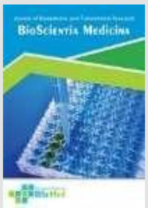
eISSN (Online): 2598-0580



Bioscientia Medicina: Journal of Biomedicine & Translational Research

Journal Homepage: www.bioscmed.com

Successful Management of Acute Respiratory Failure Following Drowning in a Child: A Case Report

Diki Septian[1*], Anggun Pulihana Wilujeng[2]

[1]Department of Emergency, Dr. Soedirman Hospital, Kebumen, Indonesia

[2]Faculty of Medicine, Universitas Sebelas Maret, Surakarta, Indonesia

ARTICLE INFO

Keywords:
Acute respiratory failure
Case report
Drowning
Mechanical ventilation
Pediatric

***Corresponding author:**
Diki Septian

E-mail address:
dikiseptian121@gmail.com

All authors have reviewed and approved the final version of the manuscript.

https://doi.org/10.37275/bsm.v9i5.1284

ABSTRACT

Background: Drowning is a significant global public health issue, leading to a substantial number of deaths annually, particularly among children. Acute respiratory failure (ARF) is a common and life-threatening complication of drowning, necessitating prompt and effective management. This case report describes the successful management of ARF in a 6-year-old child following a drowning incident. **Case presentation:** A 6-year-old male child was brought to the emergency department (ED) after being rescued from a river. He was unconscious, cyanotic, and in respiratory distress. Initial assessment revealed a Glasgow Coma Scale (GCS) score of 9, oxygen saturation of 45% on room air, and crackles on lung auscultation. He was immediately intubated and placed on mechanical ventilation. A chest X-ray showed evidence of pneumonia and pulmonary edema. Arterial blood gas analysis confirmed acute hypoxemic respiratory failure. The patient was transferred to the intensive care unit (ICU) and managed with mechanical ventilation, antibiotics, and corticosteroids. He demonstrated gradual improvement in respiratory status and neurological function, leading to successful extubation and eventual discharge with a full recovery. **Conclusion:** This case highlights the critical role of prompt recognition and aggressive management of ARF in drowning victims. Early intubation and mechanical ventilation, along with supportive care, can lead to successful outcomes even in severe cases. This report emphasizes the importance of raising awareness about drowning prevention and the need for readily available emergency medical services to improve outcomes in such incidents.

1. Introduction

Drowning constitutes a significant global public health concern, claiming a substantial number of lives annually, with a disproportionate impact on children. The World Health Organization (WHO) estimates over 500,000 annual deaths due to unintentional drowning, with a disproportionate impact on low- and middle-income countries. Children are particularly vulnerable, with drowning being a leading cause of death in this age group. Drowning occurs when submersion in a liquid, most commonly water, leads to respiratory impairment. The pathophysiology of drowning involves a complex interplay of factors, including hypoxia, aspiration of water and foreign material, surfactant dysfunction, pulmonary edema, and ventilation-perfusion mismatch. These physiological disturbances can result in severe complications, including acute respiratory failure (ARF), acute respiratory distress syndrome (ARDS), and even death. ARF is a critical consequence of drowning, characterized by the inability of the lungs to maintain adequate oxygenation and/or carbon dioxide elimination. The management of ARF in drowning victims requires prompt and aggressive interventions, including airway management, oxygenation, and ventilatory support. Mechanical ventilation (MV) plays a crucial role in improving respiratory function and tissue oxygenation, particularly when supplemental oxygen alone is insufficient to resolve hypoxia.[1-4]

The severity of outcomes following a drowning incident can vary widely depending on a multitude of factors, including the duration of submersion, the amount of aspirated fluid, and the presence of any underlying medical conditions. Submersion time is a critical determinant of outcome, with longer submersions leading to more severe hypoxia and a higher risk of irreversible brain damage. The amount of aspirated fluid, whether it be water or other liquids, can also significantly impact the severity of respiratory complications. Aspiration can lead to surfactant dysfunction, pulmonary edema, and pneumonia, further compromising respiratory function. The presence of underlying medical conditions, such as asthma, congenital heart disease, or epilepsy, can also increase the risk of complications and worsen the prognosis following a drowning incident.[5-7]

The management of drowning victims requires a multidisciplinary approach, with a focus on airway management, oxygenation, and ventilatory support. Early intubation and mechanical ventilation are crucial in restoring adequate oxygenation and ventilation, preventing further hypoxic damage, and allowing for the resolution of underlying pulmonary pathology. The choice of ventilator mode and settings should be individualized based on the patient's clinical condition and respiratory mechanics. In addition to respiratory support, the management of drowning victims also involves addressing other potential complications, such as hypothermia, electrolyte imbalances, and infection. Hypothermia can occur due to prolonged exposure to cold water, leading to decreased metabolic rate and potential cardiac arrhythmias. Electrolyte imbalances, such as hyponatremia and hypokalemia, can result from aspiration and fluid shifts, requiring careful monitoring and correction. Infection, particularly pneumonia, is a common complication due to the aspiration of water and foreign material, necessitating prompt antibiotic therapy.[8-10] This case report presents the successful management of ARF in a 6-year-old child following a drowning incident.

2. Case Presentation

A 6-year-old male child was brought to the emergency department (ED) following a drowning incident in a river. The estimated submersion time was between 5 and 10 minutes. Prior to arrival at the ED, the child had received initial management at a local health center, including suctioning of the airway. However, he experienced a seizure episode while being transported to the ED. Upon arrival at the ED, the child's condition was critical. He was unconscious, cyanotic (exhibiting a bluish discoloration of the skin and mucous membranes due to lack of oxygen), and experiencing significant respiratory distress. His extremities were cold and cyanotic, further indicating compromised circulation and oxygenation. The child's vital signs were alarming. His Glasgow Coma Scale (GCS) score was 9, indicating significantly impaired consciousness. The GCS is a neurological scale used to assess a patient's level of consciousness based on eye-opening, verbal response, and motor response. A score of 9 falls within the moderate severity range, suggesting a significant alteration in mental status. His heart rate was 154 beats per minute (bpm), significantly elevated above the normal range for his age, indicating tachycardia. His respiratory rate was 49 breaths per minute (bpm), also markedly elevated, indicating tachypnea and respiratory distress. His oxygen saturation (SpO_2) was critically low at 45% on room air, signifying severe hypoxemia. Normal SpO_2 levels are typically above 95%. His body temperature was 37.5°C, within the normal range. Physical examination revealed symmetrical chest movements, suggesting no major obstruction or injury to the chest wall. However, bilateral crackles were auscultated upon listening to his lungs, indicating the presence of fluid in the alveoli, which is consistent with pulmonary edema and/or pneumonia. Cardiovascular examination revealed tachycardia but no murmurs or gallops, suggesting no immediate signs of underlying heart disease. Neurological examination confirmed the child's unconscious state with a GCS of 9 and revealed no focal neurological deficits, meaning there were no signs of localized brain damage at that time. Arterial blood gas (ABG) analysis was performed to assess the child's respiratory and metabolic status. The results confirmed acute hypoxemic respiratory failure, characterized by a low blood pH of 7.25 (indicating acidosis), a high partial pressure of carbon dioxide ($PaCO_2$) of 60 mmHg (indicating hypercapnia), and a low partial pressure of oxygen (PaO_2) of 60 mmHg (indicating hypoxemia). The bicarbonate level (HCO_3^-) was 20 mmol/L, and the calculated oxygen saturation (SaO_2) was 85%. The PaO_2/FiO_2 ratio, a measure of the efficiency of oxygen transfer from the lungs to the blood, was 86.5, further confirming severe respiratory failure. Electrolyte analysis revealed mild hyponatremia (low sodium level) with a sodium concentration of 130 mmol/L and mild hypokalemia (low potassium level) with a potassium concentration of 3.2 mmol/L. These electrolyte imbalances can occur due to fluid shifts and aspiration in drowning cases. Renal function was assessed and found to be normal. Chest X-ray imaging showed increased and blurred bronchovascular markings, hilar haze, and a "batwing" appearance, all suggestive of alveolar pulmonary edema. Additionally, there was a "cotton wool" appearance, indicating the presence of bilateral pneumonia. These findings further supported the diagnosis of acute respiratory failure with aspiration pneumonia. Based on the clinical presentation, laboratory findings, and imaging results, the primary diagnosis was drowning with acute hypoxemic respiratory failure and aspiration pneumonia. The secondary diagnoses were mild hyponatremia and mild hypokalemia. This comprehensive assessment of the child's condition upon arrival at the ED provided a clear picture of the severity of his illness and guided the immediate and subsequent management decisions (Table 1).

The management of this young patient with acute respiratory failure (ARF) following drowning was a multi-faceted approach, focusing on immediate respiratory support, intensive care monitoring, pharmacological interventions, and gradual weaning off ventilatory support as his condition improved. The critical nature of the child's condition upon arrival at the ED necessitated immediate intervention to secure his airway and provide respiratory support. Endotracheal intubation was performed promptly to establish a secure airway, and mechanical ventilation was initiated using the DuoPAP mode. This mode provides pressure-supported breaths synchronized with the patient's spontaneous respiratory efforts, allowing for greater patient comfort and ventilator synchrony. The initial ventilator settings were; Peak Inspiratory Pressure (Pins): 16 cm H_2O; Pressure Support (PS): 7 cm H_2O; Positive End-Expiratory Pressure (PEEP): 7 cm H_2O; Fraction of Inspired Oxygen (FiO_2): 70%. These settings were aimed at providing adequate oxygenation and ventilation while minimizing the risk of ventilator-induced lung injury. Following initial stabilization in the ED, the patient was transferred to the ICU for continuous monitoring and further management. Continuous hemodynamic monitoring was instituted to closely track his heart rate, blood pressure, and oxygen saturation. Frequent neurological assessments, including GCS scoring, were performed to monitor his level of consciousness and detect any signs of neurological deterioration. Respiratory parameters, such as respiratory rate, tidal volume, and FiO_2, were also closely monitored to guide ventilator management. Several medications were administered to address the various aspects of the patient's condition; Antibiotics: Empiric broad-spectrum antibiotics were initiated to treat the aspiration pneumonia. The antibiotic regimen included Amoxicillin/clavulanic acid 1 g intravenously (IV) every 8 hours and Levofloxacin 750 mg IV once daily. The duration of antibiotic therapy was 7 days; Corticosteroids: Moderate-dose corticosteroid therapy with Prednisone 80 mg IV daily was administered to reduce inflammation and improve lung function. The corticosteroid dose was tapered over 5 days; Fluid Management: Intravenous fluids were administered to maintain hydration and correct the electrolyte imbalances, specifically the mild hyponatremia and hypokalemia; Other Medications: Sedatives (midazolam) and analgesics (fentanyl) were used to manage agitation and pain. Neuromuscular blocking agents (rocuronium) were available if required to ensure ventilator synchrony, but their use was not documented in this case. As the patient's respiratory status improved, ventilator support was gradually weaned by decreasing the FiO_2, PEEP, and pressure support. The goal was to transition the patient to spontaneous breathing while maintaining adequate oxygenation and ventilation. After 48 hours of mechanical ventilation, the patient was successfully extubated as he demonstrated the ability to maintain adequate spontaneous breathing and oxygenation. The patient's clinical course was marked by gradual improvement in both respiratory status and neurological function. Following extubation, he remained in the ICU for 2 days and was subsequently transferred to the general ward. The total length of hospital stay was 6 days. At the time of discharge, the patient was in a stable condition with no neurological deficits. He was discharged home with outpatient follow-up with a pediatrician to monitor for any potential long-term complications. This case demonstrates the successful management of ARF following drowning in a child. The prompt initiation of respiratory support, appropriate antibiotic therapy, corticosteroid treatment, fluid and electrolyte management, and gradual weaning off ventilatory support all contributed to the favorable outcome. This case underscores the importance of a multidisciplinary approach and meticulous supportive care in managing such critical cases (Table 2).

Table 1. Summary of patient presentation.

Feature	Details
Demographics	
Age	6 years
Gender	Male
Anamnesis	
Presenting complaint	Unconscious, cyanotic, dyspnea
History of present illness	Rescued after drowning in a river (submersion time 5-10 minutes), initial management at local health center (suctioning), seizure episode prior to ED arrival
Past medical history	No significant past medical history and no history of seizures
Physical examination	
General appearance	Unconscious, cyanotic, cold, and cyanotic extremities
Vital signs	GCS 9 (E3V2M4), HR 154 bpm, RR 49 bpm, SpO_2 45% on room air, Temperature 37.5°C
Respiratory system	Symmetrical chest movements, bilateral crackles on auscultation
Cardiovascular system	Tachycardia, no murmurs or gallops
Neurological system	Unconscious, GCS 9, no focal neurological deficits
Laboratory investigations	
Arterial blood gas	pH 7.25, $PaCO_2$ 60 mmHg, PaO_2 60 mmHg, HCO_3^- 20 mmol/L, SaO_2 85%, PaO_2/FiO_2 ratio 86.5
Electrolytes	Mild hyponatremia (sodium 130 mmol/L), mild hypokalemia (potassium 3.2 mmol/L)
Renal function	Normal
Imaging	
Chest X-ray	Increased and blurred bronchovascular markings, hilar haze, batwing appearance, and cotton wool appearance, suggestive of alveolar pulmonary edema and bilateral pneumonia
Diagnosis	
Primary diagnosis	Drowning with acute hypoxemic respiratory failure and aspiration pneumonia
Secondary diagnosis	Mild hyponatremia, mild hypokalemia

Table 2. Management and outcome.

Feature	Details
Initial management	
Airway management	Immediate endotracheal intubation in the ED
Respiratory support	Mechanical ventilation initiated with DuoPAP mode (Pins 16 cm H_2O, PS 7 cm H_2O, PEEP 7 cm H_2O, FiO_2 70%)
Intensive care unit (ICU) management	
Monitoring	Continuous hemodynamic monitoring (heart rate, blood pressure, oxygen saturation), frequent neurological assessments (GCS), respiratory parameters (RR, tidal volume, FiO_2)
Medications	
- Antibiotics	Empiric broad-spectrum antibiotics: Amoxicillin/clavulanic acid 1 g IV every 8 hours; Levofloxacin 750 mg IV once daily; Duration: 7 days
- Corticosteroids	Moderate dose corticosteroid therapy: Prednisone 80 mg IV daily; Duration: Tapered over 5 days
- Fluid management	Intravenous fluids to maintain hydration and correct electrolyte imbalances
- Other medications	Sedatives (midazolam) and analgesics (fentanyl) for agitation and pain control; Neuromuscular blocking agents (rocuronium) if required for ventilator synchrony
Respiratory support	
- Ventilator management	Gradual weaning of ventilator support as respiratory status improved (decreasing FiO_2, PEEP, and pressure support)
- Extubation	Extubate after 48 hours of mechanical ventilation when able to maintain adequate spontaneous breathing and oxygenation
Outcome	
Length of ICU stay	2 days
Length of hospital stay	6 days
Discharge status	Discharged home in stable condition, no neurological deficits
Follow-up	Outpatient follow-up with a pediatrician to monitor for any long-term complications

3. Discussion

Drowning, a global public health crisis, tragically claims hundreds of thousands of lives each year, inflicting a disproportionate burden on children and marginalized communities. It ranks as a leading cause of unintentional injury and death worldwide, underscoring the urgent need for comprehensive prevention and intervention strategies. The World Health Organization estimates that over 320,000 people die annually from drowning, with low- and middle-income countries bearing the brunt of this devastating toll. The impact of drowning extends far beyond the immediate loss of life. Non-fatal drowning incidents can result in long-term health consequences, including brain damage, respiratory problems, and psychological trauma. These incidents can also place a significant financial burden on families and healthcare systems, further exacerbating existing inequalities. Drowning constitutes a major public health challenge across the globe, affecting individuals of all ages, but particularly children. The highest drowning rates are observed in low- and middle-income countries, particularly in regions with limited access to safe water and swimming facilities and where supervision and water safety education are lacking. The global burden of drowning is substantial, with an estimated 320,000 deaths occurring annually. Children are disproportionately affected, with drowning being a leading cause of death in this age group. The risk of drowning is particularly high in young children, especially those under the age of 5. Several factors contribute to the risk of drowning, including age, gender, socioeconomic status, and access to safe water environments. Young children, particularly those under the age of 5, are at the highest risk of drowning due to their natural curiosity, limited swimming ability, and lack of awareness of water dangers. Males are more likely to drown than females, possibly due to risk-taking behaviors and greater exposure to water-related activities. Socioeconomic factors also play a role, with drowning rates being higher in low-income communities and regions with limited access to safe water and swimming facilities. Drowning can be classified into various categories based on the outcome, water type, and specific circumstances. The most common classification distinguishes between fatal drowning, where the victim dies as a result of the drowning incident, and non-fatal drowning, where the victim survives, but may experience a range of health consequences. The pathophysiology of drowning is complex and involves a series of physiological events that occur when a person is submerged in water. The initial response is typically panic and a struggle to breathe, which can lead to aspiration of water or other fluids. Aspiration can disrupt the normal function of the lungs, leading to surfactant dysfunction, alveolar collapse, and impaired gas exchange. The lack of oxygen (hypoxia) and accumulation of carbon dioxide (hypercapnia) in the blood trigger a cascade of physiological responses, including reflex laryngospasm (closure of the larynx), which can further impede breathing. If laryngospasm persists, it can lead to severe hypoxia and cardiac arrest. However, even if laryngospasm subsides, aspiration can still occur, leading to further respiratory complications. The hypoxemia and hypercapnia also affect other organ systems, including the brain. Cerebral hypoxia can lead to altered mental status, seizures, and ultimately, irreversible brain damage if not addressed promptly. Drowning is preventable, and a multi-faceted approach is crucial to effectively address this public health issue. Constant and vigilant supervision of children around water is paramount. Young children should never be left unattended near water, even for a moment. This requires active engagement and awareness from parents, caregivers, and responsible adults. Installing barriers, such as fences around pools and water bodies, can help prevent unsupervised access to water, particularly for young children. These barriers should be properly maintained and secured to ensure their effectiveness. Teaching children basic water safety skills, such as floating and swimming, can empower them to stay safe around water. Water safety education should be incorporated into school curricula and community programs, reaching children of all ages and backgrounds. Encouraging the use of life jackets or personal flotation devices, especially for non-swimmers and when boating or engaging in water activities, can significantly reduce the risk of drowning. Life jackets should be properly fitted and worn at all times when on or near water. Learning basic water rescue skills and cardiopulmonary resuscitation (CPR) can be life-saving in drowning emergencies. These skills should be taught to individuals and communities, empowering them to respond effectively in drowning situations. Implementing community-based programs that promote water safety education, provide access to swimming lessons, and establish safe water environments can have a significant impact on drowning prevention. These programs should be tailored to the specific needs of the community and involve collaboration among various stakeholders, including government agencies, healthcare providers, schools, and community organizations. Drowning has significant public health implications, impacting not only individuals and families but also healthcare systems and communities. The economic burden of drowning is substantial, including the costs of healthcare, rehabilitation, and lost productivity. These costs can strain healthcare resources and create financial hardship for families and communities.

Moreover, drowning can have profound psychological and emotional consequences for survivors, families, and communities. The trauma of witnessing or experiencing a drowning incident can lead to long-term mental health issues, such as anxiety, depression, and post-traumatic stress disorder (PTSD). These psychological and emotional impacts can have lasting effects on individuals and communities, requiring ongoing support and mental health services.[11,12]

The pathophysiology of drowning is a complex and dynamic process, involving a series of interconnected physiological events that unfold rapidly upon submersion. It is characterized by a cascade of insults to various organ systems, primarily the respiratory and central nervous systems, ultimately leading to life-threatening complications if not addressed promptly. The pathophysiological cascade begins with submersion, triggering an immediate and instinctive struggle to breathe. This struggle is often accompanied by panic and anxiety, further exacerbating the physiological response. The primary goal of the body is to prevent water from entering the lungs. Interestingly, submersion in cold water can also trigger the mammalian diving reflex, a physiological response that conserves oxygen and slows the heart rate in an attempt to prolong survival underwater. This reflex is more pronounced in children and may contribute to their higher survival rates in cold water drowning incidents. Aspiration of water or other fluids is a key event in the pathophysiology of drowning. Aspiration disrupts the delicate balance of the alveolar environment, leading to surfactant dysfunction. Surfactant, a complex mixture of lipids and proteins, plays a crucial role in reducing surface tension within the alveoli, preventing their collapse and maintaining lung compliance. When surfactant is compromised, the surface tension increases, causing alveolar collapse and atelectasis (incomplete expansion of the lungs). This collapse impairs gas exchange, leading to hypoxemia (low blood oxygen levels) and hypercapnia (high blood carbon dioxide levels). The resulting ventilation-perfusion mismatch further compromises oxygenation and carbon dioxide elimination. The initial hypoxemia triggers a series of physiological responses, including reflex laryngospasm (closure of the larynx). Laryngospasm is a protective mechanism aimed at preventing further aspiration, but it can also impede breathing and worsen hypoxemia, creating a vicious cycle. If laryngospasm persists, it can lead to severe hypoxia and cardiac arrest. Even if laryngospasm subsides, aspiration can still occur, leading to the aforementioned complications. The hypoxemia and hypercapnia also affect other organ systems, including the brain. Cerebral hypoxia can lead to altered mental status, seizures, and ultimately, irreversible brain damage if not addressed promptly. Aspiration of water can also lead to pulmonary edema, a condition characterized by the accumulation of fluid in the lungs. This fluid further impairs gas exchange and can contribute to the development of acute respiratory distress syndrome (ARDS), a severe lung injury characterized by widespread inflammation and fluid buildup in the lungs. The inflammatory response in drowning is complex and involves various mediators, including cytokines, chemokines, and reactive oxygen species. This inflammation can further damage the lungs and contribute to the development of ARDS. The severity of lung injury can range from mild pulmonary edema to severe ARDS, depending on the amount of aspirated fluid, the individual's immune response, and the presence of any pre-existing lung conditions. Cerebral hypoxia is a major concern in drowning, as it can lead to a range of neurological consequences, from mild cognitive impairment to severe brain damage and even death. The extent of neurological damage depends on the severity and duration of hypoxia, as well as the individual's resilience and pre-existing health conditions. In severe cases, cerebral hypoxia can lead to cerebral edema (swelling of the brain), which can further compromise brain function and increase the risk of long-term neurological deficits. The neurological consequences of drowning can be devastating, affecting cognitive function, motor skills, and overall quality of life. While the respiratory and central nervous systems are the primary targets of injury in drowning, other organ systems can also be affected. Hypoxemia and hypoperfusion can lead to multi-organ dysfunction, including cardiac arrhythmias, renal failure, and liver damage. These systemic effects can further complicate the clinical picture and worsen outcomes. The pathophysiological response to drowning can vary significantly among individuals, depending on factors such as age, underlying health conditions, water temperature, and the amount of aspirated fluid. Young children are particularly vulnerable to the effects of drowning due to their smaller lung capacity, immature immune systems, and greater propensity for laryngospasm. Individuals with pre-existing health conditions, such as asthma or heart disease, may also be at increased risk of complications following drowning. Cold water drowning can lead to hypothermia, which can further complicate the pathophysiological response and worsen outcomes. The combination of these factors contributes to the wide spectrum of severity observed in drowning cases, ranging from mild respiratory distress to severe multi-organ failure and death.[13,14]

Acute respiratory failure (ARF) stands as a critical and often life-threatening consequence of drowning, representing the primary cause of mortality in these incidents. It is characterized by the inability of the lungs to maintain adequate oxygenation and/or carbon dioxide elimination, leading to a state of hypoxemia (low blood oxygen levels) and/or hypercapnia (high blood carbon dioxide levels). The severity of ARF can vary widely, ranging from mild respiratory distress to severe respiratory failure requiring mechanical ventilation. The pathophysiology of ARF in drowning is complex and multifactorial, involving a series of interconnected events that disrupt the normal function of the lungs. The initial insult is typically aspiration of water or other fluids, which can lead to surfactant dysfunction, alveolar collapse, and impaired gas exchange. Surfactant, a complex mixture of lipids and proteins, plays a crucial role in reducing surface tension within the alveoli, preventing their collapse and maintaining lung compliance. When surfactant is compromised, the surface tension increases, causing alveolar collapse and atelectasis (incomplete expansion of the lungs). This collapse impairs gas exchange, leading to hypoxemia and hypercapnia. In addition to surfactant dysfunction, aspiration can also trigger an inflammatory response in the lungs, leading to pulmonary edema (fluid accumulation in the lungs) and further compromising gas exchange. The inflammatory response can also contribute to the development of acute respiratory distress syndrome (ARDS), a severe lung injury characterized by widespread inflammation and fluid buildup in the lungs. The combined effects of surfactant dysfunction, alveolar collapse, and pulmonary edema lead to a ventilation-perfusion mismatch, where the ventilation (airflow) and perfusion (blood flow) in the lungs are not properly matched. This mismatch further impairs gas exchange, leading to more severe hypoxemia and hypercapnia. Hypoxemia, the hallmark of ARF, has profound systemic effects, affecting multiple organ systems. The brain is particularly vulnerable to hypoxemia, which can lead to altered mental status, seizures, and ultimately, irreversible brain damage if not addressed promptly. Other organs, such as the heart and kidneys, can also be affected by hypoxemia, leading to cardiac arrhythmias, renal failure, and other complications. The systemic effects of hypoxemia can further complicate the clinical picture and worsen outcomes in drowning victims. The clinical presentation of ARF in drowning can vary depending on the severity of the condition. In mild cases, individuals may present with tachypnea (rapid breathing), dyspnea (shortness of breath), and mild hypoxemia. These individuals may be able to maintain adequate oxygenation with supplemental oxygen and supportive care. In more severe cases, individuals may exhibit cyanosis (bluish discoloration of the skin and mucous membranes), altered mental status, and respiratory distress requiring mechanical ventilation. These individuals require prompt and aggressive respiratory support to prevent further deterioration and complications. Physical examination findings in

ARF can include tachypnea, dyspnea, use of accessory muscles of respiration, and abnormal lung sounds such as crackles or wheezes. In severe cases, cyanosis, altered mental status, and signs of respiratory failure, such as decreased air entry and decreased breath sounds, may be present. Arterial blood gas analysis is a crucial diagnostic tool in ARF, providing information about oxygenation, ventilation, and acid-base status. Hypoxemia is characterized by a low partial pressure of oxygen (PaO_2), while hypercapnia is characterized by a high partial pressure of carbon dioxide ($PaCO_2$). Acidosis (low blood pH) may also be present due to the accumulation of carbon dioxide and lactic acid. A chest X-ray may show evidence of pulmonary edema, aspiration pneumonitis, and/or ARDS. These findings can help confirm the diagnosis of ARF and guide treatment decisions. The management of ARF in drowning focuses on restoring adequate oxygenation and ventilation, preventing further lung injury, and addressing any underlying complications. It requires a multidisciplinary approach, involving respiratory therapists, intensivists, nurses, and other healthcare professionals. The cornerstone of treatment is respiratory support, which may range from supplemental oxygen to mechanical ventilation. In mild cases, supplemental oxygen may be sufficient to improve oxygenation. However, in more severe cases, mechanical ventilation is often required to maintain adequate ventilation and oxygenation. The choice of ventilator mode and settings should be individualized based on the patient's clinical condition and respiratory mechanics. Positive end-expiratory pressure (PEEP) may be used to improve oxygenation and prevent alveolar collapse. In addition to respiratory support, other supportive measures may be necessary, such as fluid management, electrolyte correction, and treatment of any underlying infections. Corticosteroids may also be used to reduce inflammation and improve lung function in some cases. The prognosis of ARF in drowning depends on the severity of the condition, the presence of any underlying medical conditions, and the promptness of treatment. In general, individuals with mild ARF who receive prompt and appropriate treatment have a good prognosis. However, individuals with severe ARF, especially those who develop ARDS, have a higher risk of complications and mortality. Long-term outcomes of ARF in drowning can also vary. Some individuals may experience complete recovery, while others may have persistent respiratory problems, neurological deficits, or psychological trauma. The long-term prognosis is influenced by factors such as the severity of the initial injury, the presence of any pre-existing medical conditions, and the quality of post-acute care. The best way to prevent ARF in drowning is to prevent drowning itself. This can be achieved through a combination of individual and community-based strategies, such as water safety education, supervision of children around water, and the use of life jackets or personal flotation devices. In addition to preventing drowning, prompt recognition and treatment of ARF are crucial to improving outcomes. Early intervention with respiratory support and supportive care can significantly reduce the risk of complications and mortality.[15-17]

The management of acute respiratory failure (ARF) in drowning victims is a complex and challenging endeavor, requiring a multifaceted and individualized approach. It involves a coordinated effort from a multidisciplinary team of healthcare professionals, including emergency physicians, intensivists, respiratory therapists, nurses, and other specialists. The primary goals of management are to restore adequate oxygenation and ventilation, prevent further lung injury, and address any underlying complications. The initial assessment of a drowning victim focuses on evaluating the airway, breathing, and circulation (ABCs), the fundamental pillars of life support. If the victim is not breathing or has inadequate breathing, immediate resuscitation efforts should be initiated, including rescue breaths and chest compressions if necessary. These initial steps are crucial to restoring oxygen delivery to vital organs and preventing irreversible damage. Once the airway is secured and breathing is established, attention turns to assessing the victim's oxygenation status.

Pulse oximetry, a non-invasive method to measure oxygen saturation in the blood, is used to provide a quick assessment of oxygenation. However, a more comprehensive evaluation is obtained through arterial blood gas analysis, which provides detailed information about oxygenation, ventilation, and acid-base status. This analysis helps to identify the severity of respiratory failure and guide subsequent treatment decisions. Airway management is a critical component of ARF management in drowning victims. A patent airway is essential for adequate ventilation and oxygenation. If the victim is unconscious or has a compromised airway due to obstruction, swelling, or aspiration, endotracheal intubation may be necessary to secure the airway and provide mechanical ventilation. Endotracheal intubation involves inserting a tube through the mouth or nose into the trachea, allowing for direct access to the lungs and facilitating mechanical ventilation. In some cases, non-invasive ventilation techniques, such as continuous positive airway pressure (CPAP) or bi-level positive airway pressure (BiPAP), may be used to support breathing and improve oxygenation. These techniques involve delivering positive pressure through a mask, helping to keep the airways open and improve gas exchange. The choice of airway management technique depends on the severity of the respiratory failure, the victim's level of consciousness, and the presence of any other injuries or complications. Respiratory support is the cornerstone of ARF management in drowning victims. The goal is to restore adequate oxygenation and ventilation while minimizing the risk of further lung injury. The choice of respiratory support modality depends on the severity of the respiratory failure, the victim's clinical condition, and the presence of any other complications. In mild cases of ARF, supplemental oxygen may be sufficient to improve oxygenation. Oxygen can be delivered via nasal cannula, face mask, or non-rebreather mask, depending on the victim's oxygen requirements. The goal is to maintain oxygen saturation within a safe and therapeutic range. In more severe cases of ARF, mechanical ventilation is often required to maintain adequate ventilation and oxygenation. Mechanical ventilation involves using a machine to assist or control breathing, delivering oxygen and removing carbon dioxide from the lungs. The choice of ventilator mode and settings should be individualized based on the patient's clinical condition and respiratory mechanics. Various ventilator modes are available, each with its own advantages and disadvantages. Common modes used in ARF include assist-control ventilation (ACV), synchronized intermittent mandatory ventilation (SIMV), and pressure support ventilation (PSV). Assist-control ventilation (ACV) delivers a set number of breaths per minute at a predetermined tidal volume, regardless of the patient's own respiratory effort. This mode is useful for patients who are unable to initiate or maintain adequate breathing on their own. Synchronized intermittent mandatory ventilation (SIMV) delivers a set number of breaths per minute at a predetermined tidal volume, but allows the patient to breathe spontaneously between the mandatory breaths. This mode is often used as a weaning mode, allowing the patient to gradually take over more of the work of breathing. Pressure support ventilation (PSV) provides a pressure boost to the patient's spontaneous breaths, making it easier for them to breathe. This mode is often used for patients who are able to initiate breaths but need assistance to maintain adequate tidal volume. Positive end-expiratory pressure (PEEP) is often used in mechanical ventilation to improve oxygenation and prevent alveolar collapse. PEEP helps to keep the alveoli open at the end of expiration, improving gas exchange and reducing the work of breathing. The level of PEEP is adjusted based on the patient's oxygenation status and lung compliance. The fraction of inspired oxygen (FiO_2) is adjusted to achieve target oxygen saturation levels. The goal is to provide enough oxygen to maintain adequate oxygenation while minimizing the risk of oxygen toxicity. High levels of oxygen can be harmful to the lungs, so the FiO_2 is titrated to the lowest level necessary to maintain adequate oxygenation. In addition to respiratory support, the management of ARF in drowning victims also involves addressing other potential complications, such as hypothermia, electrolyte imbalances, and infection. These complications can further compromise respiratory function and overall health, requiring prompt and appropriate management. Hypothermia, or low body temperature, is a common complication of drowning, especially in cold water drowning incidents. Hypothermia can worsen respiratory failure, decrease cardiac output, and increase the risk of cardiac arrhythmias. Passive rewarming involves removing wet clothing and covering the victim with blankets to prevent further heat loss. Active external rewarming involves using warming devices such as heating pads or warm water baths to actively rewarm the victim. Active internal rewarming involves using warmed intravenous fluids or heated humidified oxygen to rewarm the victim from the inside. The choice of rewarming method depends on the severity of hypothermia, the victim's clinical condition, and the availability of resources. Fluid and electrolyte imbalances are also common in drowning victims, due to aspiration of water, fluid shifts, and the body's response to stress. Hyponatremia (low sodium levels) and hypokalemia (low potassium levels) are common electrolyte imbalances that can occur in drowning victims. These imbalances can affect cardiac function, nerve conduction, and overall cellular function. Fluid management involves careful monitoring of the victim's fluid balance and electrolyte levels. Intravenous fluids may be necessary to correct dehydration or electrolyte imbalances. The type and rate of fluid administration are determined based on the victim's clinical condition and electrolyte status. Aspiration of water and foreign material can introduce bacteria into the lungs, increasing the risk of pneumonia and other infections. These infections can further compromise respiratory function and prolong recovery. Antibiotics may be necessary to treat or prevent infections in drowning victims. The choice of antibiotics depends on the suspected organisms and the victim's clinical condition. In some cases, prophylactic antibiotics may be given to prevent infection, especially in victims with severe aspiration or compromised immune systems. Continuous monitoring of the victim's respiratory status, oxygenation, ventilation, and hemodynamic parameters is crucial during the management of ARF. This monitoring helps to guide treatment decisions and ensure that the victim is responding appropriately to therapy. As the victim's condition improves, respiratory support can be gradually weaned. The goal is to transition the victim to spontaneous breathing while maintaining adequate oxygenation and ventilation. The weaning process should be individualized based on the victim's clinical condition and respiratory mechanics. Weaning from mechanical ventilation typically involves gradually decreasing the level of support provided by the ventilator, such as reducing the respiratory rate, tidal volume, or pressure support. The victim's respiratory status is closely monitored during the weaning process to ensure that they are able to maintain adequate breathing on their own.[18-20]

4. Conclusion

This case report describes the successful management of acute respiratory failure (ARF) in a child following a drowning incident. The child’s rapid deterioration and respiratory failure required immediate intubation and mechanical ventilation. This intervention, along with comprehensive supportive care, facilitated the gradual improvement of the child’s respiratory status and neurological function, leading to successful extubation and complete recovery. This case highlights the critical role of early recognition and aggressive management of ARF in drowning victims. The prompt initiation of respiratory support, antibiotic therapy, corticosteroid treatment, fluid and electrolyte management, and gradual weaning off ventilatory support all contributed to the favorable outcome. This report emphasizes the importance of raising awareness about drowning prevention and the need for readily available emergency medical services to improve outcomes in such incidents. The case also underscores the importance of a multidisciplinary approach and meticulous supportive care in managing such critical cases. The coordinated efforts of the emergency medical team, the intensive care unit staff, and the pediatrician ensured the successful treatment and recovery of the patient. This case serves as a reminder of the importance of prompt and aggressive management of ARF following drowning, as well as the potential for successful outcomes even in severe cases.

5. References

1. Cubattoli L, Franchi F, Coratti G. Surfactant therapy for acute respiratory failure after drowning: two children victim of cardiac arrest. Resuscitation. 2009; 80(9): 1088–9.
2. Hagiwara S, Furukawa K, Murata M, Nakamura T, Ohyama Y, Tamura J, et al. Successful treatment for a patient with acute respiratory distress syndrome due to secondary drowning. Nihon Kyukyu Igakukai Zasshi. 2011; 22(7): 319–24.
3. Ecklund MM, Wahl G, Yamshchikov AV, Smith MS. Journey of a survivor of near drowning, polymicrobial pneumonia, and acute respiratory distress syndrome. Crit Care Nurs Clin North Am. 2012; 24(4) :601–23.
4. Fettah N, Dilli D, Beken S, Zenciroglu A, Okumuş N. Surfactant for acute respiratory distress syndrome caused by near drowning in a newborn. Pediatr Emerg Care. 2014; 30(3): 180–1.
5. Biçer S, Demirkol D, Karaböcüoğlu M, Çıtak A, Uzel N. A rare cause of acute respiratory distress syndrome: Near drowning in detergent and sodium hypo chlorite containing solution. Turk J Pediatr Emerg Intensive Care Med. 2015; 2(1): 49–54.
6. Michelet P, Bouzana F, Charmensat O, Tiger F, Durand-Gasselin J, Hraiech S, et al. Acute respiratory failure after drowning: a retrospective multicenter survey. Eur J Emerg Med. 2017; 24(4): 295–300.
7. Lefort H, Nguyen T-V. Successful extracorporeal membrane oxygenation use in acute respiratory distress syndrome after freshwater drowning. Mediterr J Emerg Med. 2018; (26): 29–31.
8. Nawfal H, Abderrahim E, Brahim B, Nabil K. Drowning induced acute respiratory failure: a case report. Int J Case Rep Imag. 2018; 9: 1.
9. Kim JH, Sun KH, Park YJ. The utility of non-invasive nasal positive pressure ventilation for acute respiratory distress syndrome in near drowning patients. J Trauma Inj. 2019; 32(3): 136–42.
10. Pašalić M, Skorić B, Čikeš M, Lovrić D, Ljubas Maček J, Jurin H, et al. Venovenous extracorporeal membrane oxygenation in a patient with acute respiratory distress syndrome caused by drowning. Cardiol Croat. 2018; 13(1–2): 51–2.
11. Pezzi M, Givigliano F, Perrone O, Scozzafava A, Maglio P, Casella P, et al. The use of exogenous lung surfactant (poractant Alfa) in acute respiratory failure by drowning. Case Rep Crit Care. 2020; 2020: 9270791.
12. Mathew JR, Krishnamoorthy K. Acute respiratory distress syndrome following near drowning. Journal of Association of Pulmonologist of Tamil Nadu. 2021; 4(1): 43–5.
13. Çakmakcı S, Ergan B, Cömert B, Gökmen AN. Therapeutic approaches and mortality in acute respiratory failure due to drowning. Turk Thorac J. 2021; 22(6): 477–81.
14. Grimes AD, Kennedy R, Quang C, Albrecht R, Blair S. The management of acute respiratory distress syndrome after near drowning and low-voltage electrocution. Am Surg. 2023; 89(4): 1206–7.
15. Tenda ED, Henrina J, Setiadharma A, Pitoyo CW, Yulianti M, Santoso RFH, et al. Systemic corticosteroid as an adjunct for acute respiratory distress syndrome in non-fatal

fresh water drowning: An evidence-based case report. Acta Med Indones. 2024; 56(2): 253–9.

16. Hattori M, Kikutani K, Ohshimo S, Shime N. Hypercalcemic crisis complicated with acute respiratory distress syndrome due to hot spring drowning: a case report. Cureus. 2024; 16(4): e58431.
17. Ruggeri P, Calcaterra S, Bottari A, Girbino G, Fodale V. Successful management of acute respiratory failure with noninvasive mechanical ventilation after drowning, in an epileptic-patient. Respir Med Case Rep. 2016; 17: 90–2.
18. Yuan J-J, Zhang X-T, Bao Y-T, Chen X-J, Shu Y-Z, Chen J-L, et al. Heme oxygenase-1 participates in the resolution of seawater drowning-induced acute respiratory distress syndrome. Respir Physiol Neurobiol. 2018; 247: 12–9.
19. Qiu Y-B, Wan B-B, Liu G, Wu Y-X, Chen D, Lu M-D, et al. Nrf2 protects against seawater drowning-induced acute lung injury via inhibiting ferroptosis. Respir Res. 2020; 21(1): 232.
20. Reizine F, Fedun Y, Bodenes L, Bouju P, Fillâtre P, Frérou A, et al. Respiratory management of drowning-associated acute respiratory failure: a multicentre retrospective cohort study. Eur Respir J. 2023; 61(2): 2201269.