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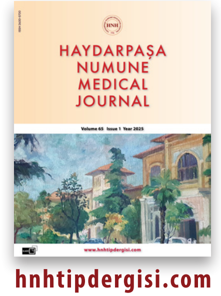

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Evaluation of Drowning Cases Followed Up in the Pediatric Intensive Care Unit: A Retrospective Single-Center Study Covering 8 Years

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Abstract

Introduction: This study aimed to evaluate the clinical characteristics, intensive care processes, complications, and prognostic indicators in pediatric drowning cases.

Methods: A retrospective review was conducted of 28 patients admitted to a tertiary pediatric intensive care unit due to drowning between January 2016 and January 2024. Patients were categorized according to saltwater or freshwater drowning. Demographic data, clinical findings, laboratory values, treatment interventions, and complications were analyzed. Additionally, a subgroup analysis was performed comparing patients with poor outcomes (mortality and/or neurological sequelae) and those with good outcomes.

Results: Among the patients, 78.6% were male. The median submersion time was 6.8 minutes. Cardiac arrest was observed in 32.1% of cases. ARDS and mortality rates were higher in the saltwater group. Subgroup analysis revealed statistically significant associations between poor outcomes and longer CPR duration, lower GCS scores, higher frequency of ARDS and cardiac arrest, lower pH, and more negative base excess ($p<0.05$).

Discussion and Conclusion: This study identifies key clinical parameters associated with poor prognosis in pediatric drowning. These findings are hypothesis-generating and should be supported by larger, multicenter, prospective studies evaluating survival and neurological recovery after drowning, particularly in saltwater drowning cases.

Keywords: Cardiac arrest; intensive care; pediatric drowning; prognostic factors.

Drowning is one of the emergencies that causes significant mortality and morbidity in childhood worldwide and is among the leading causes of death due to accidental injuries [1]. The drowning process begins with primary respiratory failure resulting from submersion in a liquid environment, followed by complications such as hypercapnia, hypoxemia, and cardiorespiratory arrest [2]. According to World Health Organization data, drowning is the third most common (7%) cause of injury-related deaths. It is estimated that approximately 359,000 people worldwide die from drowning every year [3]. Children, in particular, are at high risk of drowning due to their lack of awareness of dangers and inadequate supervision. In parallel, drowning rates are approximately three times higher in low- and middle-income countries than in high-income countries [4].

The pathophysiology of drowning is complicated by physiological processes such as laryngospasm, hypoxia, and acidosis that develop when the respiratory tract comes into contact

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with liquid after exposure. Factors such as the duration of drowning, the duration of respiratory arrest, and the duration of cardiopulmonary resuscitation (CPR) applied at the time of intervention are the main factors determining the risk of developing neurological damage. Cases in which the duration of stay in water is longer than 5 minutes or CPR is started late have been associated with a poor prognosis [5]. The duration of stay in the water, the need for CPR, and the duration of CPR, which are fundamental parameters for survival in drowning cases, are considered among the important determinants of neurological outcomes that develop in childhood [6].

Drowning incidents are common in children, especially those aged 1–4 years, due to their natural curiosity, limited perception of danger, lack of swimming skills, and lack of supervision. Drowning incidents frequently occur in unsupervised aquatic environments such as pools, open bodies of water, and bathtubs [7]. Effective and rapid intervention at the scene plays a decisive role in the clinical prognosis of pediatric drowning cases. It has been reported that properly performed CPR positively affects survival rates [8].

In view of the foregoing, the objective of this study is to contribute to pediatric intensive care practice by analyzing the prognostic factors, clinical courses, and possible recovery processes of pediatric drowning cases in our sample in comparison with relevant literature data.

Materials and Methods

Study Design

This retrospective single-center study was conducted with 28 drowning cases under the age of 18 admitted to a pediatric intensive care unit in Istanbul between January 1, 2016, and January 1, 2024. The study protocol was approved by the Istanbul Medipol University Non-Interventional Clinical Research Ethics Committee (Decision No: 999). This study was conducted in accordance with the ethical principles of the Declaration of Helsinki. The study was conducted by observing ethical principles regarding patient rights. All patient data were collected with due regard for patient confidentiality and anonymized during the analysis process.

Data Collection

Patients' demographic characteristics, including age, gender, and location of the incident (saltwater or freshwater); and clinical characteristics, including vital signs at admission such as cardiac and respiratory status, heart rate, and body temperature; blood gas parameters at admission such as pH, lactate level, and base excess; Glasgow Coma Scale (GCS) score at admission; history of comorbidities; interventions and responses to these interventions, including use of antibiotics and neuroprotective agents; use and duration of mechanical ventilation (invasive and noninvasive); use and duration of CPR; and therapeutic hypothermia; neurological and cardiopulmonary complications, including acute respiratory distress syndrome (ARDS), renal failure, cerebral edema, convulsions, sequelae, and mortality; and length of hospital stay were retrospectively compiled from patient files and analyzed.

Statistical Analysis

The statistical analyses of the collected data were conducted using SPSS 24.0 (Statistical Product and Service Solutions for Windows, Version 24.0, IBM Corp., Armonk, NY, U.S., 2016) software package. The results of the statistical analyses were expressed using descriptive statistics, i.e., median with 25th and 75th percentile values for continuous variables and numbers (n) and percentage (%) values for categorical variables. The chi-square test or Fisher's exact test was used to evaluate the relationships between categorical variables, depending on the distribution characteristics of the analyzed data. Differences in continuous variables between the groups were analyzed using the Mann–Whitney U test. Probability (p)<0.05 was deemed to indicate statistical significance.

Results

Twenty-eight patients admitted to the pediatric intensive care unit following a drowning incident were divided into two groups: patients who experienced drowning in freshwater (n=11, 39.3%) and those who experienced drowning in saltwater (n=17, 60.7%). Patients' demographic and clinical characteristics, treatment processes, and developing complications were examined comparatively between these two groups.

Demographic Characteristics

The median age of the sample, 78.6% of whom were male and 21.4% female, was 79.5 (min 9, max 176) months. 90.9% and 70.6% of those who experienced saltwater and freshwater drowning, respectively, were male (p=0.355). The median age of cases who experienced saltwater and freshwater drowning was 90 and 33 months, respectively (p=0.005). The fact that only 7.1% of patients had comorbidities indicates that pediatric drowning cases are generally seen among healthy children (Table 1). The distribution of drowning cases over the years did not indicate a significant change (Fig. 1).

Duration of Stay in Water and Vital Signs

The median time the cases remained in the water was 6.8 minutes. The median time in water for those who experi-

Table 1. Demographic, imaging and treatment characteristics of pediatric drowning cases

Variables	Overall (n=28)	Seawater (n=17)	Freshwater (n=11)	p
Gender				
Male	22 (78.6)	12 (70.6)	10 (90.9)	0.355
Female	6 (21.4)	5 (29.4)	1 (9.1)	
Comorbidity				
No	26 (92.9)	15 (88.2)	11 (100.0)	0.505
Yes	2 (7.1)	2 (11.8)	0 (0.0)	
Cardiac Arrest				
No	19 (67.9)	11 (64.7)	8 (72.7)	0.976
Yes	9 (32.1)	6 (35.3)	3 (27.3)	
Pathological Findings on Cranial Imaging				
No	25 (89.3)	16 (94.1)	9 (81.8)	0.543
Yes	3 (10.7)	1 (5.9)	2 (18.2)	
Antibiotic Use				
No	9 (32.1)	3 (17.6)	6 (54.5)	0.095
Yes	19 (67.9)	14 (82.4)	5 (45.5)	
Neuroprotective Agent Use				
No	19 (67.9)	11 (64.7)	8 (72.7)	>0.999
Yes	9 (32.1)	6 (35.3)	3 (27.3)	
Non-invasive Mechanical Ventilation				
No	13 (46.4)	6 (35.3)	7 (63.6)	0.280
Yes	15 (53.6)	11 (64.7)	4 (36.4)	
Invasive Mechanical Ventilation				
No	20 (71.4)	14 (82.4)	6 (54.5)	0.200
Yes	8 (28.6)	3 (17.6)	5 (45.5)	
Therapeutic Hypothermia				
No	26 (92.9)	17 (100.0)	9 (81.8)	0.146
Yes	2 (7.1)	0 (0.0)	2 (18.2)	

Values are presented as n (%). n: Number of cases.

enced saltwater and freshwater drowning was 5 and 7 minutes, respectively (p=0.297). The GCS scores of those who experienced saltwater and freshwater drowning were 13 and 7, respectively (p=0.162) (Table 2).

Laboratory Parameters, Cranial Imaging Findings, and Cardiac Arrest

The median blood pH of the cases at admission was 7.31. The median lactate level of those who experienced saltwater and freshwater drowning was 3.00 mmol/L and 4.00 mmol/L, respectively (p>0.05) (Table 2). Cranial computed tomography and magnetic resonance imaging revealed

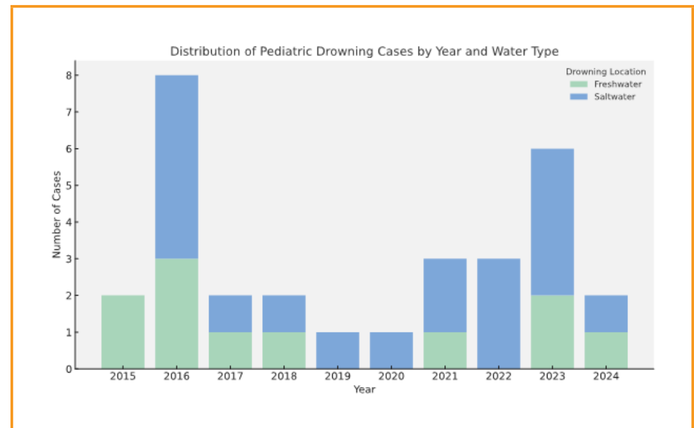

Figure 1. Distribution of Pediatric Drowning Cases by Year and Water Type (2015-2024).

This stacked bar chart illustrates the annual distribution of pediatric drowning cases treated at our pediatric intensive care unit over a 10-year period. The cases are categorized by drowning location: freshwater (light green) and saltwater (blue). The data show temporal variations in drowning incidents, with notable peaks in 2016 (8 cases) and 2023 (6 cases). Saltwater drownings were more prevalent throughout most of the study period, particularly in 2021, 2022, and 2023. Freshwater drownings were most common in 2016, with very few cases reported in 2019 and 2020. This temporal distribution analysis provides important insights for developing seasonal drowning prevention strategies and optimizing pediatric intensive care resources.

pathological findings in 10.7% of the cases, suggesting possible neurological effects of asphyxiation (Table 1). Cardiac arrest was observed in 32.1% of all patients and in 35.3% and 27.3% of those who experienced saltwater and freshwater drowning, respectively (p=0.976).

Treatment Process and Intensive Care Interventions

Noninvasive and invasive mechanical ventilation were applied in 53.6% and 28.6% of the patients, respectively. The median duration of invasive mechanical ventilation was 3.9 days and reached up to 13 days in some cases. Therapeutic hypothermia was performed in only 7.1% of cases. Antibiotic treatment was applied to 67.9% of the cases, mainly in those at risk of infection. Although the rate of patients treated with antibiotics was higher among those who experienced saltwater drowning than among those who experienced freshwater drowning, the difference was not statistically significant (p=0.95) (Table 1).

Complications

During follow-up, 14.3% of patients developed ARDS. The rate of ARDS was higher among those who experienced saltwater drowning than among those who experienced freshwater drowning (17.6% vs. 9.1%). Renal failure, observed in 7.1% of cases, occurred only among those who experienced saltwater drowning (p=0.505). Conversely, cerebral edema,

Table 2. Clinical and laboratory parameters of drowning cases at presentation and during follow-up

Parameters	Overall (n=28)	Seawater (n=17)	Freshwater (n=11)	p
Age *(months)*	79.5 (42.5-106.5)	90.0 (56.0-112.0)	33.0 (17.0-83.0)	**0.005**
Submersion Time *(minutes)*	5.0 (3.0-7.5)	5.0 (3.0-6.0)	7.0 (3.0-9.0)	0.297
Glasgow Coma Scale	12.0 (6.5-15.0)	13.0 (8.0-15.0)	7.0 (4.0-15.0)	0.162
pH	7.31 (7.25-7.38)	7.33 (7.30-7.38)	7.29 (7.10-7.33)	0.125
Lactate *(mmol/L)*	3.15 (2.05-4.30)	3.00 (2.10-3.30)	4.00 (1.70-7.00)	0.212
Base Excess	-3.45 (-5.20-(-2.00))	-3.30 (-4.00-(-2.00))	-4.00 (-9.00-(-2.00))	0.230
Heart Rate *(beats/min)*	103.5 (91.5-124.5)	95.0 (80.0-113.0)	110.0 (101.0-130.0)	0.066
Body Temperature *(°C)*	36.5 (35.9-36.8)	36.7 (36.0-36.9)	36.0 (35.8-36.7)	0.119
NIV Duration *(days)*	1.5 (1.0-2.0)	2.0 (1.0-2.0)	1.0 (1.0-2.5)	0.491
IMV Duration *(days)*	3.0 (2.0-3.5)	3.0 (2.0-13.0)	3.0 (2.0-3.0)	0.539
PICU Length of Stay *(days)*	3.0 (2.0-4.0)	3.0 (2.0-4.0)	2.0 (2.0-4.0)	0.596
Hospital Length of Stay *(days)*	4.0 (3.0-6.0)	4.0 (3.0-5.0)	4.0 (3.0-11.0)	0.720

Values are presented as Median [Interquartile Range).
Bold p-values indicate statistical significance (p≤0.05).
n: Number of cases; mmol/L: Millimoles per liter; °C: Degrees Celsius; NIV: Non-invasive Mechanical Ventilation; IMV: Invasive Mechanical Ventilation; PICU: Pediatric Intensive Care Unit.

Table 3. Complications During Treatment and Follow-up of Drowning Cases

Complications	Overall (n=28)	Seawater (n=17)	Freshwater (n=11)	p
ARDS				
No	24 (85.7)	14 (82.4)	10 (90.9)	>0.999
Yes	4 (14.3)	3 (17.6)	1 (9.1)	
Renal Failure				
No	26 (92.9)	15 (88.2)	11 (100.0)	0.505
Yes	2 (7.1)	2 (11.8)	0 (0.0)	
Cerebral Edema				
No	27 (96.4)	17 (100.0)	10 (90.9)	0.393
Yes	1 (3.6)	0 (0.0)	1 (9.1)	
Seizures				
No	24 (85.7)	16 (94.1)	8 (72.7)	0.269
Yes	4 (14.3)	1 (5.9)	3 (27.3)	
Sequelae				
No	24 (85.7)	15 (88.2)	9 (81.8)	0.529
Yes	2 (7.1)	2 (11.8)	0 (0.0)	
Mortality				
No	26 (92.9)	15 (88.2)	11 (100.0)	0.505
Yes	2 (7.1)	2 (11.8)	0 (0.0)	

Values are presented as n (%); n: Number of cases; ARDS: Acute Respiratory Distress Syndrome.

observed in 3.6% of cases, occurred only among those who experienced freshwater drowning. Convulsions were observed in 14.3% of all patients. The rate of convulsions was higher among those who experienced freshwater drowning than among those who experienced saltwater drowning (27.3% vs. 5.9%, p=0.269), suggesting that neurological effects may be more pronounced in freshwater drowning cases. The rate of patients with sequelae at discharge from the pediatric intensive care unit was 7.2%, and long-term neurological damage occurred in 10.7% of the cases (Table 3).

Mortality

Mortality occurred in 2 (7.1%) of the cases. Both cases were among those who experienced saltwater drowning (Table 3).

Subgroup Analysis Based on Clinical Outcomes

To evaluate prognostic indicators, patients were divided into two subgroups: the poor outcome group (n=4; patients who died or were discharged with neurological sequelae) and the good outcome group (n=24; patients discharged without sequelae). In the poor outcome group, compared with the good outcome group, significantly shorter submersion time (p=0.001), longer CPR duration (p=0.014), lower GCS score (p=0.004), and higher rates of cardiac arrest (p=0.022), invasive mechanical ventilation (p=0.003), and ARDS (p=0.005) were observed. Additionally, this group exhibited lower pH levels (p=0.050) and more negative base excess values (p=0.042) (Table 4).

Discussion

In this study, we evaluated the clinical characteristics, complications, and outcomes of pediatric drowning cases managed in a pediatric intensive care setting. Additionally, differences between saltwater and freshwater submersion and prognostic indicators were examined in detail. Our findings align with those in the existing literature and highlight the critical role of early intervention, clinical parameters, and intensive care interventions in determining outcomes.

Table 4. Comparison of demographic, clinical, laboratory, and outcome variables between patients with poor and good prognosis

Variable	Poor Outcome Group (n=4)	Good Outcome Group (n=24)	p
Age, median (IQR) (months)	117.5 (51.5–165)	84.5 (37.2–178.3)	
Female sex, n (%)	1 (25)	5 (20.8)	>0.999
Presence of comorbidity, n (%)	2 (50)	0 (0)	**0.016**
Submersion time, median (IQR) (min)	14 (8–42.5)	5 (2.25–6)	**0.001**
Cardiac arrest, n (%)	4 (100)	5 (20.8)	**0.022**
CPR duration, median (IQR) (min)	32.5 (22.5–42.5)	10 (6–12.5)	**0.014**
Heart rate, median (IQR) (beats/min)	100.5 (88.5–126)	115.5 (104–151)	0.144
GCS, median (IQR)	15 (12.75–15)	4.5 (4–6.5)	**0.004**
Body temperature, median (IQR) (°C)	36.6 (35.9–36.9)	35.9 (35.8–36.5)	0.164
pH, median (IQR)	7.32 (7.28–7.40)	7.11 (6.94–7.31)	**0.050**
Lactate, median (IQR) (mmol/L)	2.1 (1.2–3.7)	8 (2.2–14.4)	0.082
Base excess, median (IQR)	−3.2 (−4.67 to −1.85)	−16.9 (−21.5 to −4.95)	**0.042**
pCO_2, median (IQR) (mmHg)	39.5 (37.6–43.1)	40.4 (37–41.6)	>0.999
paO_2, median (IQR) (mmHg)	85.8 (82.8–92.1)	88 (84.9–95.8)	0.355
HCO_3, median (IQR) (mmol/L)	23.9 (22.7–24.9)	22.2 (23.3–24.9)	0.465
Sodium, median (IQR) (mmol/L)	140 (137.7–142.2)	138.7 (137.7–142.8)	0.776
Potassium, median (IQR) (mmol/L)	4.3 (3.9–4.8)	3.95 (3.5–4.6)	0.291
AST, median (IQR) (U/L)	22.3 (15.1–32.6)	18.2 (12.6–29.4)	0.427
ALT, median (IQR) (U/L)	31.7 (21.2–41.6)	30.1 (26.1–32.4)	0.681
Hemoglobin, median (IQR) (g/dL)	12.8 (12.1–13.4)	12 (11.2–14.3)	0.547
Invasive mechanical ventilation, n (%)	4 (100)	4 (16.7)	**0.003**
Therapeutic hypothermia, n (%)	1 (25)	1 (4.2)	0.270
PICU length of stay, median (IQR) (days)	3 (2–4)	3.5 (1.75–74.5)	0.590
ARDS, n (%)	3 (75)	1 (4.2)	**0.005**
Renal failure, n (%)	1 (25)	1 (4.2)	0.270
Cerebral edema, n (%)	1 (25)	0	0.143
Seizures, n (%)	1 (25)	3 (12.5)	0.481

IQR: Interquartile range; CPR: Cardiopulmonary resuscitation; GCS: Glasgow Coma Scale; BE: Base excess; AST: Aspartate aminotransferase; ALT: Alanine aminotransferase; Hgb: Hemoglobin; ARDS: Acute respiratory distress syndrome; PICU: Pediatric intensive care unit.

Sex and Age Distribution

The fact that 78.6% of cases involved male children may be associated with increased exposure of boys to environmental risks and unsupervised water contact. Smith et al. emphasized that social and behavioral factors elevate the risk of drowning in boys [9]. Appelbaum et al. also underlined that inadequate parental supervision significantly increases drowning risk, particularly in younger children [10].

Saltwater vs. Freshwater and Cardiac Arrest

The rate of cardiac arrest was higher among patients who drowned in saltwater (35.3%). This may be related to the risk of pulmonary edema and hypoxemia caused by hypertonic water. Markarian et al. reported that saltwater aspiration is associated with acute lung injury [11]. Nevertheless, other studies have emphasized that, regardless of water type, hypoxia and ventilation–perfusion mismatch are more decisive in determining mortality [12,13].

Submersion Duration, CPR, and Neurological Outcomes

The mean submersion time in our cohort was 6.8 minutes, and its impact on neurological outcomes was significant. Low GCS scores and prolonged CPR duration were significantly associated with neurological sequelae. Suominen et al. and Manglick et al. reported that prolonged submersion leads to hypoxic brain injury [14,15]. Similarly, Quan et al.'s

[12] meta-analysis demonstrated that submersion exceeding 10 minutes is strongly associated with severe neurological impairment. Our subgroup analysis statistically confirmed these findings.

Intensive Care Practices and Therapeutic Interventions

Therapeutic hypothermia was applied in only 7.1% of patients, indicating limited use of neuroprotective strategies. Chen et al. [17] have shown that therapeutic hypothermia may improve neurological outcomes in appropriately selected cases. Standardization of clinical protocols and dissemination of treatment guidelines in this area remain a key need. Respiratory support was required in 82.2% of patients, underlining the severity of pulmonary injury following drowning. ARDS developed in 14.3% of cases and was more common in the saltwater group. Yadav et al. [18] and Grimes et al. [19] reported that ARDS is a frequent complication after drowning and that early ventilation support can improve survival. The need for invasive mechanical ventilation was also found to be significantly associated with poor prognosis in our study.

Mortality

The mortality rate in our cohort was 7.1%, and all deaths occurred in the saltwater group. While this may suggest a higher risk profile for saltwater drowning, the small sample size limits generalizability. Ryan et al. highlighted that survival after drowning depends heavily on the timing and quality of intervention [20]. In our cohort, prolonged CPR was significantly associated with mortality.

Prognostic Indicators in Pediatric Drowning

Our subgroup analysis demonstrated significant associations between poor outcomes (death and/or neurological sequelae) and the following variables: prolonged CPR duration, low GCS, higher rates of cardiac arrest and ARDS, need for invasive ventilation, lower pH, and more negative base excess. These findings are in line with the results of studies by Quan et al. [12], Niamsanit et al. [22], and Pellegrino et al. [13]. In particular, the national data from Thailand reported by Niamsanit et al. identified cardiac arrest, metabolic acidosis, and renal failure as significant predictors of mortality [22]. Our findings support these associations with statistically significant relationships.

Limitations of the Study

This study provides valuable clinical insights into drowning cases admitted to a tertiary pediatric intensive care unit over an eight-year period. However, several limitations should be considered. First, the retrospective design inherently carries risks such as missing data, non-standardized records, and variability in documentation quality. Second, as a single-center study with a relatively small sample size, the generalizability of the findings is limited, and the statistical power of subgroup analyses (particularly those related to mortality or neurological sequelae) is reduced. Third, long-term neurological and developmental outcomes could not be evaluated; since data were limited to the point of discharge, the true burden of cognitive or motor sequelae may have been underestimated. Therefore, future studies with larger sample sizes, multicenter and prospective designs, and standardized neurodevelopmental assessments are essential to better understand prognosis.

Conclusion

This study identifies a range of clinical variables associated with the prognosis of pediatric drowning cases. However, due to the single-center nature and relatively small sample size, our findings should be interpreted as hypothesis-generating. Future multicenter, prospective studies with larger cohorts are needed to validate and expand upon these observations.

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