Near-Drowning
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Martin J. Nemiroff, MD
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Case History

A 25-year-old female scuba diver lost her way while exploring inside a sunken ship. She was submerged for 30 minutes at a depth of 60 feet in 40°F water. After a 10-minute airless period, she was found without her scuba mouthpiece in place. On reaching the surface, the rescuers noted that the victim had no pulse and was apneic, cyanotic, and cold to the touch. Cardiopulmonary resuscitation was begun, and a pulse and shallow respirations returned after two minutes. The patient was evacuated by air to a treatment center, where she recovered fully. She returned to graduate school and resumed her studies within a month.

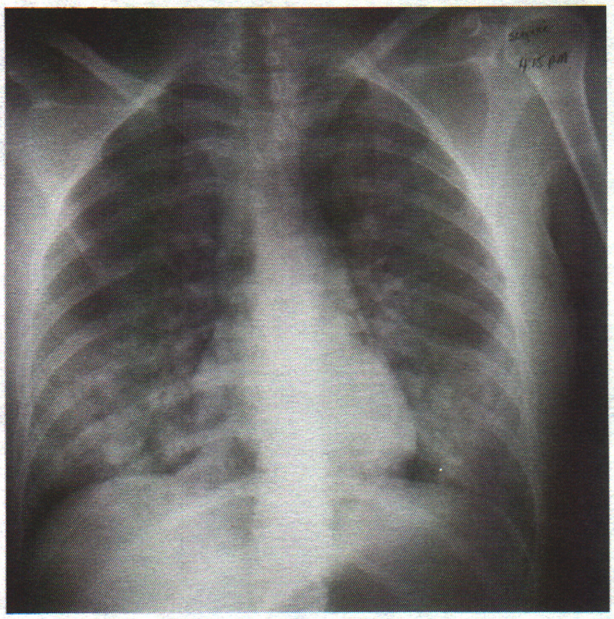

Figure 1. Near-drowning/acute pulmonary edema two hours following submersion in fresh water.

Introduction

Nearly 8000 drowning deaths occur yearly in the United States. These fatalities do not reflect the number of near-drownings that are unreported or unrecorded. When a fatality occurs from a diving accident, the cause of death is often listed as drowning or secondary death due to near-drowning. These accidents rarely occur with deep-sea hard-hat gear. They can happen when a helmet is not secured to a suit or a diver is trapped in a head-down position with a suit or helmet leak. Divers with scuba gear more commonly drown from (1) loss of, or flooding of, their mask or mouthpiece; (2) loss of their air supply; or (3) disorientation and panic.

The sequence of events in human near-drowning appears to follow animal studies closely (Table 1).

Table 1. Human near-drowning sequence.

1. Violent struggle to reach the surface.
2. Period of calmness and apnea.
3. Swallowing large amounts of fluid, followed by vomiting.
4. Gasping respirations and aspirations.
5. Convulsions, coma, and death.

The period of calmness and apnea is often unexpected and unusually pleasant. This phase may be associated with a relaxed, floating, reassuring feeling. Survivors have reported having a sexual orgasm during this period. At autopsy, 25% of human drowning victims have been found to have aspirated stomach contents in the airways. It has been estimated that 10% of drowning victims die without aspirating water. It appears that asphyxia results from laryngospasm following the first inrush of cold water. The term *dry drowning* has been used to describe this event; the significance is that such patients have the fewest sequelae to the submersion accident if they receive immediate resuscitation.

The duration of submersion a human can withstand without permanent brain damage is unknown. There are reports of survival following 10 to 40 minutes of submersion time. The determinants of complete recovery appear to be (1) younger age; (2) shorter duration of submersion; (3) cooler water temperatures (below 68°F); (4) efficiency of cardiopulmonary resuscitation; and (5) nature of the submersion fluid, e.g., swamp water, brackish water, or mud versus cleaner seawater and fresh water.

A series of unexpected survivals have recently been reported following prolonged cold-water submersion. The protective effect of the mammalian diving reflex is one explanation for the survival of infants and young children (Figure 2).

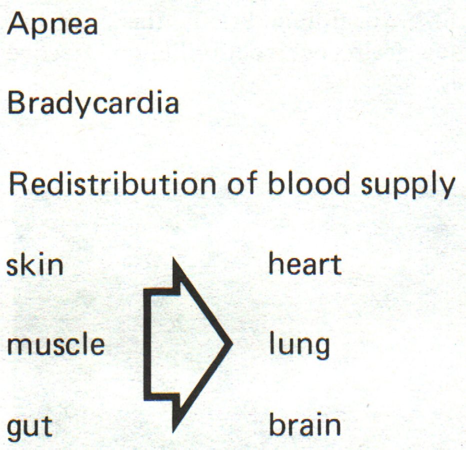

Figure 2. Mammalian diving reflex.

A reflex apnea occurs following application of cold water to the skin sensors of the ophthalmic branch of the fifth cranial nerve (forehead and upper nasal area). Bradycardia occurs in a much-attenuated form in humans compared with diving aquatic mammals. A vigorous redistribution of blood flow occurs that favors oxygen-sensitive tissues, such as heart, lung, and brain, and spares tissues that are less sensitive to oxygen, such as skin muscle and gut. Clinically, such submersion victims appear to lack a pulse and to be apneic, cold, cyanotic, and flaccid, with fixed dilated pupils. This clinical appearance has been mistaken for clinical death at the scene, yet recovery has been demonstrated on numerous occasions in the past two years.

Pathophysiology

Whether submersion occurs in seawater or fresh water, the primary pathophysiologic findings are (1) profound, persistent hypoxemia and (2) metabolic acidosis. Hypoxemia can occur when the amount of water aspirated is as little as 2.2 ml/kg body weight. The mechanism for development of hypoxemia differs in seawater compared with freshwater submersion. Following seawater aspiration, hypertonic fluid draws plasma from the circulation in the lungs, leading to fluid-filled, but perfused alveoli. Intrapulmonary shunt and hypoxemia result. Following freshwater aspiration, hypotonic fluid enters the circulation rapidly, but the surface tension characteristics of pulmonary surfactant change rapidly, leading to alveolar collapse, intrapulmonary shunting, and hypoxemia. In either type of water, aspirated fluid increases pulmonary resistance and decreases compliance and diffusion. Pulmonary edema and secondary infection are common sequelae to the above aspiration (Figure 3).

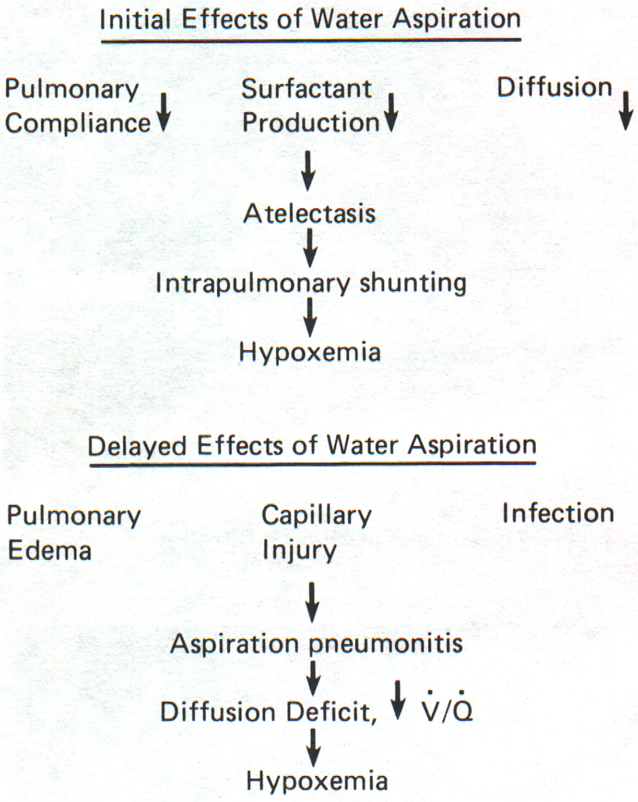

Figure 3. Initial and delayed effects of water aspiration.

On the basis of animal studies, Modell[1] has been able to approximate volumes of fluid that humans aspirate during drowning and near-drowning episodes. Most suvivors aspirate less than 22 ml/kg body weight. Significant serum electrolyte changes are rarely seen in human near-drowning victims at that level. This is in contrast to Swann's animal studies in the 1950s that showed extreme electrolyte imbalance and hemolysis in nearly drowned dogs.[2]

Chest x-ray changes may vary from minimal to the most profound acute respiratory distress syndrome pattern (Figures 4 and 5). As an index of survival, the chest x-ray is an unreliable tool. Acute pulmonary edema (the near-drowning syndrome) may develop within minutes to six hours following the accident. Patterns of radiologic progression have been reported as increasing infiltrate over the first 24 hours with eventual clearing in three to five days. Progressive infiltration suggests superinfection or development of a progressive pneumonia after 24 hours.

Emergency Care of Near-Drowning Victims

The emergency care at the scene should start with clearance of the patient's airway and mouth-to-mouth or mouth-to-nose ventilation. If the patient

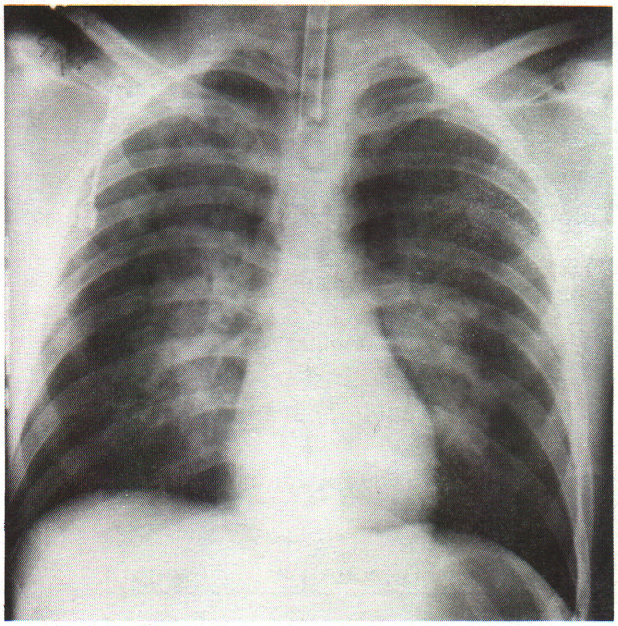

Figure 4. Minimal perihilar infiltrates.

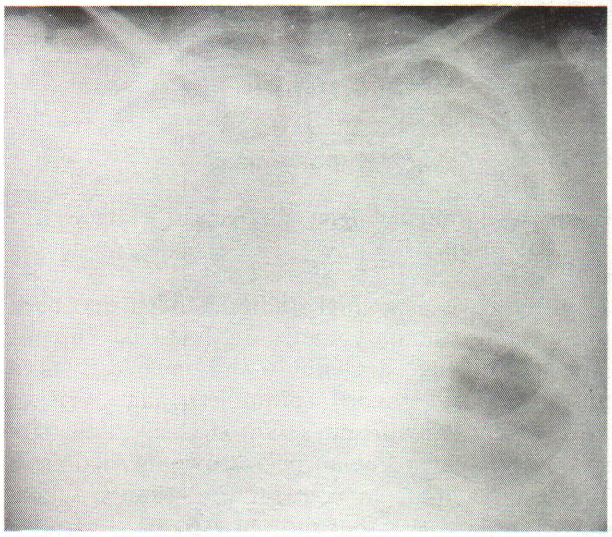

Figure 5. Acute respiratory distress syndrome.

has no pulse, external cardiac compression should be started at once. Success has been reported with complete resuscitation attempts performed in the water. Future research by the U.S. Coast Guard and other investigators will elucidate these techniques for divers. During transport, the highest concentration of inspired oxygen should be administered. Care should be taken concerning the inevitable gastric distension (Figure 6) and vomiting followed by potential aspiration. Careful positioning of the patient on his side may prevent this complication.

Hospital therapy should be directed toward obtaining near-normal arterial blood gas and acid-base levels by effective ventilation and oxygenation as well as bicarbonate administration. Mechanical ventilation, PEEP, and IMV with PEEP have been demonstrated to be useful, effective means of life support, with the goal being a PaO_2 of 60 to 90 mm Hg. Endotracheal intubation, followed by serial measurements of PaO_2, $PaCO_2$, and pH, is usually necessary. Special attention is required for the hypothermic near-drowning victim. Inhalation rewarming techniques using aerosols of 105 to 110°F 100% O_2 have been shown to facilitate resuscitation. Rewarming the myocardium briefly this way has made ineffective electroshock defibrillation effective within minutes.

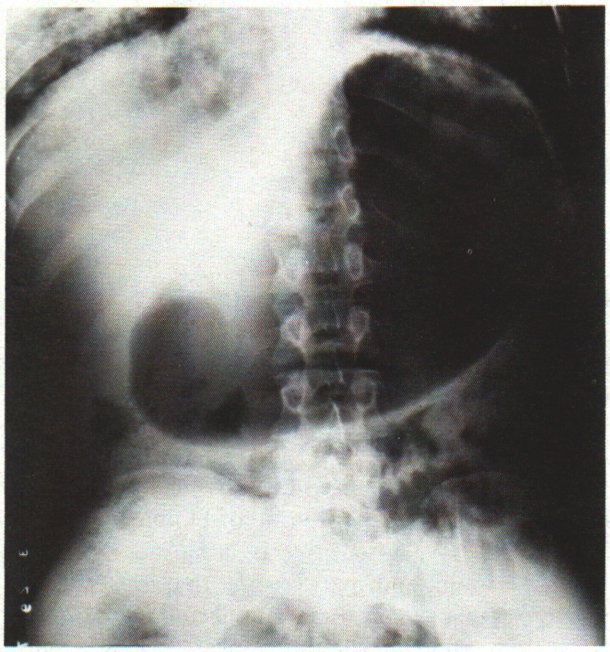

Figure 6. Gastric distension following near-drowning and CPR.

In the past, prophylactic use of antibiotics and corticosteroids was suggested for use in the treatment of near-drowning victims. Experimental animal studies in dogs failed to demonstrate increased survivability with corticosteroid use. A review of Modell's series of 91 human near-drownings failed to show improvement in the survival rates of those treated with or without steroids or prophylactic broad-spectrum antibiotics. In our center, methylprednisolone, 5 mg/kg body weight in divided doses, is given intravenously over the first 24 hours and continued for the first 72 hours of therapy. Where there is no contraindication, penicillin is administered in a dose of 6 to 9 million units intravenously. It must be understood that this action is controversial and definitive studies are not yet available to answer the question.

In summary, hypoxemia and acidosis are the primary priorities for treatment in nearly drowned individuals. The mode of therapy ranges from spontaneous breathing with oxygen supplementation to

Table 2. Protocol for the management of nearly drowned patients.

I. Procedures and studies to be initiated in the emergency department.
   A. Arterial blood gas determination, while patient is breathing room air.
   B. 100% concentration of inspired oxygen begun.
   C. X-ray examination of the chest—postero-anterior and lateral views.
   D. Electrocardiogram.
   E. Other laboratory studies: serum sodium, potassium chloride, blood urea nitrogen, creatinine, serum hemoglobin, clotting profile.

II. Admit the patient to the hospital for observation.

III. Be prepared to perform endotracheal intubation and to ventilate the patient mechanically, early.

IV. If aspiration is evident, begin methylprednisolone, 5 mg/kg body weight, in six divided doses per 24 hours. Continue for 72 hours.

endotracheal intubation and mechanical ventilation with PEEP. Intensive monitoring of serial arterial blood gases, acid-base status, and cardiac output and measures of ventilation perfusion or intrapulmonary shunting are necessary for successful treatment. Prophylactic use of antibiotics and corticosteroids is probably not indicated by the available studies to date.

Expected complications of near-drowning include acute respiratory distress syndrome, acute renal failure, hemolysis, and diffuse intravascular coagulation. The initial and subsequent laboratory studies (Table 2) are directed at the early recognition and treatment of these complications.

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NOTES

POST-STUDY QUESTIONS

1. The sequence of events in a submersion accident, as reported by the survivors, is:
   Ⓐ Violent struggle, panic, fear, coma, death
   Ⓑ Struggle, calm, gradual loss of consciousness, swallowing, vomiting, coma
   Ⓒ Convulsion, periods of waking and aspirating
   Ⓓ All of the above
   Ⓔ None of the above

2. The mammalian diving reflex has the following characteristic:
   Ⓐ Apnea, bradycardia, and redistribution of blood flow
   Ⓑ Occurs in cold water ($<68^{\circ}F$)
   Ⓒ More active in younger age groups
   Ⓓ May be a protective reflex in near-drowning
   Ⓔ All of the above

3. Freshwater and seawater near-drowning are:
   Ⓐ Indistinguishable from one another after an hour of following the patient physiologically
   Ⓑ Very different diseases with marked differences in survivability
   Ⓒ Similar in their effects on the alveoli in the first few minutes following fluid aspiration
   Ⓓ Very dissimilar in the drowning sequence
   Ⓔ None of the above

4. The pathophysiologic events of near-drowning include:
   Ⓐ Decreased lung compliance
   Ⓑ Decreased surfactant production
   Ⓒ Decreased diffusion
   Ⓓ Ventilation-perfusion abnormalities
   Ⓔ All of the above

5. Chest x-rays in nearly drowned individuals:
   Ⓐ May worsen over the first 24 hours
   Ⓑ Usually improve after 24 hours
   Ⓒ May worsen after 24 hours if superinfection or pneumonia intervenes
   Ⓓ Show an acute pulmonary edema pattern in severe cases
   Ⓔ All of the above

6. Immediate emergency care of the nearly drowned patient includes:
   Ⓐ Head-low position and epigastric compression
   Ⓑ Mouth-to-mouth ventilation
   Ⓒ External cardiac compression, if needed
   Ⓓ All of the above
   Ⓔ B and C

7. Primary attention in the care of the nearly drowned patient must be directed toward:
   Ⓐ Correcting electrolyte imbalance
   Ⓑ Correcting hypoxemia and acidosis
   Ⓒ Prophylactic antibiotics
   Ⓓ Steroid administration
   Ⓔ Nasogastric intubation and suction

QUESTIONS ON PREVIOUS TOPICS

8. After a dive to 20 feet for 15 minutes, a diver surfaced rapidly, complaining of chest pain and cough. Among the following, the most likely diagnosis is:
   Ⓐ Contaminated compressed air
   Ⓑ Chokes
   Ⓒ Stingray envenomization
   Ⓓ Scombroid poisoning
   Ⓔ Cold-water-induced bronchospasm

9. After a dive to 100 fsw for 20 minutes total bottom time (TBT), a one-hour surface interval, then a dive to 80 feet for 30 minutes, a diver complained of ''tingling'' in his right foot. The most likely diagnosis is:
   Ⓐ A tight wet suit
   Ⓑ A pulmonary overpressure accident
   Ⓒ A stonefish sting
   Ⓓ Spinal cord decompression sickness
   Ⓔ Limb bends

PRE-STUDY QUESTIONS

10. The vasovagal (vasodepressor) syncope has been assumed to be involved in accidents and possibly death in sport divers. This syncope involves:
    Ⓐ A biphasic circulatory change
    Ⓑ More males than females
    Ⓒ Sympathetic activation
    Ⓓ Emotional components
    Ⓔ All of the above

11. In sport-diving fatalities, the presumed major cause is:
    Ⓐ Equipment failure
    Ⓑ Marine hazards, such as sharks
    Ⓒ Inadequate support from boats and handlers
    Ⓓ Panic and sequelae
    Ⓔ Decompression sickness

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