Management of Victims with Submersion Injury

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Abstract

Submersion injury remains high mortality and morbidity in little babies and adolescents. Because most of these events are due to accidents, preventive measures are the first priority to be considered. Hypoxemia and subsequent multi-organ insults, especially for the brain, are devastating sequelae. Aggressive pulmonary support are thus encouraged and required. There is still no definite prognostic scale that accurately predicts the patients' outcome. However, those presenting with clear consciousness at arrival are almost 100% survived. Traditional HYPER therapy (hypothermia, hyperventilation, steroids, dehydration, barbiturate coma, and neuromuscular blockade) has been proven not to improve the prognosis.*(Ann Disaster Med. 2004;2 Suppl 2:S89-S96)*

Key words: Submersion; Drowning; Near-Drowning; Environmental Medicine

Introduction

Submersion injury consists of drowning and near-drowning.[1-8] Drowning is defined as death secondary to asphyxia while immersed in a liquid, usually water, or within 24 hours of submersion, whereas near-drowning means those who eventually survive from the submersion or immersion.[1-8] Because of complicated medical conditions, near drowning suggests an immersion episode severe enough to warrant medical attention to avoid morbidity and mortality.[1-8]

Epidemiological studies revealed that there are more than one thousand and fifty thousands reported deaths from drowning worldwide, but some of the densely populated countries did not have the data of near drowning incidents.[7,8] The prevalence or incidence of submersion injury and drowning deaths can thus not be measured accurately. However, the limited data showed that there is a bimodal age distribution of drowning deaths, with an initial peak in the toddler age group and a second peak in adolescent to young adult males.[7,8]

In pediatric populations, trauma remains the leading mortality and drowning also always presents as the big three.[9] Accordingly, morbidity from submersion occurs in 12-27% of survivors in this age group.[9] In America, preschool-aged boys are at greatest risk of submersion injury. Approximately 10% of children younger than 5 years had an experience judged a "serious threat" of near drowning.[9] Swimming pools at home are the most common submersion site in this age group. Epidemiological studies revealed that male-to-female ratios are ap-

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proximately 12:1 for boat-related drowning and 5:1 for non-boat-related drowning, whereas the girls predominate only in bathing incidents.[10,11] The peak age groups are children younger than 4 years and adolescents/young people between 15 and 24 years.[1-9] Mortality is primarily due to laryngospasm and lung injury, resulting hypoxemia, and its subsequent neurological and/or other systemic damages.[8] Morbidity is always due to neurological insult and multiple organ system failure. Thirty-five percent of immersion episodes in children are fatal; one third results in some degree of neurological impairment, one tenth in severe neurological complications.[9,12] In addition, a high risk of death exists secondary to the development of adult respiratory distress syndrome (ARDS) or so-called postimmersion syndrome.[1-8] The devastating events mentioned above and the fact that these incidents always involve a toddler left unattended, an adolescent found floating in the water, or a victim diving and not resurfacing demonstrated that prevention is the most important measure.[8-11]

Community education is the key to prevention. Every one should know his own swimming abilities and never do anything above the limitations.[13] Parents should always supervise children carefully around water. Children should be taught safe conduct around water and during water sports. Use of alcohol or other recreational drugs is contraindicated when swimming or doing water sports. Appropriate boating equipment should be used, and sufficient barriers must be used around any water-containing devices at home. Every one should seriously considers learning CPR and water safety training to provide immediate and necessary rescue and resuscitation if needed.

Pathophysiology of Submersion Injury

Hypoxemia is the major pathologic consequence of subimmersion injury. Airway management and good ventilation are still the first priority for those victims. That is why the ACLS algorithm assumes that one should resuscitate firstly instead of call for help, as he should do for the victims of those less than 8 years old, those with trauma or intoxication. After initial gasping, and possible aspiration, immersion stimulates hyperventilation, followed by voluntary apnea and a variable degree and duration of laryngospasm. Hypoxemia has begun since then. Furthermore, the persistent hypoxemia and subsequent acidosis, also make the patient prone to cardiac arrest and central nervous system damage. The victims in submersion are traditionally considered to have dry lungs because of the initial laryngospasm. However, there are more and more data revealing that asphyxia may lead to smooth muscle relaxation of the airway and then permits the lungs to fill with water in significant portion of the victims. There may be only 10-20% of the patients keep laryngospasm until cardiac arrest and do not aspirate any fluid. In other words, most of the patients have wet lungs may develop pulmonary edema, and a small part of them dry lungs.

Past physiological studies also demonstrated that sudden immersion in cold water may induce diving reflex which is manifested as apnea, bradycardia, and peripheral vasoconstriction with resultant shunting of blood to the vital organs such as the heart and the brain.

The lung is the first target organ that submersion injury attacks. Most of the damages to other organs are largely secondary to hypoxemia, ischemia and tissue acidosis. Aspiration of water into the lungs produces vagotonia, pulmonary vasoconstriction and hypertension. For those with fresh water aspiration, water moves rapidly across the alveolar-capillary membrane and destroys the surfactant to result in alveolar instability, atelectasis, decreased compliance and ventilation/perfusion mismatching that may be as high as 75%. In contrast, salt water can cause surfactant washout, produce protein-rich fluid exudates in the alveoli and pulmonary interstitium and alveolar-capillary basement membrane damage to result in stiff lung and shunting. All of the above phenomena contribute to severe hypoxia and possibly cerebral insult.

Besides, fresh water and hypoxemia may cause lysis of red blood cells and subsequent hyperkalemia. Salt water may decrease blood volume and increase serum electrolyte concentrations. However, most of the victims do not aspirate enough fluid to cause substantial changes of blood volume and serum electrolyte concentrations.

Clinical Aspects

The victims of submersion injury should be always treated as those with trauma. For example, cervical spine injuries and head trauma, which result from diving into shallow water, surfing, water skiing, jet skiing or other hazards, may occur. Concomitant secondary trauma should be evaluated and managed according to the guidelines of Advanced Trauma Life Support (ATLS) or other related principles. In addition, most of the victims may be hypothermic that deserves special clinical alert and management such as rewarming.

Some histories may be of beneficial in managing the patients with submersion injury. They include special environment such as cold water or hot water, past history of systemic diseases such as pulmonary, heart or seizure disorders, conscious level at presentation and during transportation, presence of vomiting, concomitant drug or alcohol use.

A classification of the victims of submersion incidents attributes them into asymptomatic, symptomatic, cardiopulmonary arrest and death. Symptomatic patients may present with altered vital signs, arrhythmia, hypothermia, tachypnea, dyspnea, hypoxia, conscious change, and metabolic acidosis. More than half of the victims with cardiopulmonary arrest present with asystole, thirty percent ventricular tachycardia or fibrillation, and less than 20% bradycardia. Immersion syndrome and apnea are usually the manifestations of cardiopulmonary arrest due to submersion. However, normotheric victims with asystole, apnea, rigor mortis and dependent lividity always suggest definite death refractory to resuscitation.

Some special considerations should be taken. Bathtub and pail drownings may represent child abuse. Examine the child carefully for other evidence of injury and review the details of the incident very carefully with the child's parent or guardian. Alcohol and, to a lesser extent, other recreational drugs are implicated in many cases. It is most important in older adolescents and adults who drowned in boating incidents, as determined by blood alcohol concentrations. In addition, always consider the underlying disease/illness in all age groups. They include seizure disorder, myocardial infarction or syncopal episode, malignant arrhythmia, poor neuromuscular control (such as significant arthritis, Parkinson, or other neurological disorders), major depression/suicide, diabetes and hypoglycemia.

Laboratory examination consists of arterial blood gas (ABG), complete blood cell counting, electrolytes, biochemistry, coagulation profile, and urine analysis. Arterial blood gas (ABG) analysis is probably the most reliable clinical parameter in patients who are asymptomatic or mildly symptomatic. Serial estimations of serum creatinine should be performed when there are elevated serum creatinine, marked metabolic acidosis, abnormal urinalysis, or significant lymphocytosis initially. Acute renal impairment is frequent in near drowning, ranging from mild to severe renal failure requiring dialysis. Consider a blood alcohol level and urine toxicology screen for abuse of drugs in specific situations mentioned above.

First Aids and Management

Prehospital care. Maintenance of the ABC is still the first priority, with particular focus on securing the airway and providing adequate oxygenation and ventilation, especially for those with altered mental status. Immediately place the patient on 100% oxygen by mask. If the patient remains dyspneic or low oxygen saturation, continuous positive airway pressure (CPAP) or consider endotracheal intubation with appropriate use of positive end-expiratory pressure (PEEP) should be indicated although there is still no such equipment in most of the ambulances in Taiwan. Cervical immobilization during resuscitation and transportation should be performed. Begin rewarming as soon as possible if hypothermia occurs.

Emergency department care. Provide all victims of a submersion injury with supplemental oxygen during their evaluations. Evaluate early associated injuries such as cervical spine injury that may complicate airway management. Intubation may be required for a patient unable to maintain a pO_2 of greater than 60-70 mm Hg in adults or >80 mm Hg in kids with 100% oxygen by face masks. A trial of bilevel positive airway pressure (BiPAP)/CPAP can be considered to provide adequate oxygenation before intubation is performed for the alert and cooperative patients. Altered level of consciousness, inability to protect airway, high alveolar-arterial (A-a) gradient, PaO_2 of 60-80 mm Hg or less on 15 L oxygen nonrebreathing mask, $PaCO_2$ >45 mm Hg, and worsening ABG results also indicate intubation. For these victims, PEEP has been shown to improve ventilation in the noncompliant lung. Prevention of expiratory airway collapse, shifting out interstitial pulmonary water, increasing alveolar ventilation, decreasing capillary blood flow, and bronchodilatation to improve distribution of ventilation may be the possible mechanisms.

Patients with core temperatures less than 32°C after sudden and rapid immersion may display slowing of metabolism and preferential shunting of blood to the heart, brain, and lungs. However, most of the immersion victims become hypothermic gradually at a risk for ventricular fibrillation and brain insult, and need aggressive rewarming. Diving reflex that has been postulated to be reflex inhibition of the respiratory center (apnea), bradycardia, and vasoconstriction of nonessential capillary beds triggered by the sensory stimulus of the face by cold water may have protective effects after prolonged immersion in cold water. These responses preserve the circulation to the vital organs and conserve oxygen to increase survival. Sudden drop of temperature inhibits cellular metabolism significantly and thus limits the harm of hypoxia and metabolic acidosis. Place a nasogastric tube to assist in rewarming efforts and urinary catheter to assess urine output. Core rewarming with warmed oxygen, continuous bladder lavage with fluid at 40°C, and intravenous (IV) infusion of isotonic fluids at 40°C should be initiated during resuscitation. Warm peritoneal lavage may be required for core rewarming in severely hypothermic patients. Warm inspired air is also needed. Thoracotomy with open heart massage and warm mediastinal lavage may be indicated. A hypothermic heart is refractory to pharmacological and electrical therapies. More aggressive rewarming such as extracorporeal bypass may be used in severely hypothermic patients failing the above treatment. Central venous access should be attempted very cautiously because of possible stimuli for the hypothermic atrium with resultant dysrhythmias. A submersion victim cannot be declared death until he has been warmed to a minimum of 30°C. Initiate appropriate treatment of electrolyte imbalances, seizures, bronchospasm, and cold-induced bronchorrhea, dysrhythmias, and hypotension as needed.

Disposition decision depends on the history, presence of associated injuries, and degree of immersion injury. Patients able to relay a good history of minor immersion injury, without evidence of significant injury and without evidence of bronchospasm, respiratory distress, or inadequate oxygenation can be discharged from the ED after 6-8 hours of observation. Victims of mild to moderately severe submersion, who only have mild symptoms that improve during observation and have no abnormalities on blood gas or chest radiograph, can be also discharged after 6-8 hours of observation in the ED. Observe victims of severe submersion with only mild symptoms and normal laboratory findings for a more prolonged period. Admit the patients with mild to moderately severe hypoxemia. Some of them improve easily with oxygen and can be discharged after resolution of hypoxemia with no complications. Patients requiring intubation and mechanical ventilation should be admitted to the intensive care units.

Admission care. The victims may suffer from varying degrees of neurologic as well as pulmonary insults. In patients with significant lung disease but a reasonable likelihood of neurologic recovery, extracorporeal membrane oxygenation has been employed successfully to treat pulmonary insufficiency. Look for evidence of acute respiratory distress syndrome (ARDS); multiple organ system failure; nosocomial infection, especially pneumonia; and/or gastric stress ulceration. Management of ARDS due to submersion is similar to that of ARDS from other causes. Use of permissive hypercapnia to decrease barotrauma in many ARDS patients may not be appropriate in this setting of hypoxic ischemic CNS injury. The extent of invasive monitoring needed (eg, arterial catheter, pulmonary artery catheter, and/or central venous pressure catheter) is determined by the degree of hemodynamic or respiratory instability and the presence of renal failure.

Prognosis

Survival depends upon multiple factors. The submersion time, water temperature, water tonicity, symptoms, associated injuries (especially cervical spine and head), type of rescue, and response to initial resuscitation are all relevant factors. Patients who are alert or mildly obtunded at presentation have an excellent chance for full recovery. Patients who are comatose, receiving CPR at presentation to the ED, or have fixed and dilated pupils and no spontaneous respirations have a poor prognosis. The classic protocol for cerebral resuscitation, which included neuromuscular blockade, barbiturate coma, dehydration, hyperventilation, hypothermia, and corticosteroids (HYPER therapy) does not improve outcome.

Summary

Submersion injury remains high mortality and morbidity in little babies and adolescents and prevention is the best policy to reduce the incidence. Hypoxemia and subsequent multi-organ insults are devastating. Pulmonary support is the most important treatment. Concomitant trauma should also be in detail evaluated and treated. Those presenting with clear consciousness at arrival are almost 100% survived. HYPER therapy has been abandoned.

References

1. Newman AB, Stewart RD. Submersion incidents. In: Wilderness Medicine: Management of Wilderness and Environmental Emergencies. Chicago: Mosby; 1995: 1209-33
2. Asher KN, Rivara FP, Felix D, et al. Water safety training as a potential means of reducing risk of young children's drowning. Inj Prev 1995;1: 228-33
3. Olshaker JS. Near drowning. Emerg Med Clin North Am 1992;10: 39-50
4. Bross MH, Clark JL. Near-drowning. Am Fam Physician 1995;51:1545-51
5. Sachdeva RC. Near drowning. Critical Care Clinics 1999;15:281-96
6. Fiser DH. Near-drowning. Pediatr Rev 1993;14:148-51
7. Weinstein MD, Krieger BP. Near-drowning: epidemiology, pathophysiology, and initial treatment. J Emerg Med 1996; 14:461-7
8. Szpilman D. Near-drowning and drowning classification: a proposal to stratify mortality based on the analysis of 1,831 cases. Chest 1997;112: 660-5
9. Fields AI. Near-drowning in the pediatric population. Crit Care Clin 1992; 8:113-29
10. Chochinov A. Alcohol "on board," man overboard—boating fatalities in Canada. CMAJ 1998;159:259-60
11. Howland J, Smith GS, Mangione T, et al. Missing the boat on drinking and boating. JAMA 1993;270:91-2
12. Norberg WJ, Agnew RF, Brunsvold R, et al. Successful resuscitation of a cold water submersion victim with the use of cardiopulmonary bypass. Crit Care Med 1992;20:1355-7
13. Thompson DC, Rivara FP. Pool fencing for preventing drowning in children. Cochrane Database Syst Rev 2000;2:CD001047
14. Dunagan DP, Cox JE, Chang MC, Haponik EF. Sand aspiration with near-drowning. Radiographic and bronchoscopic findings. Am J Respir Crit Care Med 1997;156:292-5
15. Ender PT, Dolan MJ. Pneumonia associated with near-drowning. Clinical Infectious Diseases 1997;25:896-907

16. Bolte RG, Black PG, Bowers RS, et al. The use of extracorporeal rewarming in a child submerged for 66 minutes. JAMA 1988;260:377-9
17. Causey AL, Tilelli JA, Swanson ME. Predicting discharge in uncomplicated near-drowning. Resuscitation 2000;46:273-77
18. Spicer ST, Quinn D, NyiNyi NN, et al. Acute renal impairment after immersion and near-drowning. Journal of the American Society of Nephrology 1999;10: 382-86
19. Christensen DW, Jansen P, Perkin RM. Outcome and acute care hospital costs after warm water near drowning in children. Pediatrics 1997;99:715-21
20. Graf WD, Cummings P, Quan L, Brutocao D. Predicting outcome in pediatric submersion victims. Ann Emerg Med 1995;26: 312-9
21. Kyriacou DN, Arcinue EL, Peek C, Kraus JF. Effect of immediate resuscitation on children with submersion injury. Pediatrics; 94(2 Pt 1):137-42
22. Levin DL, Morriss FC, Toro LO, et al. Drowning and near-drowning. Pediatr Clin North Am 1993;40:321-36
23. Shatz DV, Kirton OC, McKenney MG, et al. Personal watercraft crash injuries: an emerging problem. J Trauma 1998;44:198-201
24. Peake PW. Emergency management of near drowning. Aust Fam Physician 1992;21:42-6

溺水者的照護

王宗倫

摘要

對於小嬰兒及年輕人的溺水患者，仍存在高比例的死亡率和後續的傷害。大部分這些不幸事件的發生通常是出於意外，所以如何妥善的預防是防止不幸再次發生的首要課題。缺氧和隨後產生的其他器官的傷害，特別是腦部的受損，是主要造成嚴重後遺症的原因。有鑒於此，必須給予患者必要且積極的呼吸照護。目前仍還沒有一套完善的預後評估方法可準確的預測病患的預後；然而據統計，只要在到達醫院時，意識仍是清醒的患者，存活率幾乎可達百分之百。傳統的HYPER治療(降低體溫，給予過度換氣，類固醇的投予，脫水，巴比妥鹽昏迷法及神經肌肉阻斷法)並未被證明對預後有很好的幫助。*(Ann Disaster Med. 2004;2 Suppl 2:S89-S96)*

關鍵字：溺水；溺斃；瀕臨溺斃；環境醫學

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