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Drowning Among Tunisian Children: Clinical Patterns and Outcomes

La noyade chez l'enfant en Tunisie: aspects cliniques et pronostiques

Safa Mdimegh[1,2], Boulbeba Elleuch[1], Marwa Abdelbari[2,3], Nesrine Jaballah[2,3], Mouna Ben Guedria[2,3], Samia Tilouche [1,2], Lamia Boughamoura[2,3]

1. Department of Pediatrics Intensive Care. Farhat Hached University Hospital, Sousse, Tunisia
2. University of Sousse, Faculty of medecine. Sousse, Tunisia
3. Department of Pediatrics, Farhat Hached University Hospital, Sousse, Tunisia

Abstract

Purpose: Describe clinical and therapeutic aspects of pediatric drowning and analyse predictive factors of mortality.

Methods: We conducted a retrospective analysis of patients under 16 years of age admitted between 2018 and 2022 to the Pediatric Intensive Care Unit at Farhat Hached University Hospital.

Results: Our study included 64 patients. The sex ratio was 1.46. The mean age was 7.1 ± 4.3 years. Most drowning occurred during the summer (92.2%), in seawater (76.6%). The mean estimated immersion time was 4 ± 5.8 minutes. The majority of these drownings (70.3%) were severe (stage 3, 4, 5, or 6). The most frequent clinical signs were: tachypnea (93.8%), auscultation abnormalities (93.8%), oxygen saturation < 92% (73.4%), and tachycardia (71.9%). Chest X-ray was abnormal in 75% of cases. Mechanical ventilation was indicated in 14.1% of cases. Vasopressor drugs were used in 12.5% of cases. Antibiotic therapy was initiated in 70.3% of patients. The mortality rate was 10.9%. In multivariate analysis, predictive factors for mortality were: a Szpilman stage equal to 6 (p <0.005), a Glasgow score < 8 (p <0.005), pupillary abnormalities (p <0.005), hypothermia < 35 (p<0.005), hepatic cytolysis (p = 0.02), and blood pH < 7.1 (p <0.005).

Conclusions: Drowning is a fatal, yet preventable global public health problem, particularly touching children and young adults. Mortality depends on several epidemiological, clinical and biological factors.

Keywords: Drowning- Child - Resuscitation - Mechanical ventilation - Mortality - Prognosis

Résumé

Objectif: Décrire les aspects épidémiologiques, cliniques, thérapeutiques et évolutifs, et analyser les facteurs prédictifs de mortalité des noyades chez une population pédiatrique tunisienne.

Méthodes : Il s'agit d'une étude rétrospective, descriptive et analytique, menée sur une période de 5 ans entre janvier 2018 et décembre 2022. Elle concerne les enfants âgés de moins de 16 ans admis pour noyade au service de pédiatrie et de réanimation pédiatrique du CHU Farhat Hached à Sousse.

Résultats : Nous avons colligé 64 cas de noyade pédiatrique. Le sex-ratio était de 1,46. L'âge moyen était de 7,1 ± 4,3 ans. La plupart des noyades ont eu lieu pendant l'été (92,2%), dans l'eau de mer (76,6%). La noyade était majoritairement primaire (95,3%). La durée estimée moyenne d'immersion était de 4 ± 5,8 minutes. La majorité des ces de noyades (70,3%) étaient des noyades graves (stade 3, 4, 5 ou 6). Les signes cliniques les plus fréquents étaient : la polypnée (93,8%), les anomalies à l'auscultation (93,8%), une saturation en oxygène < 92% (73,4%) et la tachycardie (71,9%). La radiographie thoracique était pathologique dans 75% des cas. La ventilation mécanique était indiquée dans 14,1% des cas. Les drogues vasopressives ont été utilisées dans 12,5% des cas. Une antibiothérapie a été instaurée chez 70,3% des patients. Le taux de mortalité était de 10,9%. En étude multi-variée, les facteurs prédictifs de mortalité étaient : un stade de Szpilman égal à 6 (p<0,005), un score de Glasgow < 8 (p<0,005), des anomalies pupillaires (p<0,005), une hypothermie < 35 (p<0,005), une cytolyse (p=0,02) et un pH sanguin < 7,1 (p<0,005).

Conclusion: La noyade chez l'enfant constitue un motif fréquent d'admission en réanimation dans notre pays. Elle est responsable d'un taux de mortalité non négligeable. La mortalité dépend de plusieurs facteurs épidémiologiques, cliniques et biologiques.

Mot clés: Noyade - Enfant - Réanimation - Ventilation artificielle - Mortalité - Pronostic

Correspondance
Safa Mdimegh
Department of Pediatrics Intensive Care. Farhat Hached University Hospital, Sousse, Tunisia
Email: safa.mdimegh99@gmail.com

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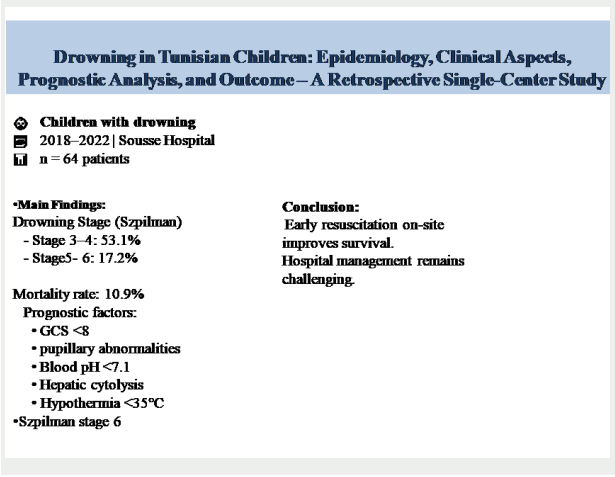

Introduction

Drowning remains a common condition, particularly among young children. It is a significant global public health issue. According to the World Health Organization (WHO), drowning is the sixth leading cause of death for those aged 5 to 14 years (1). In Tunisia, a Mediterranean country, drowning is a major concern. National statistics on causes of death in Tunisia in 2020 show that drowning and accidental submersion are the leading external causes of death among children aged 1 to 4 years (2). Despite these figures, preventive measures and management strategies in our country are limited.

Drowning is defined as a process of impaired respiratory function resulting from submersion or immersion in a liquid environment (3). It represents a true episode of acute hypoxia that can compromise both vital and functional prognosis. Its pathophysiology relates to the effects of prolonged hypoxemia on various organ systems (4).

Efforts to combat drowning require rigorous epidemiological monitoring to establish a high-quality chain of survival, from primary resuscitation at the scene to hospital-based critical care management. The prognosis depends on the circumstances of the drowning as well as the quality of prehospital and hospital care. The primary focus is on treating hypoxemia by ensuring adequate oxygenation and ventilation through oxygen therapy and, in some cases, non-invasive or invasive ventilation (5).

The objective of our study is to describe the epidemiological, clinical, paraclinical, therapeutic, and outcome aspects, and to analyze the predictive factors of mortality in drowning cases among a Tunisian pediatric population.

Methods

This is a retrospective, descriptive, and analytical study conducted over a 5-year period from January 2018 to December 2022. It includes all children under the age of 16 admitted for drowning at the pediatric and pediatric intensive care unit of CHU Farhat Hached in Sousse. We excluded non-analyzable records from this study.

Data were collected using an extraction from the patients' hospital records. We studied the epidemiological, clinical, paraclinical data, as well as pre-hospital and hospital management, mortality, and its predictive factors.

Drowning was classified according to the Szpilman classification (6).

Stage 1: Normal lung auscultation, with coughing
Stage 2: Abnormal lung auscultation, with some rales
Stage 3: Acute pulmonary oedema without hypotension
Stage 4: Acute pulmonary oedema with hypotension
Stage 5: Respiratory arrest
Stage 6: Cardiorespiratory arrest

Statistical analysis was performed using IBM SPSS software version 20. Pearson's Chi-square test and Fisher's exact test were used for frequency comparisons. The significance level for all statistical tests was set at a p-value ≤ 0.05. Multivariate analysis was conducted using logistic regression.

Results

During the study period, 64 children were admitted for drowning. The average annual incidence was 12.6 cases of drowning per year. The sex ratio was 1.46 with a male predominance (59.4%). The mean age was 7.1 ± 4.3 years, ranging from 5 months to 15 years. The most affected age group was between 10 and 15 years old (37.5%) (Table I). Three-quarters of the children were from urban areas, while 25% were from rural areas. Among the victims, 7.8% had epilepsy, 6.3% had asthma, and 6.3% had psychomotor delay.

Regarding the circumstances of the drowning, it occurred mainly in the afternoon (71.9%) and in the morning (23.4%). Most drownings took place during the summer period (92.2%). Drowning occurred in seawater (saltwater) in 76.6% of cases. It took place in a swimming pool in 15.6% of cases. Other locations included: a bucket (4.7%), a water tank (1.6%), and a well (1.6%). The liquid was freshwater in 20.3% of cases, soapy water in 1.6%, and bleach water in 1.6% of cases.

Drowning was primary in 95.3% of cases. It was secondary to a seizure in 4.7% of cases. Only one victim presented with a spinal trauma associated with the drowning. The average duration of immersion was 4 ± 5.8 minutes, ranging from 30 seconds to 30 minutes (Table 1).

Referring to Szpilman's classification, most drownings (70.3%) were severe (stages 3, 4, 5, or 6) (Figure 1).

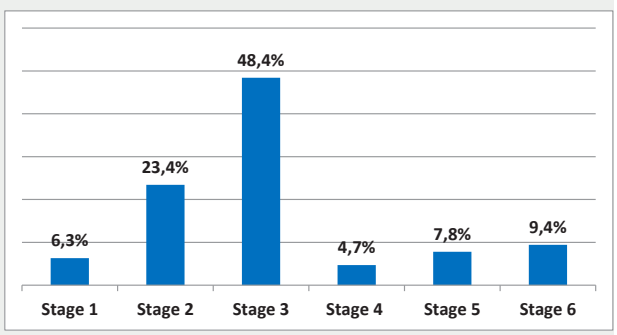

Figure 1. Distribution of patients by stage of drowning

Table 1. Epidemiological, Clinical, and Biological Characteristics of Our Study

Category	Number	Percentage
Sex		
Male	38	59.4%
Female	26	40.6%
Age		
[0-2 years]	8	12.5%
[2-6 years]	18	28.1%
[6-10 years]	14	21.9%
[10-15 years]	24	37.5%
Comorbidities		
Epilepsy	5	7.8%
Asthma	4	6.3%
Psychomotor delay	4	6.3%
Immersion Duration		
< 2 min	21	32.8%
[2-5 min]	35	54.7%
[5-10 min]	2	3.1%
> 10 min	6	9.4%
Respiratory Signs		
Tachypnea	60	93.8%
Auscultation abnormalities	60	93.8%
Crackles	54	84.4%
O2 Saturation < 92%	47	73.4%
Respiratory distress signs	36	56.3%
Bradypnea	4	6.3%
Hemodynamic Signs		
Sinus tachycardia	46	71.9%
Arterial hypotension	10	15.6%
Bradycardia	4	6.3%
Neurological Signs		
GCS ≤ 3	7	10.9%
[4-8]	1	1.6%
[9-12]	8	12.5%
[13-15]	48	75%
Normal dilated pupils	58	90.6%
Bilateral unreactive mydriasis	3	4.7%
Bilateral miosis	3	4.7%
Psychomotor agitation	6	9.4%
Seizures	4	6.3%
Digestive Signs		
Vomiting	26	40.6%
Gastric distension	12	18.8%
Other Clinical Signs		
Hypothermia	29	45.3%
Hyperthermia	5	7.8%
Capillary blood glucose > 2 g/L	8	12.5%
Capillary blood glucose < 0.5 g/L	1	1.6%
Biological abnormalities		
Metabolic acidosis	32	50%
Mixed acidosis	17	26.6%
Respiratory acidosis	4	6.3%
Hypokalemia	24	37.5%
Hypernatremia	20	31.2%
Rhabdomyolysis	18	28.1%
Elevated troponin	11	17.2%
Acute renal failure	10	15.6%
Hepatic cytolysis	9	14.1%

First aid was administered on-site to 85.9% of the victims. Basic cardiopulmonary resuscitation (CPR) was performed by a trained individual in 28.1% of cases. Transport was provided by civil protection in 54.7% of cases, by the emergency medical service in 23.4%, and by civilians in 21.9% of cases. The average admission time was 39 ± 17 minutes, ranging from 10 to 90 minutes.

The most frequent respiratory signs upon admission were tachypnea (93.8%) and abnormal pulmonary auscultation (93.8%). Auscultation revealed crackling rales in 84.4% of cases, oxygen (O2) saturation below 92% was observed in 73.4% of patients. Cardiac rhythm analysis revealed sinus tachycardia in 71.9% of cases and bradycardia in 6.3% of cases. No cases of cardiac arrhythmia or conduction disorders were noted. Shock with hypotension was identified in 15.6% of patients.

As for neurologic disorders, 12.5% of patients had a Glasgow Coma Scale (GCS) score below 9, and 10.9% of patients had severe coma with a GCS score of 3. Pupillary abnormalities were observed in 9.4% of patients. Psychomotor agitation was present in 9.4% of cases, and seizures were noted in 6.3% of patients.

Reported digestive symptoms included vomiting (40.6%) and gastric distension (18.8%). Hypothermia was observed in 45.3% of patients. Hyperglycemia was observed in 12.5% of patients and hypoglycemia in one (1.6%). Table 1 summarises clinical signs in our series.

Blood gas analysis, performed on all patients upon admission, showed metabolic acidosis in half of patients (50%), respiratory acidosis in 6.3%, and both respiratory and metabolic acidosis in 26.6% of them. It was normal in 17.2% of cases. The most frequent electrolyte imbalances were hypernatremia (31.2%) and hypokalemia (37.5%). Hyponatremia was noted in 12.5% of cases. We documented rhabdomyolysis in 28.1% of patients, acute renal failure in 15.6%, hepatic cytolysis in 14.1%, a low prothrombin rate (PT) in 14.1%, and elevated cardiac enzymes (troponin) in 17.2% of them. C-reactive protein (CRP) was positive in 9.4% of patients within the first 24 hours.

A chest X-ray was performed on all patients upon admission. It was normal in 18.8% of the children. It revealed a bilateral alveolar-interstitial syndrome in 65.6% of the patients (Figure 2), a bronchial syndrome in 12.5%, and a pulmonary consolidation focus in 3.1% of the cases. A brain CT scan was requested for two victims with a stage 6 drowning, who presented with coma and bilateral unreactive mydriasis at admission, showing cerebral oedema with cerebellar tonsil displacement both cases. A spinal CT scan, performed for one victim with spinal trauma associated with the drowning, showed no abnormalities.

Hospital Management

Invasive ventilation (IV) via orotracheal intubation was immediately required in 14.1% of the patients (9 patients) (Table 2). Mechanical ventilation was indicated due to triple respiratory, neurological, and hemodynamic distress in 8 patients, and due to severe respiratory distress in 1 patient.

Figure 2. Frontal chest X-ray showing bilateral alveolar-interstitial syndrome in a stage 3 drowning victim

Synchronized intermittent mandatory ventilation with pressure support (SIMV + PS) was used in 5 cases, while assist/control ventilation (ACV) was selected for 4 cases. Pressure-controlled ventilation was the most common mode (8 cases), with an average pressure of 21 mmHg [17-25 mmHg] and an average positive end-expiratory pressure (PEEP) of 4.5 mmHg [4-8 mmHg]. Volume-controlled ventilation was used in one 6-year-old patient with a tidal volume of 6 ml/kg. The average duration of invasive ventilation was 4 ± 6 days, ranging from 1 to 21 days. Most patients (79.7%) were initially placed on high-concentration oxygen therapy by mask. High-Flow Nasal Cannula (HFNC) was used for 4.7% of patients.

Continuous Positive Airway Pressure (CPAP) was indicated in one patient (1.6%). No failure requiring a switch to Invasive Ventilation (IV) was noted in patients receiving oxygen therapy or non-invasive ventilation. The drugs used for sedation and analgesia included: Midazolam (6.3%), Sufentanil (3.1%), Ketamine (1.6%), and Remifentanil (1.6%). Circulatory support with saline solution was administered to 10 patients (15.6%) showing signs of peripheral hypoperfusion or arterial hypotension, and vasopressors were required in 12.5% of children, using Adrenaline (9.4%), Noradrenaline (7.8%), and Dobutamine (1.6%). Anticonvulsants were given to 3 patients (4.7%), including Midazolam (3.1%), Diazepam (1.6%), and Clonazepam (1.6%). Mannitol osmotherapy was administered for 2 patients with cerebral oedema. Antibiotics were prescribed to 70.3% of patients, including Amoxicillin-clavulanic acid (64.1%), Cefotaxime (3.1%), Metronidazole (3.1%), Vancomycin (1.6%), Amikacin (1.6%), and Imipenem (1.6%). Diuretic therapy with Furosemide was administered to 65.6% of patients presenting with clinical and radiological signs of acute pulmonary oedema.

The average hospital stay was 2.5 ± 2.8 days, ranging from 1 to 21 days.

Mortality

The mortality rate was 10.9%. Causes of death included multiorgan failure (3 cases), refractory shock (2 cases), and cerebral herniation (2 cases). Univariate and multivariate analysis revealed several predictive factors of mortality from drowning (Table 2 and 3).

Table 2. Univariate Analysis of Predictive Factors for Mortality in Cases of Drowning

Factor		Mortality		Total	p-value
Age	< 3 years	3 (42.9%)	11 (19.3%)	14 (21.9%)	0.17
	> 3 years	4 (57.1%)	46 (80.7%)	50 (78.1%)	
Location	Sea	3 (42.9%)	46 (80.7%)	49 (76.6%)	0.047
	Other	4 (57.1%)	11 (19.3%)	15 (23.4%)	
Immersion Duration	> 5 min	7 (100%)	1 (1.8%)	8 (12.5%)	<0.005
	< 5 min	0 (0%)	56 (98.2%)	56 (87.5%)	
Presence of Witness	Yes	0 (0%)	45 (78.9%)	45 (70.3%)	<0.005
	No	7 (100%)	12 (21.1%)	19 (29.7%)	
First Aid Provided	Yes	3 (42.9%)	52 (91.2%)	55 (85.9%)	0.006
	No	4 (57.1%)	5 (8.8%)	9 (14.1%)	
Szpilman Stage	Stage 6	6 (85.7%)	0 (0%)	6 (9.4%)	<0.005
	Other	1 (14,3%)	57 (100%)	58 (90,6%)	
Medical evacuation	Yes	4 (57.1%)	46 (80.7%)	50 (78.1%)	0,17
	No	3 (42.9%)	11 (19.3%)	14 (21.9%)	
Arterial Hypotension	Yes	7 (100%)	3 (5.3%)	10 (15.6%)	<0.005
	No	0 (0%)	54 (94.7%)	54 (84.4%)	
Glasgow Coma Scale (GCS) < 8		7 (100%)	1 (1.8%)	8 (12.5%)	<0.005
Pupillary Abnormalities	Yes	6 (85.7%)	0 (0%)	6 (9.4%)	<0.005
	No	1 (14.3%)	57 (100%)	58 (90.6%)	
Temperature	< 35	7 (100%)	1 (1.8%)	8 (12.5%)	<0,005
	≥ 35	0 (0%)	56 (98.2%)	56 (87.5%)	
Blood glucose	≥ 2g	5 (71.4%)	3 (5.3%)	8 (12.5%)	<0,005
	< 2g	2 (28.6%)	54 (94.7%)	56 (87.5%)	
Blood pH	< 7.1	7 (100%)	2 (3.5%)	9 (14.1%)	<0.005
	≥ 7,1	0 (0%)	55 (96.5%)	55 (85.9%)	
Rhabdo-myolysis	Yes	7 (100%)	11 (19.3%)	18 (28.1%)	<0,005
	No	0 (0%)	46 (80.7%)	46 (80.7%)	
Hepatic cytolysis	Yes	7 (100%)	2 (3.5%)	9 (14.1%)	<0,005
	No	0 (0%)	55 (96.5%)	55 (85.9%)	
Acute Kidney injury	Yes	6 (85.7%)	4 (7%)	10 (15,6%)	<0,005
	No	1 (14.3%)	53 (93%)	54 (84,4%	
Low prothrombin time	Yes	6 (85.7%)	3 (5.3%)	9 (14.1%)	<0,005
	No	1 (14.3%)	54 (94.7%)	55 (85.9%)	
Troponin level	Elevated	6 (85,7%)	5 (8.8%)	11 (17.2%)	<0,005
	Normal	1 (14.3%)	52 (91.2%)	53 (82.8%)	

Table 3. Multivariate analysis of predictive factors of mortality in drowning victims

Studied factors	Threshold value	p-value
Szpilman score	Score 6	**< 0.005**
Glasgow Coma Scale (GCS)	< 8	**< 0.005**
Pupillary abnormalities	Present	**< 0.005**
Body temperature	< 35°C	**< 0.005**
Hepatic cytolysis	Present	0.02
Blood pH	< 7.1	**< 0.005**

Discussion

According to the WHO global report, drowning is responsible for more than 372,000 deaths annually worldwide, with the pediatric population particularly affected.

In our series, drowning was more common in boys, consistent with data from the literature (7,8). Our study showed that the most affected age group was between 10 and 15 years, whereas other studies report that the highest drowning rates occur among children aged 1 to 4 years, followed by those aged 5 to 9 years (9). In our series, drowning occurred mainly in seawater, especially during the summer, as the city is coastal.

In most cases, drowning in our study was primary. It was secondary to a seizure in 4.7% of cases. In fact, drowning can be primary or secondary to a medical cause, such as a seizure or cardiac arrhythmia (Long QT syndrome), loss of consciousness following head trauma, or syncope due to a sudden temperature difference between the air and the water. Epilepsy and autism spectrum disorders have been shown to increase the relative risk of drowning in childhood (10,11).

In our study, we classified drownings according to the Szpilman algorithm, published in 1997. This is the most recent and widely used classification. It is a prognostic and therapeutic classification based on clinical data observed at the accident scene during the initial rescue efforts. It is useful in practice for emergency physicians, allowing them to predict mortality risk based on the initial stage observed (3,6).

Pre-hospital care is crucial, playing a significant role in the prognosis of drowning victims (12). In fact, the prognosis is linked to the promptness and quality of care provided at the scene: "TIME IS BRAIN, TIME IS LIFE." The fundamental principles of this care are: preventing hypoxia, restoring cardiovascular stability, fighting hypothermia, and quickly transporting the victim to a specialized center. Szpilman developed a universal drowning survival chain (3), whose implementation helps reduce drowning-related mortality. It includes a series of interventions, starting with preventing drowning. Other interventions include recognizing distress and alerting help, providing flotation devices, safely removing the person from the water, and finally, providing basic and advanced care, if necessary.

In our series, first aid was administered in 85.9% of cases, but only 28.1% of cases by a trained person. Early CPR at the scene is the key to a good prognosis (13). It should not be delayed and must be performed by an experienced rescuer. Initial actions include assessing if the victim is breathing normally and conscious. If the victim is unconscious and not breathing, basic CPR should begin. Upon the arrival of emergency services, a primary assessment using the Pediatric Assessment Triangle (PAT) is crucial, allowing for quick visual assessment of the child's clinical status based on three components: A = Appearance, B = Work of Breathing, and C = Circulatory status. Resuscitation efforts should continue by the responders. If the patient is conscious, oxygen therapy should be provided via a mask. Positive end-expiratory pressure (PEEP) ventilation is also beneficial (14). In the absence of spontaneous breathing or in cases of acute respiratory failure, or if the Glasgow Coma Scale (GCS) score is ≤8, the patient should be intubated and mechanically ventilated after rapid sequence induction, with the insertion of a gastric tube. If ventricular fibrillation occurs, defibrillation must be performed. Preventing hypothermia is critical; drying the patient and covering them with a blanket is necessary. Vascular access should be achieved through a peripheral vein or intraosseous route, with fluid resuscitation if circulatory failure is present (3,4,15). In our study, only 23.4% of cases were transported by the SAMU. Transportation to a specialized center should occur after the victim is stabilized and must be medicalized due to the risk of secondary clinical deterioration (16).

Hospitalization in an intensive care unit is recommended for drowning victims with a Szpilman stage of 3 or higher. Patients with stage 2 can be observed in the emergency department, and those with stage 1 can be discharged home (17).

In our study, respiratory symptoms were the most prevalent clinical signs. Tachypnea, observed in 93.8% of cases, were present in most studies (4). Bradypnea is a sign of exhaustion and signals an imminent cardiopulmonary arrest. Desaturation indicates hypoxemia and requires oxygen therapy. Respiratory effort may be present. Lung auscultation may reveal wheezes or crackles associated with pulmonary edema or aspiration pneumonia (15,17,18). Lung ultrasound can detect pulmonary edema, pleural effusion, or alveolar consolidation (19). Regarding hemodynamic abnormalities, tachycardia was the most frequent sign in our study, consistent with other studies (17). Bradycardia is rare but signals imminent cardiopulmonary arrest in children. Peripheral hypoperfusion signs may be present, and hypotension occurs late, signalling cardiovascular decompensation (13). Cardiac ultrasound, by assessing cardiac output and systolic ejection fraction, helps guide fluid resuscitation and vasopressor therapy (20). Hypoxia and hypothermia can cause arrhythmias, leading to cardiopulmonary arrest (21). Hypoxemia causes ischemic neuronal damage, potentially progressing to cerebral oedema and increased intracranial pressure (22,23). The Glasgow Coma Scale (GCS) is essential for assessing the neurological status of any child who has drowned, guiding therapeutic decisions, and establishing a prognosis (24,25). The detection of bilateral fixed and dilated pupils is considered a grave prognostic sign, underscoring the importance of meticulous pupillary evaluation (25). Agitation may occur, related to cerebral hypoperfusion secondary to hypoxemia or hemodynamic instability. Seizures may occur at the scene, during transport, or upon admission, exacerbating primary brain damage and increasing cerebral oxygen demand. Transcranial Doppler, by evaluating cerebral hemodynamics, can identify high-risk patients for cerebral ischemia, necessitating cerebral hemodynamic optimization (26). Hypothermia is an inevitable consequence of immersion, and its occurrence during drowning may extend survival without neurological damage, acting as a neuroprotective factor

(27).

Considering biological parameters, blood gas analysis is essential to identify hypoxemia and detect acid-base imbalances, respiratory or metabolic acidosis (24). Metabolic acidosis, common in our series, is secondary to tissue hypoxia and anaerobic lactic metabolism. The most frequent electrolyte disturbances in our study were hypokalemia and hypernatremia. Hypokalemia is due to hyperdiuresis, hyperkaliuresis, and hemodilution, while hypernatremia results from the digestive absorption of saltwater and hemoconcentration. Acute renal failure is also common, secondary to rhabdomyolysis, hypoperfusion, and lactic acidosis (17). Hyperglycemia reflects adrenergic hyperactivity due to stress (17).

As for radiology findings, a chest X-ray was systematically requested in our series to detect alveolar-interstitial syndrome, aspiration pneumonia, ventilation disturbances, and associated traumatic injuries. A brain CT scan may be performed in the initial phase of drowning in cases of suspected head trauma or to detect cerebral oedema or ischemic brain lesions (23). It can also be used to diagnose brain death. Spinal CT is useful for detecting fractures and other bony abnormalities in cases of suspected spinal trauma.

Respiratory management is a crucial component of drowning care in children, involving oxygen therapy, non-invasive ventilation (NIV), or invasive ventilation. In our series, none of the patients initially placed on NIV required invasive ventilation. Indeed, NIV, by applying PEEP, promotes good alveolar recruitment and improves oxygenation. Its advantages include rapid clinical improvement and reduced hospitalization time (28,29).

Invasive ventilation was immediately indicated in 14.1% of cases in our study, with pressure mode being the most commonly used. Mechanical ventilation must be protective to minimize barotrauma: a tidal volume of 6 ml/kg to achieve SpO2 ≥ 92% and normocapnia, an initial PEEP of 5 cm H2O, which can be increased as needed (PaO2/FiO2 ≥ 250), and the lowest possible FiO2 (13,30). In cases of acute respiratory distress syndrome (ARDS), a protective pulmonary ventilation strategy should be used (28,30). Hemodynamically, circulatory failure can be corrected through oxygenation, crystalloid infusion, and restoring normal body temperature (28). The use of vasopressors and inotropes is guided and monitored by cardiac ultrasound (20). Studies have not shown the benefit of fluid restriction or diuretic use (3). Extracorporeal membrane oxygenation (ECMO) may be considered when the patient has profound hypothermia or insufficient oxygenation under conventional respiratory support (28).

Neurological resuscitation is based on neuroprotection by combating secondary systemic brain injuries (ACSOS) and ensuring adequate cerebral perfusion pressure (3,15,23). Ventilatory targets include SpO2 ≥ 95%, PaO2 ≥ 80mmHg, and PaCO2 between 35 and 40 mmHg. Good sedation reduces cerebral metabolism and thus oxygen consumption. Rapid treatment of seizures or possible intracranial hypertension is essential. Routine antibiotic prophylaxis is not recommended. Broad-spectrum antibiotics should be initiated immediately in cases of drowning in water with a high pathogen load (UFC>1020). In other cases, antibiotics should be considered based on the patient's clinical, radiological, and biological status (3).

In our study, the mortality rate was 10.9%. This rate varies between 8% and 22% according to different series (31–33). The poor prognostic factors for mortality identified in our study were a Szpilman score of 6, a Glasgow Coma Scale (GCS) score < 8, pupillary abnormalities, a body temperature < 35°C, biological markers of hepatic cytolysis, and a blood pH < 7.1. The Szpilman classification is correlated with mortality (13). A Szpilman stage 6 is associated with a survival rate not exceeding 12% (Table 4). Studies have shown that neurological sequelae following drowning mainly occur in victims with a GCS score below 8 (31). Bilateral mydriasis has been described as a poor prognostic sign (34). Based on various publications, biological abnormalities associated with poor prognosis and higher mortality include: low blood bicarbonate levels, arterial pH <7.1, blood glucose >11.2 mmol/L, cytolysis, hypernatremia, and acute kidney injury (34–36).

Table 4. Survival According to Szpilman Classification

Stage	Survival
Stage 1	100%
Stage 2	99%
Stage 3	95–96%
Stage 4	78–82%
Stage 5	56–69%
Stage 6	7–12%

In addition to the factors identified in our study, the duration of submersion is an important prognostic factor, although it is often difficult to estimate. It is correlated with survival rates: the shorter the submersion time, the better the chance of survival (37). A submersion duration exceeding 5 minutes is associated with significantly higher mortality and greater neurological impairment (3,38). Orlowski also demonstrated in his study that early initiation of resuscitative measures was the most critical factor influencing survival (39). Cardiopulmonary resuscitation (CPR) initiated within 10 minutes of submersion is considered a favorable prognostic factor (35). Indeed, the rapid recovery of cardiac activity, as well as its spontaneous presence, is a sign of good prognosis (35).

A prognostic score was developed by Orlowski based on several parameters (39). Each parameter is assigned one point. A total score of ≥ 3 indicates a poor prognosis, with only a 5% chance of survival, whereas a score of ≤ 2 is associated with a 90% likelihood of favorable outcome. The poor prognostic factors included in this score are: age less than 3 years, comatose state upon hospital admission, estimated submersion time exceeding 5 minutes, initiation of resuscitation more than 10 minutes after submersion, and arterial pH at admission below 7.1. The main limitation of our study is the small sample size. This underlines the need for a national multicenter study

that would allow for a more representative overview of the Tunisian population.

Conclusion

Drowning in the pediatric population is frequent in our country, particularly during the summer months. This accident can be life-threatening and is associated with significant morbidity and mortality. Early management, focused on countering the consequences of hypoxia and ensuring high-quality cardiopulmonary resuscitation (CPR) initiated at the site of submersion, is crucial to improving prognosis and survival rates.

Drowning is a major cause of morbidity and mortality in children worldwide, particularly during the summer.
Prognostic factors for mortality in drowning include duration of submersion, initial neurological status, and early resuscitation quality.
There is limited data from North African countries, including Tunisia, regarding pediatric drowning outcomes.
This study provides epidemiological and clinical data on pediatric drowning cases in a Tunisian tertiary center.
It identifies prognostic factors specific to this population, including Szpilman stage, Glasgow Coma Scale score, and biological abnormalities.
The findings support the need for early intervention and may guide preventive strategies in Tunisia and similar settings.

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