Practical Therapeutics

Near-Drowning

MICHAEL H. BROSS, M.D., and JACQUELYN L. CLARK, M.D.
University of Mississippi Medical Center, Jackson, Mississippi

Near-drowning and drowning are major causes of neurologic injury and death in young persons. Most victims aspirate water, and pulmonary edema develops in many of these cases. Prolonged submersion causes cerebral asphyxia and adversely affects the brain within five minutes. Immediate ventilation and oxygenation are essential in the reversal of cerebral anoxia. During field resuscitation, precautions should be taken to protect the cervical spine because of the possibility of injury. The Heimlich maneuver is used only after unsuccessful attempts at ventilation suggest foreign-body obstruction. Prehospital advanced cardiac life support with tracheal intubation is indicated in patients with severe injuries. On arrival at the hospital, ventilation with continuous positive airway pressure or positive end-expiratory pressure enhances pulmonary function. Many water submersion accidents are avoidable; close supervision of infants and toddlers, installation of a fence around home swimming pools, and abstinence from alcohol during participation in water sports are some practical precautions.

Over 4,000 persons die each year in the United States as a result of drowning.[1] A disproportionate number of drowning victims are young. Thus, drowning is responsible for the loss of many years of potential life. Survival after asphyxiation due to submersion in water is referred to as "near-drowning." Many persons who have a near-drowning incident die minutes to days later because of secondary complications.[2] Victims of near-drowning often sustain serious neurologic injuries and require prolonged rehabilitation and care. Prompt treatment of the near-drowning victim is essential for a favorable outcome.

Each year members of a different medical faculty prepare articles for "Practical Therapeutics." This is the 10th in a series from the University of Mississippi School of Medicine, Jackson. Guest editor of the series is Bill Replogle, Ph.D.

Epidemiology

Drowning is the fifth leading cause of accidental death in the United States, and it is the second most common cause of loss of potential life due to accidental death in persons under 65 years of age. Eighty-two percent of drowning victims are male. The highest drowning rates occur from birth to four years of age.[1] Most cases of infant drowning occur in the bathtub.[3] Toddler drownings occur primarily in home swimming pools,[4] but bathtubs and industrial buckets[5] are other common sites. In cases of near-drowning among infants and toddlers, the possibility of abuse or neglect should be considered.

Another high-risk group consists of males between the ages of 15 to 34 years.[6] In this subset of patients, alcohol use is associated with roughly half of the drownings, and the drownings occur primarily in rivers, lakes and oceans.[7] For every drowning incident, an estimated 500 to 600 near-drowning events occur.[8]

Etiology

The classic image of the drowning victim who gasps for air and thrashes the water is rarely reported by witnesses. More often, observers describe the victim as suddenly motionless in the water or diving into the water and never resurfacing, swimming under water and appearing to "play possum," or quietly disappearing below the surface. Such reports point to the lack of a

typical situation and suggest etiologies other than the inability to swim.[9]

Drowning is often a secondary event. Head or neck injuries sustained during a dive may prevent the diver from resurfacing. Also, young swimmers often hyperventilate before diving into the water. Hyperventilation decreases the partial pressure of carbon dioxide ($PaCO_2$), while the partial pressure of oxygen (PaO_2) does not change significantly. During underwater swimming, the PaO_2 can decrease to a level of 30 to 40 mm Hg while the $PaCO_2$ rises to a normal level that is insufficient to stimulate breathing. This hypoxia can result in loss of consciousness and drowning.[7]

Cardiac arrhythmias, myocardial infarctions, cerebrovascular accidents and syncope can also incapacitate swimmers. Children with seizure disorders have been found to have a relative risk of 13.8 for drowning and 95.6 for drowning in a bathtub, compared with children without seizure disorders.[10] Drug and alcohol use may impair judgment and swimming ability. Immersion in cold water results in loss of body heat and soon leads to hypothermia with resulting confusion, incoordination and muscle rigidity. Icy water immediately incapacitates most swimmers.[11]

Pathophysiology

Pulmonary complications result from the aspiration of fluid. Aspiration occurs in approximately 90 percent of drowning and near-drowning victims, with laryngospasm preventing aspiration of fluid in the remaining 10 percent.[12] Aspirated fresh water is hypotonic and passes rapidly from the alveoli to the intravascular compartment. Surfactant is reduced, leading to alveolar instability and atelectasis. Salt water is hypertonic, resulting in fluid shifting into the alveoli. Pulmonary edema commonly occurs after aspiration of fresh water or salt water, with impairment of ventilation producing a large intrapulmonary right-to-left shunt. Tissue hypoxia leads to metabolic acidosis. Additional pulmonary compromise may result from laryngospasm, bronchospasm and aspiration of foreign material or gastric contents.

Neurologic complications result from anoxia, which adversely affects the brain after five minutes of submersion.[8,13] Neuronal damage can lead to diffuse cerebral edema and increased intracranial pressure. Rapidly induced hypothermia caused by submersion in icy water may offer an extended protective effect.

Cardiovascular and renal complications may also result from near-drowning, since most patients are hypovolemic because of fluid shifts. Cardiac arrhythmias can occur secondary to hypoxia or hypothermia. Renal complications include acute tubular necrosis from hypoxemia, myoglobinuria and hemoglobinuria.

Management

The goal of resuscitation is immediate ventilation and oxygenation to interrupt the sequence of events leading to cerebral anoxia. This goal is best accomplished by aggressive field and hospital resuscitation.

FIELD RESUSCITATION

All near-drowning victims should receive cardiopulmonary resuscitation.[14,15] The victim should first be retrieved from the water. In the field, monitoring includes checking the victim for the presence of pulse, respirations, purposeful movement and color. If the patient is apneic, any debris should be

The Authors

MICHAEL H. BROSS, M.D.
is an associate professor and director of community and rural medicine in the Department of Family Medicine, University of Mississippi Medical Center, Jackson. He earned his medical degree at the University of Oklahoma Health Sciences Center, Oklahoma City, and completed a residency in family medicine at the University of Arkansas Area Health Education Center, Pine Bluff, Ark.

JACQUELYN L. CLARK, M.D.
is an assistant professor and clinic director, Department of Family Medicine, University of Mississippi Medical Center. She earned her medical degree and completed a residency in family medicine at the University of Mississippi Medical Center.

cleared from the airway. Rescue breathing should begin as soon as possible and can be initiated in the water, provided the rescuer is not endangered.[14] The Heimlich maneuver is indicated only after unsuccessful attempts at ventilation suggest foreign-body obstruction.[9,16] Basic cardiopulmonary resuscitation is begun with two initial breaths of 1.0 to 1.5 seconds' duration.[17] Quicker, more forceful breaths may cause air to enter the stomach, increasing the risk of emesis and aspiration. The Sellick maneuver is an effective means of preventing aspiration. This maneuver involves application of pressure to the cricoid cartilage, pushing it against the cervical vertebra to compress the esophagus. Thus, air is prevented from entering the stomach and causing subsequent regurgitation of stomach contents.[14]

Supplemental oxygen (100 percent) should be administered to all patients who have survived near-drowning. Tracheal intubation achieves definitive airway control in the apneic patient. Early, aggressive prehospital advanced cardiac life support, including necessary field intubation, improves outcome.[16]

Cervical spine injury, other trauma and hypothermia should always be suspected. If there is any suspicion that the patient has sustained a cervical spine injury, care must be taken in removing the patient from the water and positioning the head and neck during rescue breathing. In these cases, jaw-thrust or chin-lift maneuvers are indicated to open the airway, and tilting of the head is contraindicated.[17]

The near-drowning victim who is hypothermic should be handled gently because the heart is prone to ventricular fibrillation. The patient may appear to not have a pulse secondary to severe bradycardia and vasoconstriction. Chest compressions should be initiated only when rhythm is arrested (i.e., asystole, ventricular fibrillation).[7] Rewarming at the scene is usually only possible by passive external means: removing wet clothing, drying the patient and wrapping the patient in blankets.

Fluid resuscitation is indicated in patients with hypovolemia.

Indications for pharmacologic intervention in the field are limited. Hypoglycemia can be related to hypothermia and alcohol use; therefore, dextrose should be administered to victims who are comatose or have altered consciousness. Naloxone and thiamine are also administered to patients with altered mental status. The treatment of lactic acidosis with sodium bicarbonate is controversial. However, 1 mEq per kg of sodium bicarbonate is recommended as a reasonable approach in patients who are comatose.[7] Any additional bicarbonate treatment should be guided by assessment of blood gases.

Field resuscitation is the window of opportunity for medical intervention in the patient who has had a near-drowning incident. Patients who require cardiopulmonary resuscitation on arrival in the emergency department most often have a dismal outcome.[12,18-20]

HOSPITAL TREATMENT

Advanced cardiac life support and advanced trauma life support should be performed, with emphasis on protection of the cervical spine when indicated (*Figure 1*). A rectal temperature probe and a Foley catheter should be inserted. Placement of a nasogastric tube is recommended, even in neurologically intact patients, because they are also at risk for aspiration.[15]

Intubation is indicated in patients with absent or minimal respirations. When respirations appear to be adequate, elective but urgent intubation is recommended in certain circumstances. Comatose or near-comatose patients benefit from airway protection. Severe pulmonary edema is best treated with ventilation and positive pressure support. Patients who are unable to maintain adequate oxygen saturation while receiving high-flow oxygen with a non-rebreathing mask require intubation and mechanical ventilation.[7]

Diagnostic evaluation in the emergency

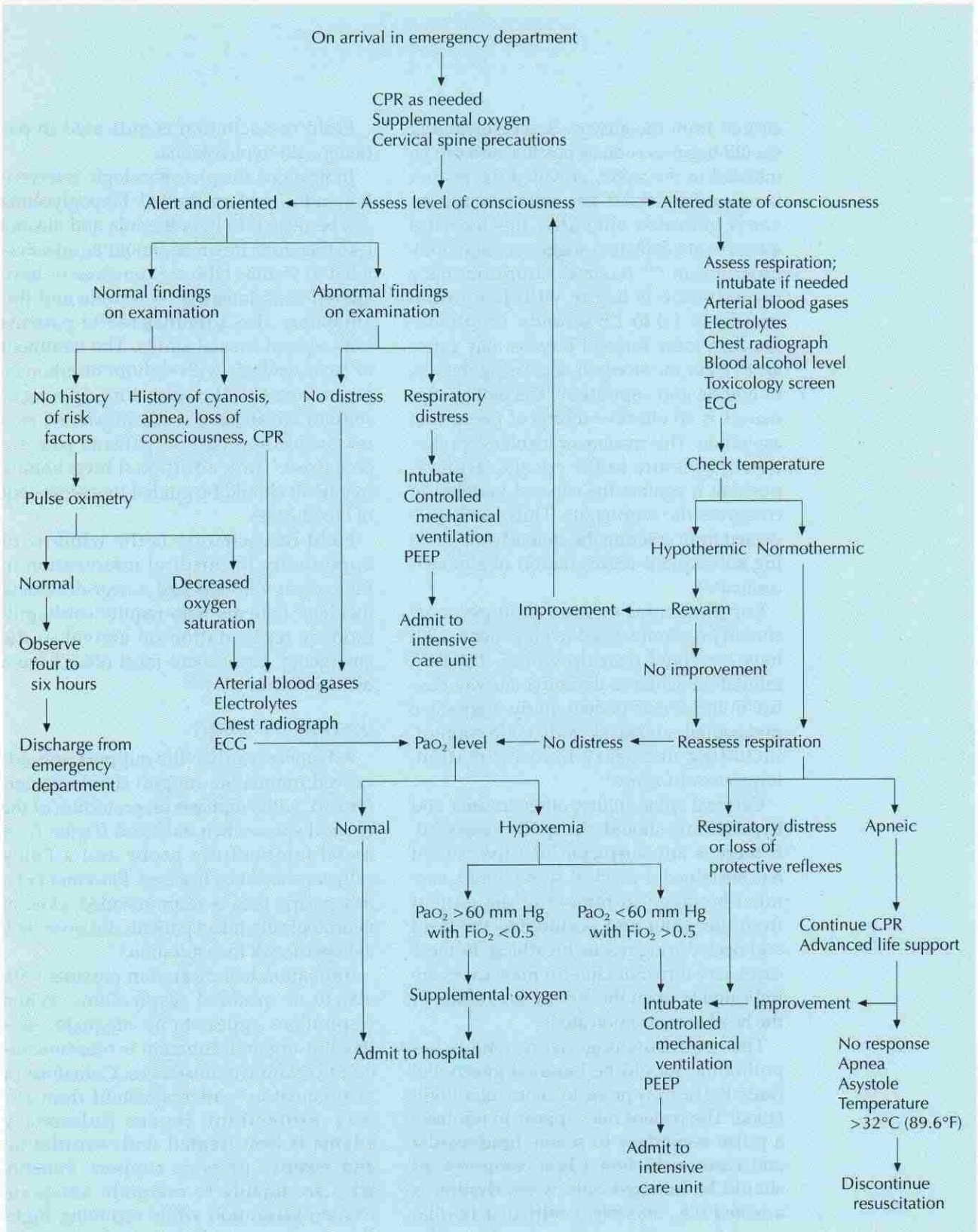

FIGURE 1. Algorithm for the management of a patient who had a near-drowning incident. (CPR = cardiopulmonary resuscitation; ECG = electrocardiogram; Pa_{O_2} = partial pressure of arterial oxygen; Fi_{O_2} = fraction of inspired oxygen; PEEP = positive end-expiratory pressure)

department is outlined in *Table 1*. Noninvasive monitoring of oxygen saturation using pulse oximetry can be used to assess the patient for possible pulmonary injury and deterioration. Arrhythmias secondary to hypoxic or hypothermic injury can be detected by cardiac monitoring. Further invasive monitoring (e.g., arterial line, pulmonary artery catheter) may be required depending on the severity of injury.

All near-drowning victims should be observed in the emergency department for at least four to six hours. After a trivial episode of submersion, physical examination and pulse oximetry to assess oxygen saturation are often sufficient. Patients with a history of apnea, cyanosis or loss of consciousness or those who initially required cardiopulmonary resuscitation are at risk for deterioration and later complications. Hypoxemia, acidosis or an abnormality detected by chest radiograph or physical examination places a patient at increased risk. Patients with such findings should be admitted to the hospital for at least 24 hours for observation and monitoring. Admission to the intensive care unit is recommended for patients who required prolonged resuscitation or ventilation or whose mental status is persistently altered.[14]

TABLE 1

Diagnostic Tests in the Evaluation of the Near-Drowning Patient

Arterial blood gases
Electrolytes
Blood urea nitrogen
Creatinine
Complete blood count
Glucose
Creatine phosphokinase
Blood type and cross-match (if trauma is suspected)
Toxicology screen and blood alcohol level (if indicated)
Chest radiograph
Cervical spine radiographs (if neck injury is suspected)
Pediatric whole skeletal survey (if child abuse is suspected)
Electrocardiogram (to document normal cardiac function after the event and to rule out prolonged QTc as dysrhythmia resulting in near drowning)

Further Management Issues

PULMONARY

The early use of continuous positive airway pressure (CPAP) or positive end-expiratory pressure (PEEP) is important to reduce intrapulmonary shunting, diminish the ventilation-perfusion mismatch and increase the functional residual capacity.[7,14] CPAP is the physiologic equivalent to PEEP plus pressure support. CPAP can be applied by face mask in the alert patient who is breathing spontaneously. Intubated patients require mechanical ventilation, such as intermittent mandatory ventilation with CPAP or controlled mechanical ventilation with PEEP.

Ideally, CPAP or PEEP is begun in the emergency department at 5 cm H_2O. Incremental increases of 2.5 cm H_2O are initiated until a PaO_2 of 70 mm Hg or more is achieved, using nontoxic oxygen concentrations of 50 percent or less. Cardiac output can be depressed by PEEP or CPAP, thus limiting the pressure required. Other complications include pneumothorax, pneumomediastinum, pneumonia and a potential increase in intracranial pressure.

Bronchospasm in the near-drowning victim is treated with beta-adrenergic aerosols. Management is consistent with the treatment of acute asthma.[7] Studies of the use of prophylactic corticosteroid therapy have not demonstrated any therapeutic benefit and, in fact, have noted an association with increased mortality.[12,21]

Prophylactic antibiotics have been associated with increased antibiotic resistance[19] and higher mortality.[12,21] Antibiotics are recommended only in cases of suspected pulmonary infection after appropriate sputum Gram stain and cultures have been taken.

NEUROLOGIC

The management of cerebral injury has been controversial. Initial studies of barbiturate-induced coma and controlled hypothermia suggested benefit in patients with serious sequelae[22,23]; however, subsequent research has not duplicated those results.[19,20,24,25] The need for intracranial monitoring has been questioned,[25] especially since poor neurologic outcome is not always associated with increased intracranial pressure. Widely accepted treatment of hypoxic cerebral injury consists of mild hyperventilation to achieve a $PaCO_2$ between 25 mm Hg and 30 mm Hg. Thirty percent elevation of the head (if there is no suspicion of cervical spine injury), fluid restriction, muscle relaxation and closely supervised use of diuretics are also beneficial.[7,24] Standard anticonvulsant therapy is used for control of hypoxic seizures.

HYPOTHERMIA

Hypothermia should be considered a possibility in all patients who have survived a near-drowning incident. Severe hypothermia is defined as a core temperature below 28°C (82.4°F). In addition to using traditional rewarming methods, many hospitals also employ warmed, humidified oxygen and warmed fluids for intravenous resuscitation, gastric lavage, peritoneal lavage, enemas and baths. These methods can be successful in correcting severe hypothermia when circulation is intact.

Patients with severe hypothermia who have absent circulation may benefit from core rewarming by extracorporeal circulation.[7] Resuscitation must be continued until a core temperature of greater than 32°C (89.6°F) is achieved and cardiac activity has still not resumed,[11] supporting the principle not to consider the patient dead until he has been rewarmed.

Prognosis

Case studies of patients who have survived a near-drowning incident identify several prognostic indicators. Prehospital predictors of good outcome are submersion time of five minutes or less, period before cardiopulmonary resuscitation of less than 10 minutes, and the presence of sinus tachycardia and reactive pupils.[13]

The patient's level of consciousness on arrival at the hospital correlates strongly with outcome.[19,21,26] Patients who are awake on arrival usually have favorable outcomes. Blunted patients—those who are lethargic, semi-comatose, agitated and confused—have favorable outcomes, with occasional exceptions. Comatose patients have poor outcomes, with mortality rates of 34 to 68 percent.[19,21,26] Severe brain damage affects 13 to 47 percent of coma survivors.[19,21,26]

Prevention

By identifying age-related drowning risks, communities can affect drowning rates. Infant bathing must be closely supervised at all times. Toddlers are very mobile and curious. Bathtubs, toilets and cleaning buckets represent household hazards. Installation of a fence around home swimming pools has been shown to decrease the incidence of drowning by at least 50 percent.[27] Alcohol should never be consumed by persons who are engaged in swimming or water sports. Swimming instruction programs benefit patients of all ages. Patients with medical conditions that may impair consciousness, such as seizure disorder, cardiac disease and diabetic hypoglycemia, should always swim with a partner. Also, showers are safer than baths for these patients. Finally, adolescents and adults should be encouraged to participate in an instruction course for cardiopulmonary resuscitation.

A patient information handout on water safety is provided on page 1555.

The authors thank Ms. Bonnie Toop for assistance in the preparation of this manuscript.

Figure 1 from Shaw KN, Briede CA. Submersion injuries: drowning and near-drowning. Emerg Med Clin North Am 1989;7(2):367. Reprinted with permission from W.B. Saunders.

REFERENCES

1. National Safety Council. Accident facts, 1993. Itasca, Ill.: National Safety Council, 1993.
2. Modell JH. Drown versus near-drown: a discussion of definitions [Editorial]. Crit Care Med 1981;9: 351-2.
3. Hazinski MF, Francescutti LH, Lapidus GD, Micik S, Rivara FP. Pediatric injury prevention. Ann Emerg Med 1993;22(2 Pt 2):456-67.
4. Wintemute GJ. Childhood drowning and near-drowning in the United States. Am J Dis Child 1990;144:663-9.
5. Jumbelic MI, Chambliss M. Accidental toddler drowning in 5-gallon buckets. JAMA 1990;263: 1952-3.
6. Healthy people 2000: national health promotion and disease prevention objectives. Washington, D.C.: Department of Health and Human Services, Public Health Service, 1990; DHHS publication no. 91-50213:103,277.
7. Olshaker JS. Near drowning. Emerg Med Clin North Am 1992;10:339-50.
8. Orlowski JP. Drowning, near-drowning, and ice-water drowning [Editorial]. JAMA 1988;260:390-1.
9. Modell JH. Drowning. N Engl J Med 1993;328:253-6.
10. Diekema DS, Quan L, Holt VL. Epilepsy as a risk factor for submersion injury in children. Pediatrics 1993;91:612-6.
11. Corneli HM. Accidental hypothermia. J Pediatr 1992;120:671-9.
12. Modell JH, Graves SA, Ketover A. Clinical course of 91 consecutive near-drowning victims. Chest 1976;70:231-8.
13. Quan L, Kinder D. Pediatric submersions: prehospital predictors of outcome. Pediatrics 1992;90:909-13.
14. Shaw KN, Briede CA. Submersion injuries: drowning and near-drowning. Emerg Med Clin North Am 1989;7:355-70.
15. Levin DL, Morriss FC, Toro LO, Brink LW, Turner GR. Drowning and near-drowning. Pediatr Clin North Am 1993;40:321-35.
16. Quan L. Drowning issues in resuscitation. Ann Emerg Med 1993;22(2 Pt 2):366-9.
17. Albarran-Sotelo R, Flint LS, Kelly KJ, eds. Healthcare provider's manual for basic life support. Dallas: American Heart Association, 1990:35-45.
18. Quan L, Wentz KR, Gore EJ, Copass MK. Outcome and predictors of outcome in pediatric submersion victims receiving prehospital care in King County, Washington. Pediatrics 1990;86:586-93.
19. Oakes DD, Sherck JP, Maloney JR, Charters AC 3d. Prognosis and management of victims of near-drowning. J Trauma 1982;22:544-9.
20. Lavelle JM, Shaw KN. Near drowning: is emergency department cardiopulmonary resuscitation or intensive care unit cerebral resuscitation indicated? Crit Care Med 1993;21:368-73.
21. Modell JH, Graves SA, Kuck EJ. Near-drowning: correlation of level of consciousness and survival. Can Anaesth Soc J 1980;27:211-5.
22. Conn AW, Edmonds JF, Barker GA. Cerebral resuscitation in near-drowning. Pediatr Clin North Am 1979;26:691-701.
23. Conn AW, Edmonds JF, Barker GA. Near-drowning in cold fresh water: current treatment regimen. Can Anaesth Soc J 1978;25:259-65.
24. Nussbaum E, Maggi JC. Pentobarbital therapy does not improve neurologic outcome in nearly drowned, flaccid-comatose children. Pediatrics 1988;81:630-4.
25. Bohn DJ, Biggar WD, Smith CR, Conn AW, Barker GA. Influence of hypothermia, barbiturate therapy, and intracranial pressure monitoring on morbidity and mortality after near-drowning. Crit Care Med 1986;14:529-34.
26. Bierens JJ, van der Velde EA, van Berkel M, van Zanten JJ. Submersion in The Netherlands: prognostic indicators and results of resuscitation. Ann Emerg Med 1990;19:1390-5.
27. Milliner N, Pearn J, Guard R. Will fenced pools save lives? A 10-year study from Mulgrave Shire, Queensland. Med J Aust 1980;2:510-1.