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Original Article

Therapeutic Approaches and Mortality in Acute Respiratory Failure due to Drowning

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Abstract

OBJECTIVE: Drowning is a process of submersion and can lead to respiratory failure. Annually, there are an estimated 320 000 deaths worldwide due to drowning, in addition to nonfatal drowning events. There are limited data for respiratory failure due to drowning and its prognosis in Turkey. The aim of this study was to identify the therapeutic modalities used for acute respiratory failure (ARF) due to drowning, and its prognosis in hospitalized patients.

MATERIAL AND METHODS: All adult drowning cases (according to the International Classification of Disease (ICD) diagnosis code) who were admitted to either the emergency department (ED) or the intensive care units (ICU), or the pulmonology inpatient clinics between 2008 and 2018 were included in the study. Data for demographic characteristics, radiologic evaluations, respiratory support and mechanical ventilation, hospital stay duration, and hospital mortality were retrospectively collected from hospital records.

RESULTS: A total of 117 patients (47 females, 70 males, mean age: 57.3 years) were included in the study. The drowning accidents most commonly occurred in summer (86.3%). Of them, 31 victims (26.4%) were admitted to ICU due to severe respiratory failure. The mean pH was 7.32, and PaO_2 was 69.13 mmHg in the arterial blood gas at admission. Invasive and noninvasive mechanical ventilation were performed in 24.7% and 25.6% of the patients respectively. The PaO_2/FiO_2 of 106 patients (who had accessible FiO_2 values) were >300 in 12 (11%), 201-300 in 32 (30%), 101-200 in 49 (46%), and <100 in 13 (12%) patients. Bilateral opacities were observed in 85.4% of the patients. Cardiopulmonary resuscitation was performed in 8 (6.8%) patients. The hospital mortality rate was 6%.

CONCLUSION: The present study results show that with appropriate therapeutic and support strategies, respiratory failure due to drowning can be treated successfully.

KEYWORDS: Drowning, respiratory failure, intensive care unit, mechanical ventilation, high-flow nasal cannula
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INTRODUCTION

According to the World Health Organization (WHO), drowning is the third leading cause of accidental injury and death worldwide and accounts for 7% of all injury-related deaths.[1] Worldwide, there are an estimated 320 000 deaths due to drowning annually. Drowning, a major public health problem, is underestimated according to world estimates. Children, males and individuals with greater access to water are most at risk. Statistics for nonfatal drowning are more difficult to obtain, but these events may occur several hundred times as frequently as the reported drowning deaths.[2,3] Since some cases of fatal drowning are not classified as such according to the codes of the International Classification of Disease (ICD), this number underestimates the real figures, even for high-income countries,[4] and does not include drownings that occur as a result of floods, tsunamis, and boating accidents.

Drowning usually begins with panic, and then continues with the loss of normal breathing patterns, breath-holding, air hunger, and the victim's struggle to stay above water. Reflex inspiratory efforts eventually occur, leading to hypoxemia due to aspiration and also reflex laryngospasm.[5-7] Nonfatal drowning results in decreased lung compliance, ventilation–perfusion mismatch, and intrapulmonary shunting, leading to hypoxemia that causes diffuse organ dysfunction.[8] The temperature of the water and the presence of contaminants may affect patient outcomes.[6,7,9] Both saltwater and freshwater washout surfactant, often causing noncardiogenic pulmonary edema and sometimes the acute respiratory distress syndrome (ARDS).[2,10] From over 69 million discharges, 1 151 969 ARDS discharges and 969 567 ARDS discharges with a risk factor were identified,[9] and drowning was the least frequently reported (0.2%) and probably underreported.

There are limited data for respiratory failure due to drowning and its prognosis in Turkey. For our country, most of the drowning data are obtained by forensic medicine,[11,12] the emergency department (ED),[13,14] pediatrics,[15] and online/newspaper[16] records. Data on the development of respiratory failure, intensive care unit (ICU) and hospital stay, and mortality in adult hospitalized patients are limited. This study aimed to determine the development of respiratory failure, identify the therapeutic modalities used for acute respiratory failure (ARF) due to drowning, and also the prognosis and mortality in

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the patients who were planned to be hospitalized treatment after drowning.

MATERIAL AND METHODS

The study was planned as a retrospective cohort study, and ethical approval was obtained from the Dokuz Eylül University ethics committee (No. 2018/26-05). Consecutive adult drowning victims were evaluated retrospectively according to the ICD diagnostic codes (T71, T75.1, W73, W74, Y21), between 2008 and 2018 at Dokuz Eylül University Hospital. The victims were decided to be hospitalized, and followed either in the ICU or the pulmonology inpatient unit depending on severity. The demographic characteristics, arterial blood gas findings, radiological evaluation data, respiratory support and mechanical ventilation data, if any, and the duration of hospital stay and hospital mortality were recorded.

Statistical Analysis

All categorical variables were expressed as numbers and percentages, and continuous variables were expressed as mean and standard deviation (SD) or median and interquartile range (IQR). Categorical variables between groups were compared with the chi-square or Fisher's exact test, continuous variables were compared with the Mann–Whitney *U*-test. A two-tailed *P*-value of .05 was considered statistically significant. Statistical analysis was performed with SPSS v. 22 (IBM SPSS Corp.; Armonk, NY, USA).

RESULTS

A total of 117 patients who were admitted to the ED with the diagnosis of drowning and consulted to the pulmonology department were included. Of them, 47 (40.2%) of the cases were female and 70 (59.8%) were male, the mean age was 57.3 years (±19.4) (Table 1). The drowning accidents most commonly occurred in summer (86.3%). The drowning event occurred mostly in the sea (116 [99.1%]; 1 [0.85%] in the pool). Data for the duration of transfer time from the scene to the hospital were unavailable due to lack of information in the medical records. Radiologic evaluations with chest x-ray were normal in 5 (4.3%) patients, revealed unilateral infiltration in 11 (9.4%), bilateral infiltration in 100 (85.4%), and accompanying pleural effusion in 2 (1.7%) patients, and an incidental mass in 1 (0.9%) patient. Prophylactic antibiotherapy was given to 94 (80%) of these patients.

Table 1. Demographic Characteristics of the Patient Cohort

	Total, *n* = 117
Age (years)	57.3 (19.4)
Gender (%)	
Male	70 (59.8)
Female	47 (40.2)
Seasonal frequency of drowning (%)	
Summer	101 (86.3)
Autumn	12 (10.2)
Spring	4 (3.4)
Winter	None
Scene of accident (%)	
Sea	116 (99)
Pool	1 (0.85)
No comorbidities (%)	29 (24.8)
Major comorbidities(%)	
HT	38 (32.5)
DM	23 (19.6)
CAD	21 (17.9)
Epilepsy	13 (11.1)
Alcoholism	5 (4.3)
GCS at admission to ED (%)	13.6 (3.5)
Chest X-ray involvement (%)	
Normal	5 (4.3)
Unilateral infiltration	11 (9.4)
Bilateral infiltration	100 (85.4)
Incidental mass	1 (0.9)
Accompanying pleural effusion	2 (1.7)
Admission (%)	
Inpatient unit	51 (43.5)
ICU	30 (25.6)
Referral to another center	27 (23)
Discharged due to patient's will	9 (7.7)

*All values are expressed as *n* (%) or mean (±SD) unless otherwise stated.
CAD, coronary artery disease; DM, diabetes mellitus; ER, emergency department; GCS, Glasgow Coma Score; HT, hypertension; ICU, intensive care unit.

MAIN POINTS

- Drowning has been an overlooked and preventable cause of morbidity and mortality in our country surrounded by seas on 3 sides.There are limited data for respiratory failure due to drowning and its prognosis in Turkey.
- This situation can cause acute respiratory failure (ARF) easily. The most powerful weapon we have against this situation is to understand the patient's condition and to provide appropriate supportive therapy and oxygen/mechanical ventilation support.
- With appropriate interventions, disasters due to drowning can be prevented.

The mean Glasgow Coma Score (GCS) at the time of admission to the ED was 13.6 (±3.5). During emergency follow-up, 27 cases were referred to another hospital because of bed insufficiency either in the hospital or in the ICU. Another 9 patients wanted to be discharged, of their own will. Of the remaining patients the number of patients who were followed up in the ICU admission was 30 (25.6%), and in the pulmonology department inpatient unit, the number of patients was 51 (43.5%).

All patients were treated with either supplemental oxygen therapy or mechanical ventilation support (Figure 1). In the

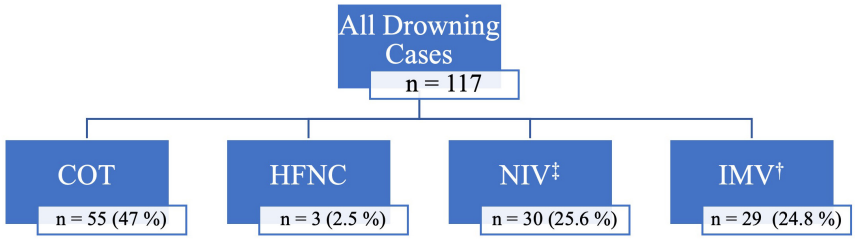

Figure 1. Respiratory Support Types *All values are expressed as *n* (%) unless otherwise stated. ‡HFNC was used between NIV sessions in 3 patients †One patient was intubated after NIV failure. COT, conventional oxygen therapy; HFNC, high-flow nasal cannula; IMV, invasive mechanical ventilation; NIV, noninvasive mechanical ventilation.

study, 55 patients (47%) received conventional oxygen therapy (COT), and 3 patients (2.5%) received high-flow nasal cannula (HFNC). HFNC was used between noninvasive mechanical ventilation (NIV) sessions in 3 patients. Thirty patients (25.6%) needed NIV and 29 patients needed invasive mechanical ventilation (IMV) support. NIV treatment was initially performed in the ER. One patient was intubated after NIV failure.

The mean (±SD) values of the first arterial blood gas values obtained in ED were as follows; pH 7.32 (±0.12), carbon dioxide partial pressure in arterial blood ($PaCO_2$) 40.0 mmHg (±10.1), oxygen partial pressure in arterial blood (PaO_2) 69.13 mmHg (±47.01), lactate 3.38 mmol/L (±3.06), bicarbonate (HCO_3) 20.19 mmol/L (±3.74) and arterial oxygen saturation (SaO_2) 84.4% (±12.9). The mean pH values were lower in the IMV group due to additional metabolic acidosis (Table 2). PaO_2/FiO_2 data were not available in 11 patients. The PaO_2/FiO_2 ratios of the remaining 106 patients were as follows: >300 in 12 (11%), 201-300 in 32 (30%), 101-200 in 49 (46%), and <100 in 13 (12%). The PaO_2/FiO_2 ratio in patients with bilateral infiltration was most commonly 101-200.

Of 117 patients, 31 (26.4%) patients were admitted to ICU (1 with COT, 1 with HFNC, 8 with NIV, and 21 with IMV support). The mean GCS at the time of admission to ICU was 7.9 (±5.8). The median duration for mechanical ventilation support was 1.5 days (IQR 0.1-70 days). The median duration of ICU stay was 5 days (IQR 1-70 days), and the hospital stay of these patients was 10 days (IQR 1-80 days) in ICU patients. The median duration of hospital stay was 3 days (IQR 1-80 days) in the overall group.

Cardiopulmonary resuscitation was performed in 8 (6.8%) patients after admission. One patient survived post-CPR.

Hospital Mortality

The mortality rate was 6% (*n* = 7). It was observed that patients who died had mixed respiratory and metabolic acidosis (mean pH was 7.04 (±0.2), $PaCO_2$ was 52.4 mmHg (±12.2), HCO_3 was 13.0 mmol/L (±4.9) and lactate was 11.7 mmol/L (±5.4)).

Table 2. Patient Groups According to Treatment Modalities

	Total, *n* = 117	COT/HFNC (Group 1), *n* = 58	NIV (Group 2), *n* = 30	IMV (Group 3), *n* = 29
ABG†				
pH	7.32 (0.12)	7.37 (0.06)	7.32 (0.08)	7.20 (0.16)
PaO_2 (mmHg)	69.13 (47.01)	66.79 (19.86)	66.97 (54.51)	65.46 (43.71)
$PaCO_2$ (mmHg)	40.0 (10.1)	35.28 (7.27)	42.31 (8.7)	49.29 (10.83)
Lactate (mmol/L)	3.38 (3.06)	2.77 (2.4)	2.91 (1.52)	5.47 (4.70)
HCO_3 (mmol/L)	20.19 (3.74)	20.97 (2.97)	20.84 (3.92)	17.34 (4.07)
SaO_2 (%)	84.4 (12.9)	89.41 (7.57)	82.61 (10.72)	73.96 (18.51)
PaO_2/FiO_2 ratio (%) ‡				
<100	13 (12)	1 (1.7)	2 (7.4)	10 (47.6)
101-200	49 (46)	18 (31)	23 (85.2)	8 (38.1)
201-300	32 (30)	27 (46.5)	2 (7.4)	3 (14.2)
>300	12 (11)	12 (20.7)	0 (0)	0 (0)
Mortality (%)	7 (6)	0 (0)	1 (3.33)	6 (20.7)

†Data were not available in 7 patients.
‡Data were not available in 11 patients.
*All values are expressed as *n* (%) or mean (±SD) unless otherwise stated.
ABG, arterial blood gas; COT, conventional oxygen therapy; FiO_2, the fraction of inspired oxygen; HCO_3, bicarbonate; HFNC, high-flow nasal cannula; IMV, invasive mechanical ventilation; NIV, noninvasive mechanical ventilation; $PaCO_2$, arterial partial pressure of carbon dioxide; PaO_2, arterial partial pressure of oxygen; pH, hydrogen ion concentration (acidity/base); SaO_2, arterial oxygen saturation.

DISCUSSION

The aim of the study was to determine therapeutic approaches and prognosis in ARF. In this study, population mortality was observed as 6%. About half of the cases needed mechanical ventilation support, either invasive or noninvasive.

In another trial, it was found that 3216 people died due to drowning in Turkey; 84% (*n* = 2703) were males, and 16% (*n* = 513) were females.[16] Death rates due to drowning over the years were 0.89; 1.44 per 100 000 for men and 0.28 per 100 000 for women. Natural water environments such as fresh/still water, and the sea were the main scenes (75.7%) of all deaths. Similarly, the rate of male patients and male mortality were found to be higher in our study too, and the sea was the main accident scene that we identified the most.

This is the first study to evaluate chest x-ray findings in adult victims of drowning in Turkey. Chest X-rays were examined, and bilateral infiltration was mostly seen in this trial. The PaO_2/FiO_2 ratio was 200-300 in 1 of the 5 patients with normal chest radiography findings, this rate was >300 for the other 4 patients. For the patients with bilateral infiltration, the most seen (*n* = 44; 49%) PaO_2/FiO_2 ratio was 101-200. It is very interesting that the most commonly used type of mechanical ventilation in these patients was NIV. Of course, this choice may be related to the general health status and the presence or absence of comorbidity. In another trial of 43 patients, 34 patients (79%) had bilateral diffuse infiltrates, and 9 remaining patients with either focal infiltrates or a negative chest x-ray had hypoxemia.[17]

Fifty-five pediatric patients with submersion injury were analyzed.[15] The mean age was 10.9 ± 4.7 years. Thirty-nine patients (70.9%) were followed in the ED, 16 patients (29.1%) were admitted to the pediatric intensive care unit, and 11 patients (20.0%) died. We found the number of patients followed in the ICU was similarly almost 30%. Although the mortality rate was found to be higher in that study possibly due to the vulnerability of the victims being at pediatric age or the low compliance of lungs, this rate was 6% for adults in our study.

Although drowning has a lower percentage than other causes of ARDS, it is important due to its clustering in the summer months and its preventable occurrence. With early intervention and suitable respiratory support to be applied as soon as possible, patients can recover without sequelae. NIV is used in these patients to improve oxygenation, facilitate ventilation, reduce the work of breathing, and also prevent dyspnea, avoid intubation, and reduce complications associated with IMV. A pilot study on patients with "early" ARDS (PaO_2/FiO_2 >200 and ≤300) showed favorable outcomes such as avoidance of intubation.[18] NIV has also been studied as an alternative to intubation, and occasional reports have shown benefit.[19] Positive studies on hypoxemic, non-hypercapnic respiratory failure, mainly caused by the community or hospital-acquired pneumonia, have recorded carefully selected patients with no associated major organ dysfunction, cardiac ischemia, or arrhythmias, and without limitation in clearing secretions,[20-24] which may explain the benefits seen. The main risk of NIV for de novo ARF indication is to delay required intubation.[23] In our patient population, only 1 patient receiving NIV was then intubated. In terms of the prognosis of the patients, it is very important not to delay intubation. Although the reasons for a worse outcome are not fully understood, patients with NIV failure have higher tidal volumes before intubation[25] and develop more complications after intubation.[26] Certain risks have been identified with NIV, and there is insufficient evidence to recommend its use. In the ERS/ATS Guidelines, given the uncertainty of the evidence, they cannot make a recommendation for the use of NIV for de novo ARF.[27] We found that the PaO_2/FiO_2 ratio of the patients who received only HFNC was 101-200 and for those who received HFNC and NIV alternately, less than 100 in 2 patients and in 1 patient below 200. The PaO_2/FiO_2 ratio was 101-200 in 21 (87.5%) of 24 patients whose data were available and who received only NIV support. The use of HFNC and NIV in moderate to severe ARDS cases is becoming common day by day. By preventing intubation, it strengthens its own evidence with each study. Our study contributes to the literature on this subject. Respiratory failure due to drowning is common, and we found that approximately half of the patients needed mechanical ventilation support. It is seen that respiratory failure due to suffocation develops frequently. Sixty-two patients (53%) needed mechanical ventilation support. Among these, 3 (4.8%) received HFNC and NIV, and 3 (4.8%) received HFNC. HFNC can be a new leading mechanical ventilation option for preventing intubation. Recently, HFNC therapy has been shown to offer several advantages over NIV, including better tolerance and dead-space reduction.[28] One recent randomized controlled trial reported a survival benefit of HFNC over standard oxygen therapy and bilevel NIV, although the primary end-point of intubation was not significantly different.[29] Although HFNC therapy is not specifically addressed in these recommendations, it may play an important role in the treatment of de novo respiratory failure in the future. Therefore, more studies are needed on the role of HFNC and NIV support in respiratory failure.

Turkey is surrounded by the sea on 3 sides and is a country that contains many lakes and dams. Therefore, drowning, which is a preventable cause of accidental mortality and morbidity, is even more important for our country. The studies which focus attention on this accident in Turkey are very insufficient, and data for respiratory failure secondary to drowning are limited. Our study is valuable due to the limited data on drowning-related respiratory failure. Mortality varies between 0.1% and 20%.[13-18] In another trial, a huge variation in the age-standardized mortality rate was noted, from 0.12% in Turkey to 9.19% in Guyana.[30] In our trial, hospital mortality was 6%. The results show that respiratory failure due to drowning can be effectively treated with appropriate treatment and supportive approaches.

The study has several limitations. First, the results are from a single center, and therefore, cannot be generalizable. Second, due to the retrospective design of the study, information bias should be considered. However, there are some strengths. There is very limited data for drowning epidemiology in the adult population in Turkey. Moreover, although literature data provide some mortality rates, medical approaches and respiratory support assessment were not addressed before, which we believe make our results valuable.

CONCLUSION

Drowning is a common cause of accidental death worldwide. This type of accident can be prevented by acting proactively, providing all kinds of required training on this issue, and ensuring lifeguards on every beach. The most appropriate technique will depend on the vehicles available in the hospital and the patient's condition. The treatment of pulmonary complications depends on the lung damage. Understanding the pathophysiology of suffocation can help us understand lung injuries, and enable us to choose the best respiratory support, based on the patient's clinical and auxiliary laboratory parameters. HFNC and NIV support can be considered primarily depending on the patient's weaning from the clinic, and their healing progress.

Ethics Committee Approval: This study was approved by Ethics Committee of Dokuz Eylül University, (Approval No: 2018/26-05).

Informed Consent: Verbal and Written informed consent was obtained from the patients who agreed to take part in the study.

Peer Review: Externally peer-reviewed.

Author Contributions: Concept - S.Ç., B.E.; Design - S.Ç., B.E.; Supervision - B.E., B.C., A.N.G.; Resources - S.Ç.; Materials - S.Ç., B.C., A.N.G.; Data Collection and/or Processing - S.Ç.; Analysis and/or Interpretation - S.Ç.; Literature Search - S.Ç.; Writing Manuscript - S.Ç., B.E.; Critical Review - B.E., B.C., A.N.G.

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