatric drownings. Chlorine ions may also pass the intestinal barrier following the concentration gradient and leading to metabolic acidosis. (26) The ingestion of as little as 200 ml of water with high magnesium and calcium concentration, typical of specific environments such as the Dead Sea, may also have a significant clinical impact (27) Conversely swallowing fresh water can lead to hyponatremia, especially in children (20).

Management

Figure 3 : Reprinted with permission from Szpilman D, Webber J, Quan L, et al. "Creating a drowning chain of survival." Resuscitation 2014; 85(9):1149–1152.

Prehospital management

Reaching the patient

The timing, within deterioration in drowning patients occurs, makes early response and recognition by prehospital care providers necessary for positive outcomes.

The first challenge is to recognize a person in distress in the water and know how to act safely, and to activate the lifeguard, rescue and emergency medical services (EMS) if available. As far back as 1995, Langendorfer & Bruya identified the following key behaviours of a person at high risk of drowning: "*Near vertical body position, ineffective downward arm movements, ineffective pedaling or kicking leg actions, and little or no forward progress in water*". Sending someone to call for help after recognizing a person in water distress is crucial in the drowning response chain. (Figure 3) (28)

At first, if the drowning injury happens outside the house, the victim should be taken out of the water ensuring the safety of the rescuers, which means to prevent him entering the water. The aim is to avoid the rescuer becoming a second victim himself. The mantra of "*Reach, Throw, Row, Don't Go*" should be used. (19) (29)

Once on land, the person who has drowned should be placed in a supine position, with the trunk and head at the same level, and the rescuer should be looking for vital signs. If the person is unconscious but breathing, the recovery position (lateral decubitus) should be used. (30)

Initial Resuscitation

The **basic life support (BLS)** should be early as well as effective since it is known as a crucial factor for survival and it follows the ABC model, with attention to airway, breathing and circulation in that order (Recommendation grade: 1C). (29) Cardiac arrest from drowning is due primarily to lack of oxygen. Unlike primary cardiac arrest, drowning can produce a gasping pattern while the heart is still beating, and the person may need only rescue ventilation. Furthermore the European Resuscitation Council recommends five initial rescue breaths, followed by 30 chest compressions, and going on with two rescue breaths and 30 compressions until the spontaneous circulation returns, the rescuer becomes exhausted, or advanced life support becomes available. During CPR, if ventilation and chest compression do not result in cardiac activity, a series of intravenous doses of norepinephrine or epinephrine, a single dose of 1 mg (or 0.01 mg per kilogram of body weight) can be considered. (30)

Interruption of the drowning process as quickly as possible by supplying oxygen to the brain is paramount in order to perform a successful resuscitation of the patient. The rescue breaths can be also performed in shallow water: It is known as in-water resuscitation. It is not possible to perform adequate chest compressions within the water so they should not be attempted. To benefit from only rescue breathing, the victim must have a pulse and be unconscious with inadequate or absent breathing. Although ideal delivery of rescue breaths includes **supplemental oxygen** and a positive-pressure delivery device, any amount of oxygen delivery (eg, mouth-to-mouth, bag-valve-mask with ambient air) is better than none if supplemental oxygen is not available (Recommendation grade: 1C). (29) Adequate chest rise should be detected as a proof of efficacy during the attempt.

On the rescue scene, wet clothes should be removed and the victim should be dried and covered with dry clothes in order to prevent hypothermia. Hypothermia should be aggressively treated with active and passive measures dependent on patient conditions and available resources (Recommendation grade: 1C). (29)

Considering that ventricular fibrillation is rare, early application of an automated external defibrillator should be considered but reversal of hypoxia with ventilations and compressions should not be delayed. The chest should be dried before applying defibrillator pads.

Obtaining a clear history, including bystander account, is necessary because the clinical picture varies by the circumstances of the event. Cervical spine injuries are rarely linked with drowning events among children so that **cervical spine immobilisation** is required only in few cases (Recommendation grade: 1C). The adolescent age is an important risk factor and it should be obviously considered if a traumatic injury history is known or focal neurological deficit occur.

The evidence does not support the use of the **Heimlich manoeuver** or other positioning manoeuvres to remove aspirated water from the lungs. (Recommendation grade: 1B) (19) (29) In addition to providing immediate basic life support, it is important to alert advanced-life-support teams as soon as possible. “Because of the wide variety of clinical presentations of drowning, a classification system of six grades, with higher numbers indicating more severe impairment, can help to stratify risk and guide interventions”. (

Figure 4)

In the early moments, the victim may be able to maintain adequate oxygenation through an increased breathing rate and a greater effort: the supplementation of oxygen by face mask (at a rate of 15 litres of oxygen per minute) should be performed. Recent resuscitation data investigate the benefit of providing high oxygen concentrations in the acute setting of out-of-hospital cardiac arrest, assuming an association between hyperoxia after return of spontaneous circulation (ROSC) and increased mortality. Most of these analysis focus on the period after ROSC in the intensive care unit setting, and no studies focus specifically on cardiac arrest associated with drowning. A single retrospective case-control study involving arterial blood analysis during CPR provides support for using high levels of supplemental oxygen. This study found that the previously described potentially harmful effects of hyperoxia after the return of spontaneous circulation were not confirmed for paO2 measured during CPR. (31) Early intubation and mechanical ventilation should be considered when deterioration or fatigue occurs. Providers of prehospital care should control the oxygenation level, maintaining arterial saturation between 92% and 96%. Ventilation with positive end-expiratory pressure should be initiated as soon as possible in order to increase oxygenation. Vomiting occurs in 30% to 85% of drowning victims because of swallowing large amounts of water and positive pressure ventilation during resuscitation. (30)

A recent national Cross-Sectional Study of drowning patients across The United States is performed with a focus on prehospital time intervals, transport and cardiac arrest frequency. The results showed that the average response time was 8±5 min, according to the overall Emergency Medical Services response time, suggesting no remarkable differences due to the drowning etiology. Response time was shorter among paediatric patients, probably linked to the inherent urgency with paediatric patients. On-scene time was longer than the target time adopted by most EMS systems, suggesting a generally prolonged extrication requirement and on-scene resuscitation attempt. Once again, On-scene times were shorter for younger patients and longer for cardiac arrest patients. This is most likely due to the expedited transport preferred for paediatric patients by most prehospital providers and attempts to restore spontaneous circulation in cardiac arrest patients before transport. (32)

Emergency department

Each victim of drowning who required any kind of resuscitation (including rescue breathing alone) should be delivered to the hospital for evaluation and monitoring, despite an effective recovery. Anyone exhibiting distress (shortness of breath, persistent cough, anxiety, tachypnea, syncope, foam in the mouth or nose, change in vital signs, abnormal breath sounds, or hypotension) might be transported too. (33) On arrival to the emergency department, clinical impression should guide laboratory studies.

The access mental status should be investigated using **Glasgow Coma Scale** (GCS):

- If GCS>13: clear cervical spine, monitor O_2 saturation using pulse oximetry, observe for 4-6 hours; discharge should be considered if the parameters are normal.
- If GSC<13 as though O_2 saturation<95% or abnormal lung exam: clear cervical spine, monitor O_2 saturation and give supplemental O_2 in order to keep O_2 saturation above minimums. Otherwise intubate and ventilate with low Tidal Volume (6mL/kg), low PEEP 5/10 cm H_2O and volume ventilation (10L/min). Alternatively, follow the Acute Respiratory Failure protocol or in addition, consider extracorporeal membrane oxygenation. Weaning from vent should be delayed for 24 hours regardless of the laboratory findings. (33)

If hypothermia is a concern, infrared thermometric devices should not be used to determine **core temperature** avoiding the risk of false lower body temperatures in submersion victims. Thermal insulation of the patient should be instituted. Measurements of electrolytes, blood urea nitrogen, creatinine, and haematocrit are rarely beneficial. **Blood gas measurement** is recommended since metabolic acidosis occurs in the majority of patients but it is usually corrected spontaneously by the patient, increasing minute ventilation, or by care providers adjusting minute ventilation or peak inspiratory pressure on the mechanical ventilator. The use of sodium bicarbonate is not routinely recommended. Arterial blood gas testing in patients with evidence of hypoxemia or respiratory distress (i.e.. cyanosis, low oxygen saturation, tachypnea, persistent tachycardia) may be indicated to guide respiratory interventions. When mental status does not improve after resuscitation or when submersion is not due to a known reason,

laboratory testing investigating causes of altered mental status should be considered (Recommendation grade: 1C). (29)
An initial **chest radiograph** is usually performed but it may be unremarkable regardless of the extent of lung damage and pneumonia may be overestimated because of water in the lungs. Initial chest radiograph findings do not correlate with arterial blood gas measurements or outcome (Recommendation grade: 1C). (29)If the patient has been intubated it should be useful to assess endotracheal tube position and it may be used as a baseline for evolving acute lung injury.
CT of the head and cervical spine should be considered for drowning victims with suspected head or neck trauma. (Recommendation grade: 1C) (19) (29)
Evidence does not support the use of **prophylactic antibiotics** (Recommendation grade: 1A). (29) A recent descriptive retrospective study evaluated the antimicrobial use in the paediatric drowning population and it found out that there is no connection between antimicrobial utilization in the first 72 hours after admission and mortality. (34) It would be better to monitor patients daily for fever, leukocytosis, pulmonary infiltrates changes, and leukocyte response in the tracheal aspirate, with culture and sensitivity testing of sputum specimens obtained daily from the aspirate. Once a diagnosis is made, empirical therapy with broad-spectrum antibiotics should be started waiting the results of culture and sensitivity testing are available. (30) **Corticosteroid** routine use is not recommended as well as **surfactant** use, since there is no good evidence that its use improves the outcome as some case reports suggest. (19)

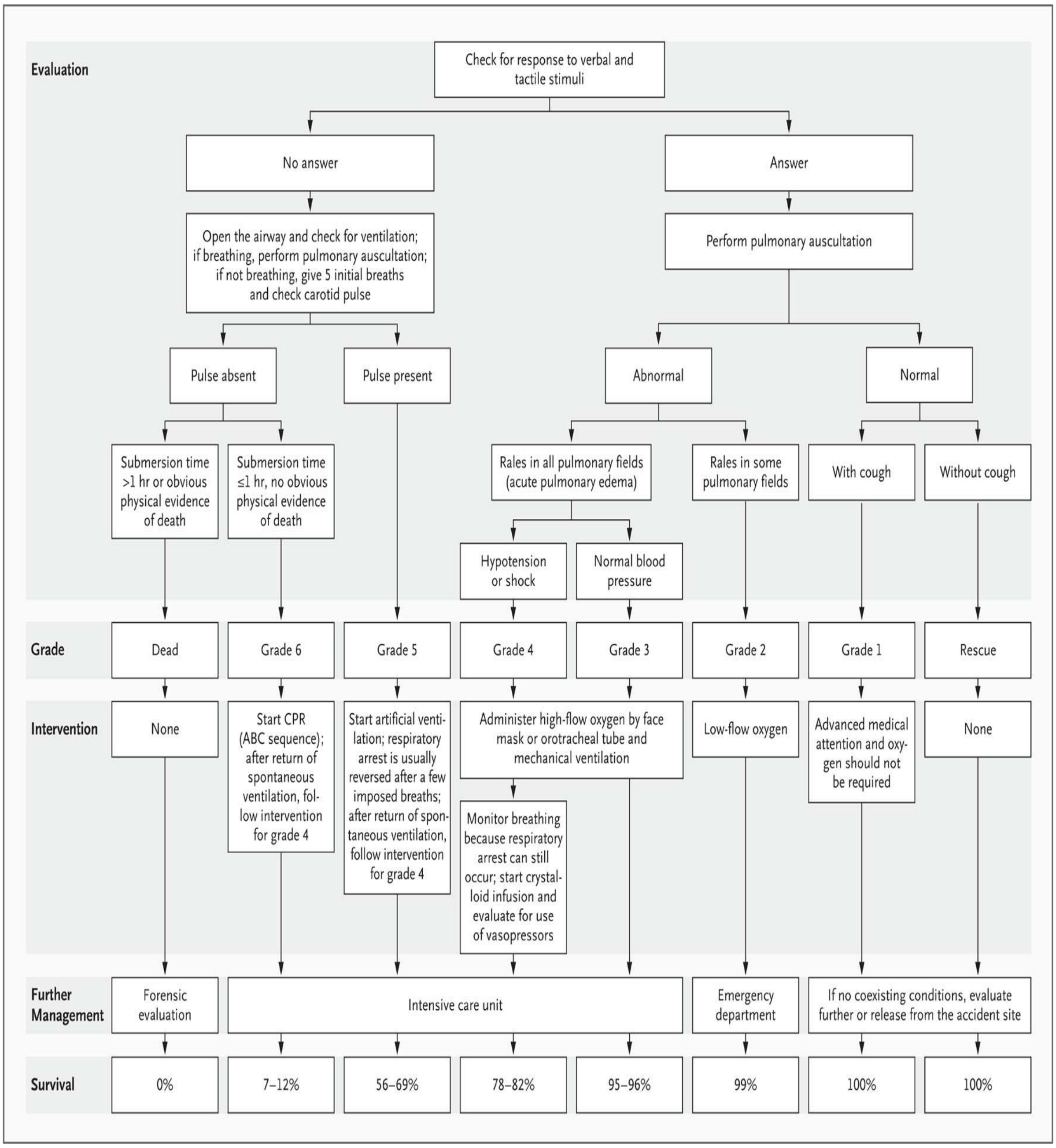

Figure 4 *: A drowning classification system has been established to classify victims at the rescue scene based on the clinical parameters of respirations, pulse, pulmonary auscultation, and blood pressure. From* ***David Szpilman, M.D., Joost J.L.M. Bierens et al.*** *"*Drowning*" 366, 31 May 2012, N Engl J Med, pp. 2102-2110.*

Prognosis

Drowning is a major source of mortality and morbidity in children worldwide. Detection of outcome predictors at the scene of drowning cases could lead prevention, care and resource employment. Quan et al. carried out a systematic review and meta-analysis of six scene predictors for drowning outcome that might be known to a rescuer at a drowning scene. The following factors has been considered: age, submersion period, salt versus fresh water, water temperature, bystander cardiopulmonary resuscitation (CPR) and Emergency Medical System (EMS) arrival time. The most robust and independent predictor was **submersion duration** since shorter submersion was linked to grater outcomes in all time categories evaluated; Submersion durations ≤10 min predicted high rates of great outcomes while submersion durations >25 min were related to bad outcome rates. Despite common beliefs, victim's age was not a predictor in this study as well as the role of cold water in preserving neurologic function. EMS response time performed well on multivariate and meta-analyses and it was an objective measurable predictor. However, the percent of favourable outcomes for those with < and ≥9 min response times overlapped suggesting the necessity of further investigations. (35)
In addition, a retrospective observational study conducted in the referral hospital of the Balearic Islands (Spain) considered the clinical picture and the course of drowned children younger than 15 years admitted in a paediatric intensive care unit. The considered potential prognostic factors were whether drowning was witnessed, kind of CPR (not accurate, basic, advanced with or without epinephrine), pupil status and reactivity at the first clinical examination, access blood pH and GCS score. The results showed that outcome was poorer when advanced CPR on the scene is required, especially with intravenous administration of epinephrine. The connection between higher pH and a better prognosis is less strong. It is also doubtful the neuroprotective effect of hypothermia since in the Mediterranean Sea, where the water is warm, hypothermia suggests prolonged immersion time.
Therefore, Considering these patients as potential organ donors, all intensive support despite the prognosis should be initially managed to evaluate this chance with the family. (36)

Considering an overview of scene factors that have been studied, an up-to-date systematic review showed that a gap in those studies was the paucity of studies in low-income countries. Moreover, they took into exam only victims who used hospital or EMS systems, excluding those who were rescued or died at the scene, so that they evaluated biased and pre-selected populations. Furthermore, many studies considered only death and survival as outcome measures disregarding the most meaningful outcome measures: survival with good neurologic function. (37)

Neurocognitive outcome of children after drowning injuries cannot be properly prognosticated in the early course of treatment. As long as spontaneous breathing and circulation are present on arrival at the ER, the term of submersion as well as the need of advanced life support at the scene of the event and the duration of CPR are the main factors related to with mild neurological deficits or intact function in survived patients. Data on long-term outcome are scarce. (38)

Despite the small number of patients (12 children), a recent retrospective analysis of drowning in children focused on the long-term neurological outcome obtaining the expected results, according to the current literature: the percentage of survivors without neurological sequelae is about 75/80% while severe neurological deficits occur in 10%; moreover, 10/35% is the rate of drowning victims who will die. Some of the survivors remain in a vegetative or minimal conscious state and their life expectancy is reduced to two to five years and survival longer than 10 years is very unusual. (39)

Many investigators have attempted to identify prognostic factors related to both survival and neurologic outcome from submersion incidents. The **PRISM SCORE** “Pediatric Risk of Mortality Score” (*Figure* 5) is a scoring system which predicts children mortality risk in critical illness. The PRISM score has 14 physiologic variables and 23 variable ranges. For each physiologic variable, a point total is provided that directly reflects the contribution of that instability to mortality risk. This tool is then used to calculate a “probability of outcome” and it appeared to distinguish accurately intact survival from death or neurologic impairment, among patients admitted to the Emergency Department after a submersion injury. (40)

Table 1. PRISM Score*

Variable	Age Restrictions and Ranges			Score
	Infants	All Ages	Children	
Systolic BP, mm Hg	130-160		150-200	2
	55-65		65-75	
	>160		>200	6
	40-54		50-64	
	<40		<50	7
Diastolic BP, mm Hg		>110		6
Heart rate, beats/min	>160		>150	4
	<90		<80	
Respiratory rate, breaths/min	61-90		51-70	1
	>90		>70	5
	Apnea		Apnea	
Pa_{O_2}/FI_{O_2}		200-300		2
		<200		3
Pa_{CO_2}		51-65		1
		>65		5
Glasgow Coma Score		<8		6
Pupillary reactions		Unequal or dilated		4
		Fixed and dilated		10
PT/PTT		1.5×control		2
Total bilirubin, µmol/L (mg/dL)		Age >1 mo >60 (>3.5)		6
Potassium, mmol/L		3.0-3.5		1
		6.5-7.5		
		<3.0		5
		>7.5		
Calcium, mmol/L (mg/dL)		1.75-2.00 (7.0-8.0)		2
		2.99-56.14 (12.0-15.0)		
		<1.75 (<7.0)		6
		<56.14 (<15.0)		
Glucose, mmol/L (mg/dL)		2.2-3.3 (40-60)		4
		13.9-22.2 (250-400)		
		<2.2 (<40)		8
		>22.2 (>400)		
Bicarbonate, mEq/L		<16		3
		>32		

Reprinted with permission from Pollack et al.[14] PRISM indicates Pediatric Risk of Mortality score; BP, blood pressure; FI_{O_2}, fraction of inspired oxygen; and PT/PTT, prothrombin time/partial thromboplastin time.

***Figure 5**: PRISM SCORE from Pollack MM, Ruttimann UE, Getson PR. Pediatric risk of mortality (PRISM) score. Crit Care Med. 1988 Nov*

Moreover, Pediatric submersion victims often require admission but the aim of Shenoi et al. was to identify of a cohort of children at low risk for submersion-related injury, who can be safely discharged from the emergency department after a period of observation. Their retrospective , single center pilot study investigated children between 0 and 18 years of age who were admitted to the Emergency Department of a tertiary-care children's hospital after a drowning event. The primary outcome was “safe discharge at 8 hours after submersion: Normal mentation and vital signs” and they tried to identify potential scoring factors and then a submersion clinical score has been derived and validated. The absence of respiratory distress, normal respiratory rate, absence of systolic hypotension, no airway support needed (bag-valve mask ventilation, intubation, and CPAP) and normal mentation are the five factors included in the score mentioned above and evaluated at the arrival on the emergency department. The maximum score is 5 and the range vary from 0 to 5: a score of 4 or higher on the arrival would suggest a safe discharge at 8 hours. Application of this score, if confirmed by a multicentre study, could help ED physicians decision making when to discharge patients after a period of observation. (41)

Some authors have recommended admission for all drowning victims due to the risk of respiratory and clinical deterioration in a seemingly well patient. A retrospective twelve years medical record review conducted in an urban tertiary care center in Israel, whose whole western boundary is the Mediterranean Sea, investigated possible predictors for admission. This twelve years retrospective study included all children ≤ 16 years old presented following a drowning event to the pediatric ED. The children were divided into two groups, those who were discharged home from the ED and those who were admitted. Crepitations on lung auscultation, oxygen desaturation, and respiratory distress were significantly higher in the admitted group ($n = 26$) compared with the discharged group ($n = 45$) ($P < 0.05$).“*Respiratory distress and lung crepitations were independent predictors for admission*”. The results of this study on asymptomatic to moderately symptomatic children after drowning events highlight the role of the clinical examination at the ED and the authors proposed e a simple algorithm (Figure 6) designed to guide the ED physician in decision-making with regard to patient disposition. (42)

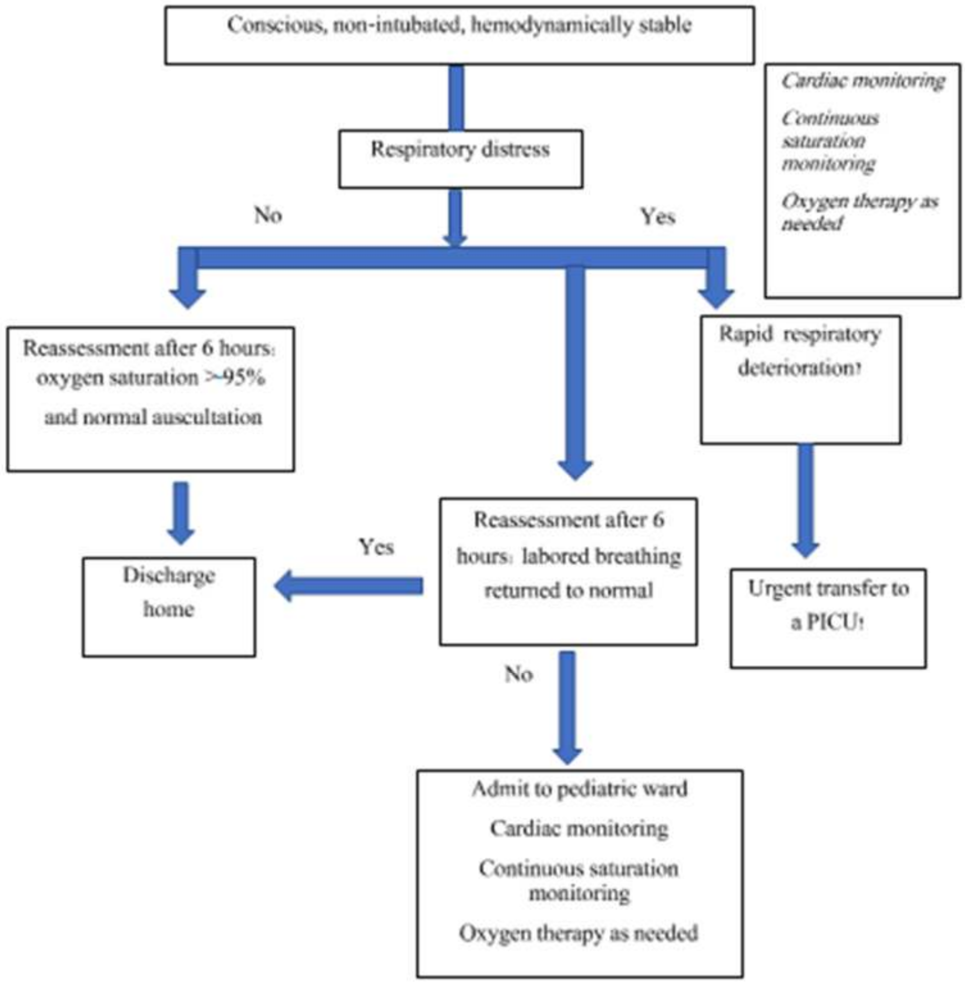

***Figure 6** : Algorithm for the disposition of children after drowning* . Predictors for hospital admission of asymptomatic to moderately symptomatic children after drowning. ***Neta Cohen, Capua, T., Lahat, S. et al.** 2019, European Journal of Pediatrics, Vol. 178*

Prevention

People drown in many different ways so that a range of prevention strategies is needed in order to target the biggest risk.

In this regard, interventions aimed at changing the environment, the individual at risk, and/or the agent of injury (in this case, water) could be identified by The Haddon Matrix paradigm for injury prevention. Multiple "layers of protection" are recommended since any single strategy will prevent drowning deaths and injuries, before, during and after the event. Five major evidence-based interventions are known: 4-sided pool fencing, life jackets, swim lessons, supervision, and lifeguards. (43)

Focusing on the Lack of **physical barriers** between people and water, it is eloquent that, even in countries with large coastlines, the majority of drowning events take place inland, especially when young children are involved. (5)

A national survey carried out in Bangladesh showed that 80% of drowning among children under 5 years of age occurred within 20 metres of home – mainly in ponds, followed by ditches and water containers. (44) A comparable study conducted in the rural community of Kaniyambadi, in India, found that almost 90% of drowning deaths among children between 1 and 12 years of age happened in a pot, well or pond. (45) What that suggests is a different interaction between people in low- and middle-income countries and water if compared to those in high-income countries, so that open wells, uncovered manholes and ditches increase the risk.

Placing barriers strategically is a method of decreasing exposure and drowning risk and effective approaches are varied: covering water tanks, using doorway barriers and playpens, fencing swimming pools with four-sided, child-resistant fences and self-closing gates with safety latches as well as legislating for the implementation of these policies. (5)

Pool fencing is the most studied and effective drowning-prevention strategy for the young child, preventing more than 50% of swimming-pool drownings of young children. Case control studies, which evaluate pool fencing interventions indicate that pool fencing significantly reduces the risk of drowning. Pool fences should completely encircles the pool and isolate it from the house. Legislation should require isolation fencing with secure, self-latching gates for all pools, public, semi-public and private. (46)

Life jacket wear is now also well proven to prevent drowning fatalities and its use has been investigated by a recent study, which found factors with both increased and decreased lifejacket use. Factors associated with decreased wear include: older age, male gender, discomfort of lifejackets, cost and accessibility, alcohol consumption and the perception of higher swimming ability. (47)

Lifeguards and CPR training also appear to be effective. A case–control study conducted in California, including 166 children from zero to 14 years of age who experienced a submersion injury investigated the impact of an early CPR on clinical outcome. This study demonstrated that children who had faced life threatening submersion events were about five times more likely to have a good clinical outcome if resuscitative efforts were performed immediately (48) It has been estimated that an additional 30% of pediatric drowning victims would survive—usually with good neurological function—if a trained resuscitator had been on the scene at Time Zero (49). Considering the crucial role of an effective CPR, Fernàndez Méndez et collegues designed a cross-sectional simulation study in order to prove the ability of 20 professional lifeguards to perform ABCDE approach. Their task was to evaluate the victim clinical status and therefore acting following the ABCDE primary assessment approach. The results showed Professional limited lifeguards practical skills since None of the study participants were able to complete correctly the ABCDE approach. That limitations should be considered in order to improve lifeguards training programmes (50).

As Emergency Medical Service takes time to reach the target, lifeguards must perform cardiopulmonaryresuscitation (CPR) for an extended time after a water rescue. A bystander can also be the first to perform CPR resuscitation contributing to a positive outcome of drowning victims. Actually, the outcome is worst if CPR is delayed, regardless of whether it is high quality CPR or not. Water rescue is also physically demanding so that the purpose of the study designed by Li et al. is to investigated the effect of fatigue caused by water rescue on subsequent CPR quality as well as the role of a bystander on CPR quality in a lifeguard rescue. This was a simulated quasi-experimental study conducted in an indoor swimming pool in Dongtai (China) involving 14 lifeguards and 14 bystanders. At first baseline measurements of CPR quality were made : each lifeguard performed CPR for 2min without any water rescue and measurements were detected. In three separate trials, a single lifeguard swam 50m to perform a water rescue in a pool and returned with the manikin another 50m then 10min of CPR was performed by a single lifeguard, two lifeguards or a lifeguard with a layperson with no CPR training. Compression depth was the only Baseline CPR quality measure, which was not adequate. After water rescue, the single lifeguard trial showed no significant differences compared with baseline measurements so that a well-trained lifeguard was able to perform single-rescuer CPR without a significant decrease in quality for at least 10min after a water rescue. When a lifeguard is available for drowning victim, laypersons are not likely to be helpful in the resuscitation (51).

It is known that a rescue performed using the correct equipment is more fast and safe than a rescue performed without it, but currently, several water rescue equipment are available. A controlled trial conducted at two Spanish beaches studied the repercussions of 4 different rescue techniques in the rescue time and the CPR quality, investigating the physiological effects of each rescue technique on 35 lifeguards. The variables taken into consideration were blood lactate levels and subjective Borg's scale effort perception. The percentage of correct ventilations was less than 50% before and after all rescue trials, with no significant differences (P>05). This study showed that lifeguards perceived less effort using the rescue board referring to the subjective Borg's scale. The difference was statistically significant if compared to the use of "no equipment" (P <0.001), fins (P<0.003), and fins with rescue tube (P<0.001) According to the study,the use of propelling and/or floating equipment saves time with impact on the reduction of drowning mortality and morbidity and The rescue board would be more beneficial .Lifeguards need more CPR training, especially considering the lack of efficient ventilations in drowned patients. (52)

A retrospective analysis conducted in Newport Beach, a suburban city in Southern California(USA) on the Pacific Ocean, described lifeguard prevention activities. All lifeguards interventions are recorded by lifeguards dispatchers used to collect the data. The aim was to characterise the nature of lifeguard primary and secondary drowning prevention Preventative actions include verbal warning by a lifeguards to a beach patron. The majority of both primary and secondary lifeguard preventative actions occurred during the summer months. The most of lifeguard activities were Preventative actions with a rate of 54.8%), while rescue rate was about 1.9%. Detailed, valid and reliable data on ocean lifeguard activity helps lifeguard agencies to achieve quality improvement resulting in a better lifeguard training. Improving surveillance methods for lifeguard activity, in order to increase the amount of data collected, should be encouraged. (53)

As the first witness, parental cpr training should play a key role in the drowning chain of survival. A study conducted in Florida, ,evaluated whether a brief videotape could motivate pregnant pool owners to be trained in infant/child cardiopulmonary resuscitation (CPR). Women were recruited from prenatal classes in South Florida the state with the highest toddler drowning rate in the country. Eligible mothers were randomized to view a video or receive standard treatment, after filling out a questionnaire. The video focuses on toddler drowning risk, and the value of isolation pool fencing and CPR training. Women got a phone call 6 months after giving birth to complete a follow-up survey. At baseline, there was no significant difference between the proportion of mothers with current CPR training in the treatment and control groups. At follow-up, viewers were significantly more likely than control group members to report current training in infant/child CPR 6 months after their babies were born. Health care facilities located in communities with high rates of toddler drowning may want to screen prenatal students for pool ownership and encourage at-risk families to be trained in infant/child CPR. (54)

Inadequate supervision is often mentioned as a crucial risk factor for childhood drowning, especially for younger children. As reported by Wang et al., who investigated drowning events of Chinese children younger than 5 years old, the primary caregivers interviewed in the survey were paying full attention to the child in only 12.8% of drowning cases when the primary caregiver was present. The results (Figure 7) indicate that Caregivers were attending to other chores and not minding the child and almost half of all children were alone when they drowned. (55) Adequate supervision of young children is described as close, constant, and attentive and vary by age and water competency.

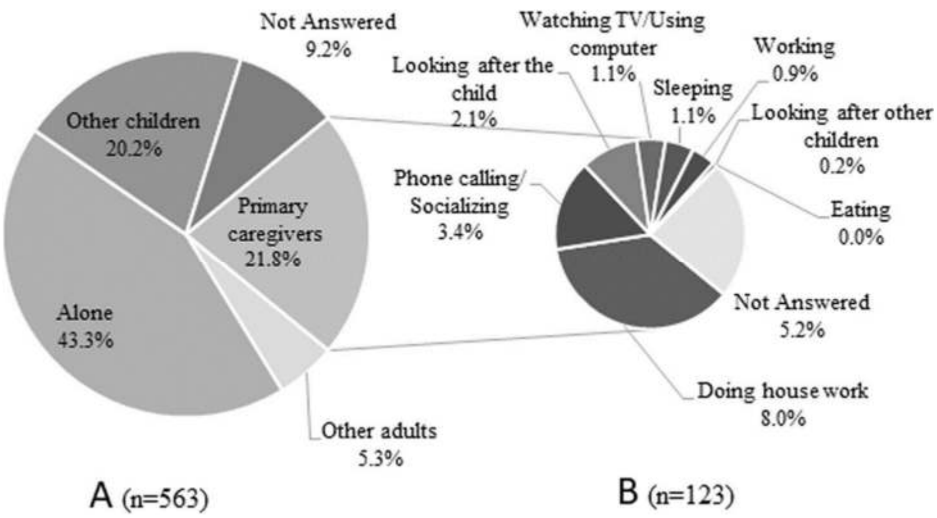

***Figure 7**: Caregiver presence and engagement at the time of drowning of Chinese children under 5 years old. A) Who was present during the child's drowning. B) The behavior of the primary caregiver at the time of the child's drowning. From *Wang et. al BMC Public Health (2020) Social and environmental risk factors for the accidental drowning of children under five in China*

For beginning swimmers It is recommended a "touch supervision," which means that the care giver should be extremely close to the child so that the adult can pull the child out of the water whenever the submersion occurs. *"Drowning is silent and only takes a minute"*. (56)

To address the lack of interventions targeting caregiver supervision for drowning prevention, a promising program called "*S.A.F.E.R. Near Water"* (Supervise by Always being Focused on the children and able to Extend your arms and Reach them) is developed and tested. The results shows that parents receiving *S.A.F.E.R. Near Water* demonstrated improvements in: beliefs about the value of supervision, judgments about children's swim skills and drowning risk and perceptions related to swim lessons and children's supervision needs, supporting the need of an educational program with an encouraging impact on drown-risk related knowledge. (57)

Aims

The objective of this study was to evaluate the impact and the epidemiology of drowning in a single pediatric Emergency Department located in Genoa, Italy. Considering that the most of studies in current literature focused on drowning events, which took place in the oceans, It is quite likely to assume that different patterns would emerge in a study conducted in the Mediteranean Sea.

We first reviewed the characteristics of pediatric drowning victims presenting to the Emergency Department of Giannina Gaslini Children Hospital to identify possible risk factors, including environmental and familiar features, in order to improve primary prevention of drowning injuries.

We aimed also to investigate possible prognostic factors in pediatric submersion cases so that we collected all clinical, laboratory and chest radiograph findings. The outcome has been defined considering the length of hospitalization as well as the amount of therapy needed.

Materials and Methods

Patients and settings

All patients younger than 14 years old admitted to the Emergency Department of Giannina Gaslini Children Hospital after a drowning event between 2010 and 2021 were included in this study. Giannina Gaslini Children Hospital located in Genoa (Italy) is a tertiary hospital, recognized as a Scientific Hospitalization and Care Institute, close to the Ligurian Sea, which counts in its approximately 30,000 hospitalizations per year and 550,000 annual outpatient services, about 42% of extra-regional origins and about 200 patients arriving from over 70 countries of the world (58).

Data acquisition

The following data have been extracted from the medical records of the patients:

- demographics characteristics: gender, and months of age at the time of the event, birth place, only/not only child if available;
- details of the event: season,the kind of water, the place, clinical findings at the scene (loss of consciousness), prehospital treatment including cardiopulmonary resuscitation (CPR) if provided, means of transport used to reach the hospital;
- Hospital investigations and treatment: vital signs detected, blood tests findings, imaging investigations and length of hospitalization. The provision of ventilatory support was also documented such as oxygen therapy, heated humidified high-flow nasal cannula (HHHFNC) or non invasive ventilation (NIV).

Definitions

-Seaside residency = resident in a seaside town.
-Summer = June to August.
-Values collected from medical records are considered “in the normal range” or “out of the normal range” once compared with Gaslini laboratory reference values.

Statistical analysis

Data are described as absolute and relative frequencies for categorical variables, while means, standard deviation (SD), medians and range are used for continuous variables. Normality of distribution was determined using the Kolmogorov-Smirnov test. Non parametric analysis (Mann-Whitney *U*-test) for continuous variables and the Chi square or Fisher's exact test for categorical variables were used to measure differences between groups.
A p-value less than 0.05 was considered statistically significant, and all p-values were based on two tailed tests. Statistical analysis was performed using SPSS Version 18.0 for Windows (SPSS Inc, Chicago, Illinois USA).

Results

Descriptive characteristics of drowned children

This investigation included 56 children admitted in the ED of the Gaslini Children's Hospital after an episode of drowning during the past twelve years (between 2010 and 2021). Two (3.6%) drowning events took place in May, 12 (21.4%) in June, 25 (44.6%) in July, 13 (23,2%) in August, 3 (5,4%) in September and only one (1,8%) in October. Our series confirmed that the majority of drowning injuries happen during the summer (N=50, 89.3%). (
Figure 8,
Figure 9)

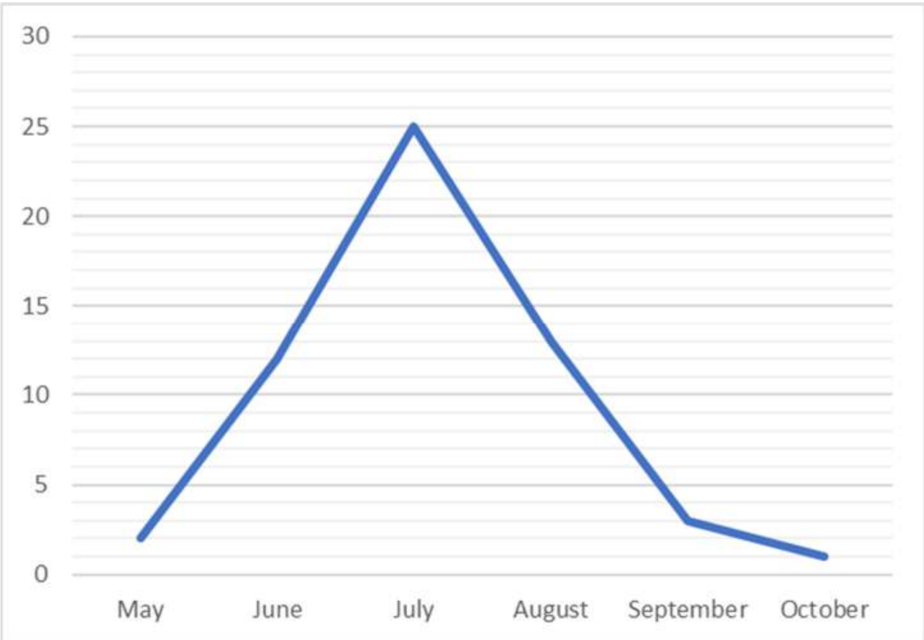

Figure 8: *Number of drowning events per month, if the month counts no event it was not mentioned in the chart*

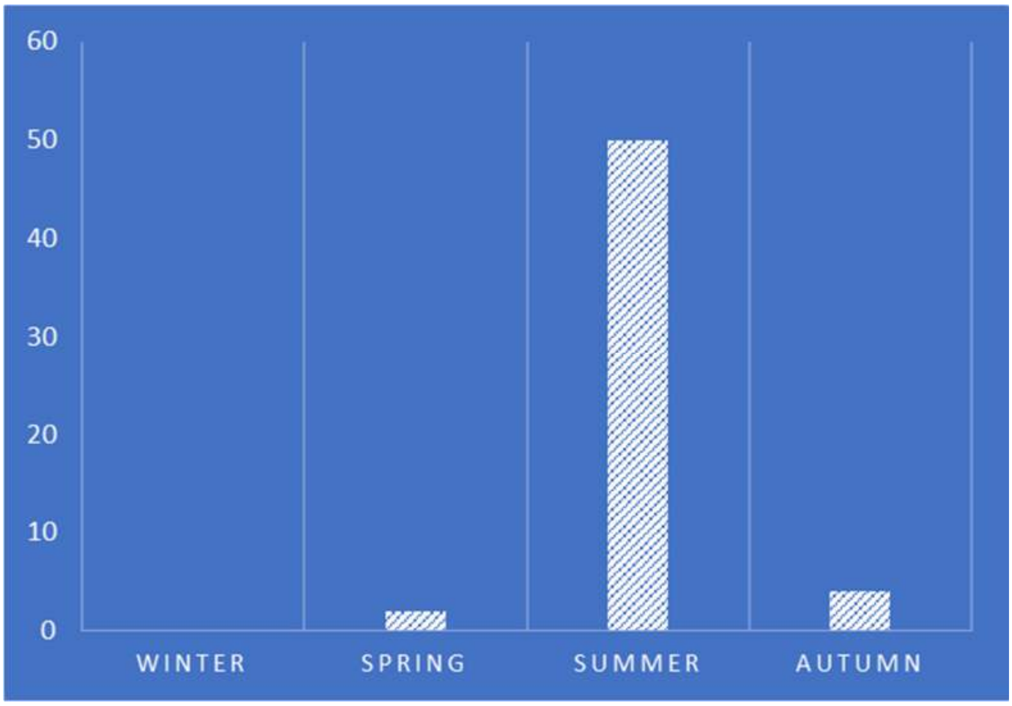

Figure 9*: Number of drowning event per season*

The proportion of male-to-female children who drowned was approximately 2:1 (37:19) . The age range was 11 to 165 months and the mean age at the time of the event was 66.61 months with a standard deviation of 37.3. In addition, there was no statistical age difference between the two gender subgroups and the mean age at the time of the injury (p=0.60) (Table 1).

	Total	**Seaside Residency**	**Not Seaside Residency**	**P**	**Females**	**Males**	**P**
	N=56	*N=33*	*N=23*		*N=19*	*N=37*	
Age at the time of the event (months)	66.61±37.3	56,15±31,31	81,61±40,63	**0.02**	*63,84±36,94*	*68,03±37,89*	0.60
Hospital stay (days)	3.61±1.55	3,42±1,60	3,87±1,46	0.32	*3,63±1,16*	*3,59±1,72*	0.89

Table 1

Among these children the 74% (n=37) were not "only-child while the rate of the first born was about 40,5% (n=15) of the total and six children (10.7%) had comorbidities Even the birth place has been considered: this study distinguish "seaside residency" from "not seaside residency" revealing that the second group accounts the 41.1% (n=23) of the drowned victims .
Matching those two subgroups and the mean age at the time of the event, we found out that the mean age was lower (56,15±31,31 SD) for drowning children resident near the sea if compared to the other subgroup (81,61±40,63) and the difference was statistically significant (p= 0.02) (Table 1).

	N	*%*
Gender		
M	37	66.1
F	19	33.9
Birth place		
Not near to the sea	23	41.1
Near to the sea	33	58.9
Kind of water		
Saltwater	39	69.6
freshwater	17	30.4
LOC at the scene		
yes	27	48.2
No	29	51.8
CPR at the scene		
performed	17	30.4
Not performed	39	69.6

Table 2*: Descriptive characteristics of drowned children in this study.*
CPR=cardiopulmonary resuscitation., LOC= loss of consciousness

Even though this is a monocentric study, based on the patients admitted at Gaslini Children's Hospital, not all the patient (56) were immediately transported there after the event (Figure 10). Twenty-one patients (37.5%) come from other hospitals, six of them (10.7%) were carried by helicopter while 15 of them (26,8%) by ambulance. Focusing on the transport used to reach the hospital, twelve children (21.4%) reached the Institute using private vehicle while 23 (41.1%)

applied the 118 rescue service: among the second group, 14 (25%) victims were brought by ambulance and 9 (16.1%) by helicopter.

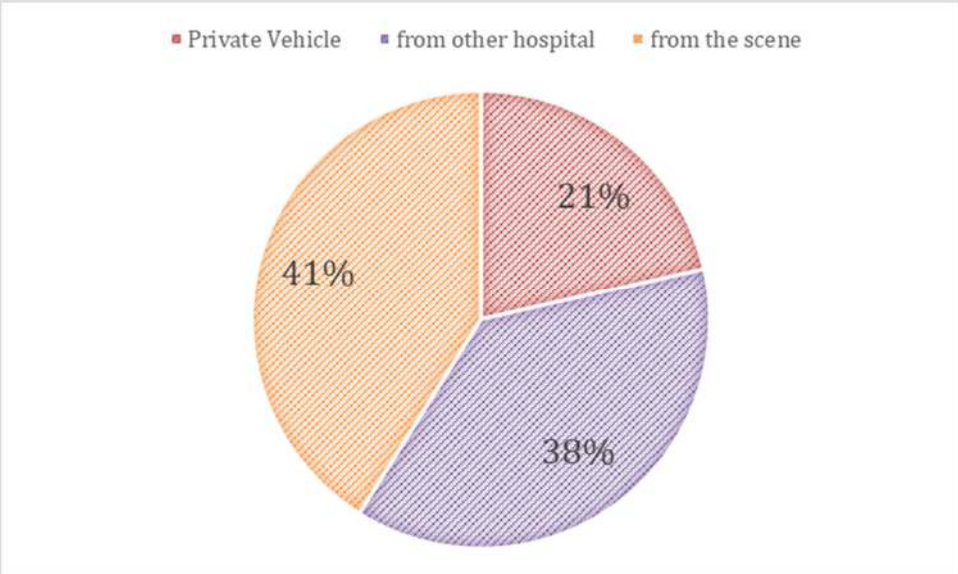

Figure 10 *provenance of the patients*

Place and dynamics of the event

Drowning occurred in saltwater in 69.6% (n=39) of the time, whereas only 17 patients drowned in freshwater. As we thought the mean blood pH among people who drowned in salt water was 7.28 with a standard deviation of 0.06, lower than the values detected when the event took place in freshwater (7.32±0.07 SD), confirming the significant association (P=0.005). An analysis of the kind of water versus the blood tests values detected at the ED admission showed the following results. (
Table 3,Table 4)

	Total	Fresh water	Salt water	P value
	N=56	*N=17*	*N=39*	
PH	*7.30±0.06*	*7.32±0.07*	*7.28±0.06*	***0.005***
HCO3	*18.33±2.49*	*18.28±2.48*	*18.35±2.53*	*0.86*
CO2	*45.98±6.84*	*42.34±6.71*	*47.55±6.35*	***0.01***
Lac	*18.72±16.06*	*23.69±27.43*	*16.57±6.59*	*0.64*
Na	*142.43±8.71*	*131.63±1.09*	*147.11±5.88*	***≤0.0001***
Cl	*109.79±8.78*	*100.56±4.02*	*113.78±7.11*	***≤0.0001***
Glicemia	*127.09±46.92*	*132.13±48.46*	*124.92±46.75*	*0.81*

Table 3

	Total	***Fresh water***	***Salt water***	***P***
	N=56	*N=17*	*N=39*	
TC	*36.56±0.82*	*36.23±0.58*	*36.71±0.88*	***0.01***
SaO2	*91.93±8.66*	*95.65±3.26*	*90.31±9.75*	***0.05***
FC	*124.37±22.82*	*119.53±23.60*	*126.49±22.45*	*0.17*
FR	*30.13±8.70*	*28.71±11.08*	*30.74±7.53*	*0.12*
GCS	*14.50±1.09*	*14.65±0.70*	*14.44±1.23*	*0.53*
PA_sis	*103.65±10.81*	*103.50±9.72*	*103.73±11.45*	*0.80*
PA_dia	*61.29±10.90*	*58.50±9.25*	*62.64±11.51*	*0.38*
Hospital stay (days)	*3.61±1.55*	*3.59±1.54*	*3.62±1.57*	*0.67*

Table 4

In the group of children drowned in salt water, lower O2 saturation was observed with a mean value of 90.31±9.75 DS compared to the O2 saturation levels detected in patients drowned in freshwater (95.65±3.26 SD) and this difference was statistically significant ($p=0.05$). However, there was no statistical hospital stay difference between the two groups ($p=0.67$).
The most frequent location was the sea (64.3%, n=36), followed by pools which covered the remnants rate (n=20). The dynamics of the event included trauma in six cases (10.7**%**) far too few that we can find statistical association between this variable and other parameters such as LOC, CPR or hospital stay.

Prehospital Findings

The loss of consciousness was experienced by the 48.2% (n=27) of the whole drowned people, similarly to the rate of children who stayed conscious (N=29, 51.8%). As we expected, this event is strongly associated with lower GCS score ($p=0.001$). Retrospectively, we noticed that children falled unconscious had higher lactate levels (23.48±20.88) at the ED admission if compared to the second group (13.77±5.76) with statistical significant difference ($p=0.01$). In the group of conscious patients lower creatine kinase.(CK) levels(110.47±70.51 SD) at blood tests were also observed as opposed to CK levels detected in people who lost the consciousness (208.89±207.67) revealing a significant association between these variables (p=0.05)(Table 5). The mean CK levels observed were also higher when the event took place in freshwater (298.44±268.14 SD) suggesting a significant association between CK raise and the kind of water (p= 0.02).

	Total (N=56)	***No LOC (N=29)***	***LOC (N=27)***	***P value***
PH	7.30±0.06	7.30±0.05	7.29±0.07	0.59
HCO3	18.33±2.49	18.56±2.47	18.11±2.54	0.54
CO2	45.98±6.84	46.29±6.45	45.68±7.30	0.66
Lac	18.72±16.06	13.77±5.76	23.48±20.88	**0.01**
Na	142.43±8.71	143.42±7.34	141.48±9.89	0.30
Cl	109.79±8.78	111.00±7.88	108.63±9.58	0.20
Glicemia	127.09±46.92	114.85±29.38	138.89±57.26	0.21
RCP t0	0.12±0.67	0.18±0.91	0.07±0.29	0.59
WBC	13863.85±4675.16	13351.15±2694.25	14376.54±6064.89	0.88
Neutrofili	9761.92±4271.39	8967.69±3579.16	10556.15±4805.92	0.29
CK	162.42±164.12	110.47±70.51	208.89±207.67	**0.05**

Table 5

Seventeen patients (30,4%) had cardiopulmonary resuscitation (CPR) performed immediately upon rescue at the site of the accident but the maiority of the patients (n= 39, 69.6%) didn't need it. By matching the vital signs and the CPR performed, we achieved the following results (Table 6).

	Total (N=56)	***no CPR (N=39)***	***CPR (N=17)***	***P value***
TC	36.56±0.82	36.68±0.87	36.30±0.63	**0.05**
SaO2	91.93±8.66	91.21±8.23	93.59±9.62	0.10
FC	124.37±22.82	121.46±21.78	131.06±24.40	0.35
FR	30.13±8.70	30.05±7.49	30.29±11.28	0.64
GCS	14.50±1.09	14.79±0.47	13.82±1.70	**0.001**
PA_sis	103.65±10.81	100.66±8.75	109.29±12.28	**0.009**
PA_dia	61.29±10.90	59.16±9.25	65.29±18.84	0.07

Table 6

In-hospital Findings

Vital signs, including were detected at the ED admission where clinical examination was also performed. The results have been collected and compared to the physiological values as reported in the following table. Mean and standard deviation were calculated for each variable considering the absolute values as well as compared to the normal range. (Table 7,Table 8)

Vital signs	***Mean ± SD***
TC	36.56±0.82
SaO2	91.93±8.66
FC	124.37±22.82
FR	30.13±8.70
GCS	14.50±1.09
PA_sis	103.65±10.81
PA_dia	61.29±10.90

Table 7: *Vital signs recorded at the ED admission, Mean and standard deviation calculated considering the absolute value*

Vital signs out of the normal range	***N (%)***
TC	20 (35.7)
SaO2	35 (62.5)
FC	27 (48.2)
FR	33 (58.9)
GCS	17 (30.4)
PA_sis	9 (18.4)
PA_dia	8 (16.7)

Table 8: *Vital signs detected at the ED admission, the rate of parameters out of the normal*

After the first clinical examination, laboratory studies, including the measurements of electrolytes, haematocrit, Blood gas measurement have been performed showing the following results. (

Table 10,Table 9)

Laboratory values considered	***Mean ±SD***
PH	7.30±0.06
HCO3	18.33±2.49
CO2	45.98±6.84
Lac	18.72±16.06
Na	142.43±8.71
Cl	109.79±8.78
Glicemia	127.09±46.92
WBC	13863.85±4675.16
Neutrofili	9761.92±4271.39
RCP t0	0.12±0.67
CK	162.42±164.12

Table 9 *Blood tests performed at the ED admission, Mean values and Standard Deviation*

Laboratory values	***N (%)***
PH	41 (77.4)
HCO3	34 (64.2)
CO2	16 (30.2)
Lac	15 (28.3)
Na	21 (39.6)
Cl	32 (60.4)
Glicemia	33 (63.5)
RCP t0	3 (5.8)
CK	11 (30.6)

Table 10 *Number and rate of Laboratory values out of the normal range*

A second RCP measurement, detected from 12 to 24 hours, was out of the normal range in 29 patients (67.4%) and the mean value was 2.42 with a standard deviation of 3.41.

Of the 56 study subjects, 28 children had an electrocardiogram (ECG) performed and no one had pathological findings while only one patient had Troponin I elevation (10% of the ten patients investigated for cardiac enzyme elevation). In addition, the only pathological value has returned in the normal range at the following control.

Chest X-Ray had been performed in all of the 56 patients (100%) and 31 (55.4%) were found to be pathological. A score between 0 and 5 has been assigned to the Chest X-ray and then we divided the imaging finding in two group: A score from 0 to 1 is considered as "normal" while a score equal or higher than 2 is defined as "pathological"(Table 11).

RX	N	%
0 Normal	10	17.9
1 pulmonary interstitium thickening with no sign of consolidation	15	26.8
2 pulmonary interstitium thickening with unilateral early consolidation	20	35.7
3 **reduced transparency**/bilateral consolidation	8	14.3
4 **reduced transparency**/bilateral consolidation with involvement of pleura	3	5.4
5 ARDS	0	0

Table 11: *Chest X-Ray findings*

By matching pathological chest x-Ray and the kind of water the results were 23 (59%) pathological X-Ray among patients who drowned in saltwater and 8 (47.1%) in freshwater so that the difference was not statistically significant (p=0.56). Our series confirmed that patients with pathological chest x-Ray had RCP level detected from 12 to 24 hours (3.31±3.82 SD) higher than those with a normal chest x-Ray (0.91±1.86DS) with a p-value of 0.007. Patients found out to have a pathological chest x-ray had higher breathing rate (32.75±9.33 DS) than those with normal one (27.00±6.81) and the difference is statistically significant (0.02)(Table 12).

With regards to CK levels, the mean value detected was significantly (p= 0.03) higher if the performed x-Ray turned out to be pathological (180.48±174.85 SD) than the contrary (121.36±135.04 SD). (Table 13)

	Total N=56	***Normal chest X-Ray N=25***	***Pathological chest X-Ray N=31***	***P-value***
TC	36.56±0.82	36.48±0.69	36.63±0.92	0.46
SaO2	91.93±8.66	93.96±5.83	90.29±10.20	0.17
FC	124.37±22.82	118.92±19.29	128.77±24.74	0.06
FR	30.13±8.70	27.00±6.81	32.75±9.33	**0.02**
GCS	14.50±1.09	14.52±1.45	14.48±0.72	0.16
PA_sis	103.65±10.81	103.00±9.95	104.10±11.52	0.95
PA_dia	61.29±10.90	60.70±7.71	61.69±12.77	0.97

Table 12 *Matching Pathological and Normal chest X-Ray and Vital signs detected*

	Total N=56	***Normal chest X-Ray N=25***	***Pathological chest X-Ray N=31***	***P***
PH	7.30±0.06	7.30±0.06	7.30±0.07	0.89
HCO3	18.33±2.49	18.39±2.12	18.29±2.76	0.99
CO2	45.98±6.84	46.05±6.72	45.94±7.03	0.87
Lac	18.72±16.06	16.09±8.43	20.58±19.72	0.50
Na	142.43±8.71	141.59±9.91	143.03±7.86	0.45
Cl	109.79±8.78	109.14±11.03	110.26±6.94	0.46
Glicemia	127.09±46.92	120.14±50.35	132.03±44.51	0.21
RCP t0	0.12±0.67	0.02±0.10	0.19±0.86	0.76
RCP 12-24h	2.42±3.41	0.91±1.86	3.31±3.82	**0.007**
WBC	13863.85±4675.16	12872.38±4944.37	14535.48±4439.03	0.54
Neutrofili	9761.92±4271.39	9030.48±4570.61	10257.42±4057.20	0.15
CK	162.42±164.12	121.36±135.04	180.48±174.85	**0.03**

Table 13: *Blood tests matched with normal and pathological chest X-Ray*

Treatments

	N	*%*
O_2	43	76.8
corticosteroids	21	37.5
Aerosol	21	37.5
HFNC/NIV	8	14.3
Antibiotics	46	82.1
bolus injection of normal saline solution	6	10.7

***Table 14:** treatments made by patients*

One of the patients (1.8%) was admitted to the pediatric intensive care unit (PICU). The mean length of hospitalization was 3.61 days with a Standard Deviation of 1.55. Oxygen therapy was necessary in the majority of the patients accounting 43 children (76.8%) who received this treatment and an analysis of duration of hospitalization versus oxygen therapy revealed a significant association (p=0.008) between these variables; (Table 14) The mean hospital stay among people who received oxygen therapy was 3,81 days with 1,26 of standard deviation compared to an average of 2,92 days with 2,18 of standard deviation. (Table 16)

Antibiotic therapy had been used in the most of patients (n=46, 82.1%) while the rate of children treated with aerosol therapy was 37.5% (n= 21) exactly the same as the rate of steroid therapy. Antibiotic therapy was prescribed to all 17 (100%) drowned children that had CPR performed at the scene versus 29 (74.4%) patients among the group who had not CPR performed. (Table 15) Six children (10.7%) received a bolus injection of normal saline solution. High-flow nasal oxygen therapy and non-invasive ventilation had been used in the 14.3% of the drowning victims (n=8), used more commonly (n=5, 29,4%) in children who received CPR (p=0.05)); Three patients who had not CPR performed on the scene (7.7%) required O2 supplementation with High-flow nasal oxygen therapy and non-invasive ventilation. Few cases (n=2, 3.6%) required other therapies and the mean number of therapy received was higher (3.18±1.07 SD) if the victim required CRP (p=0.03).

	Total	NO CPR	CPR performed	P-value
	N=56 (%)	*N=39 (%)*	*N=17 (%)*	
O_2	43 (76.8)	28 (71.8)	15 (88.2)	0.30
corticosteroids	21 (37.5)	12 (30.8)	9 (52.9)	0.14
Aerosol	21 (37.5)	16 (41)	5 (29.4)	0.55
HFNC/NIV	8 (14.3)	3 (7.7)	5 (29.4)	**0.05**
Antibiotics	46 (82.1)	29 (74.4)	17 (100)	**0.02**
bolus injection of normal saline solution	6 (10.7)	5 (12.8)	1 (5.9)	0.65

Table 15: *Treatments required matched with CPR perfromed/not perfromed at the scene*

	Total N=56	***No O2 Therapy N=13***	***O2 Therapy N=43***	***P***
Age at the time of the event (months)	*66.61±37.3*	*68,31±47,95*	*66,09±34,10*	*0.93*
Hospital stay (days)	*3.61±1.55*	*2,92±2,18*	*3,81±1,26*	***0.008***

Table 16

Discussion

Drowning is globally a major cause of morbidity and mortality in young people and the epidemiology of fatal drowning is increasingly understood. By contrast, few studies investigated the epidemiology of non-fatal drowning, especially in the Mediterranean Sea.

In this study, we retrospectively evaluated the clinical courses of 56 children admitted to the ED after a drowning event, regarding demographic characteristics, place, prehospital aid as well as laboratory investigations and chest X-ray performed once admitted in the hospital.

All the patients included in our study experienced a non-fatal drowning et only one patient was admitted in the ICU. This great survival rate is probably attributable to the effective regional Emergency Service network but also to the characteristics inherent in the Ligurian Sea, since its warm water prevent hypothermia, a possible cause of death in the ocean casuistry. In this regard, the mortality rate reported by Quan L. et al. in Washington State (USA), focusing on open water drowning, were far worse and they found no association between cold water and outcome, denying its supposed protective role (59).

In our study, the most of drowning events took place in summer, with a peak in July, and in saltwater. Seasonal trend is concordant to the retrospective study conducted in Marseille, France, from 2000 to 2011. However that study include both adult and children and Adult 25-64 years accounted the 54.8% of drowning in the sea, while drowning in the pools targeted the young children population. The results are not completely comparable (60).

In our study cohort, despite the initial O_2 saturation significantly lower in children who drowned in saltwater, there is no statistical hospital stay difference, resulting in similar outcome in both groups; this is concordant with the result of a recent study where freshwater was associated with deeper hypoxemia in the initial assessment, but latter parameters or outcome were similar too. (61)

Our series confirmed that male children are at greater risk of drowning as already known in literature (60) (62): the proportion of male-to-female children who drowned was about 2:1. In our study cohort, children who were not resident in the proximity of the sea drowned had higher mean age when the drowning event happened. This result may suggest that children resident in the proximity of the sea drown early because they experience sooner that situation but it may also suggest that children resident far from the sea should be supervised for a longer time since they are unprepared to face that risk. Cohen N. et al. (63) found no statistical age difference between patients presenting to two emergency department, near and distant from the Sea Coast, partially in contrast to our data.

Our series confirmed that there is no statistical age difference between the two gender groups. The mean age at the time of the event was about 5.5 years, according to group at higher risk indicated by several studies (63) (64).
Our study also underscores that pathological chest X-Ray at the ED admission is strongly associated with higher RCP levels from 12 to 24 hours and higher breathing rate suggesting a more troubled clinical course of patients with pathological chest X-Ray. Similarly, Brandon J. Ho et colleagues showed that an initial chest radiograph that is normal or with mild pulmonary edema/atelectasis predicts clinical improvement by 24 h post submersion (65).
The present study found that both the freshwater and the loss of consciousness may be associated to the raise of CK levels. We also noticed that the loss of consciousness is related to higher lactate levels. These results found no clear explanation since we rather expected, CK elevation after CPR performance, as reported in literature (66), but there was no statistical association (p=0.14). Interestingly, Nass RD et colleagues found that lactate levels raise is a robust metabolic stress marker, useful and complementary to CK, when assessing episodes with transient loss of consciousness due to tonic-clonic seizures (67). However, no seizure episode was documented and basal levels were obviously unknown so that we cannot exclude underlying medical conditions linked to CK raise. In addiction lactate levels were taken into consideration by a recent retrospective study conducted in the University Children's Hospital Zurich (Switzerland):blood lactate values higher than 14 mmol/L, as well as other parameters, turned out to be prognostic factors for a poor outcome; they also underlined that it seems reasonable not to consider a single factor, but to analyze the values all together in order to predict the outcome (68).
Antibiotic therapy had been used in the most of patients despite there is no evidence supporting antibiotic prophylactic use in drowning (29). It may be due to a lack of standardized treatment protocols.

Conclusion

Our study has several limitations including its retrospective design and the small number of patients involved. Furthermore, Gaslini Children Hospital is not the only children hospital in Liguria so that if the patient is admitted to another medical facility, he would not be included in this single-centre study. In addiction there is a lack of data especially regarding the dynamics of the event and the prehospital management: it would be interesting to collect more information about the activity at the time of the event, the submersion duration, the presence/absence of supervision as well as the timing of the first aid arrival.

Despite these limitations, our study possesses many strengths such as the multiple years of data: this is a twelve-year investigation. Furthermore, our study is, to our knowledge, the only study in Italy and one of the very few studies conducted in the Mediterranean Sea, to collect data on pediatric drowning, including the analysis of clinical data.

One major insight from the results of this study is the role of the residence place: "not seaside" residency turned out to be risk factors for drowning. If this result will be confirmed by future prospective studies, targeted prevention strategies would be considered.

No prognostic factor for a longer hospital stay have been proved with the exception of oxygen supplementation. Pathological chest X-Ray and CPR requirement correlated with a greater need for therapy.

We assumed that the survival rate and the few ICU admissions are due to the effective Emergency Medical Service network, with a great cooperation between hospital and territory. The disseminating basic life support training among bystanders probably plays a decisive role. However the characteristic of the Mediterranean Sea should be considered when drowning data from different countries are compared. Further studies are needed.

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